Effect of Music upon Awakening from Nap

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Abstract: *Sleep and awakening are critical issues for people under high levels of stress in modern society. However, only a few studies on the effects of music on awakening have been conducted; thus, we focused on the effect of music on comfortable awakening in humans. This paper is the first to analyze the comfort of forced awakening relative to music and the brain. This is an analytical and observational study: a descriptive study of awakening from naps with music using three psychological tests. Ten healthy subjects (5 men and 5 women) participated in this experiment. Quantitative analyses were conducted on the subjects' feelings when awakened from a nap either with music or with an alarm tone. The music changes with time: We change width of the frequency to output. Participants were awakened after naps of 30, 60, 90 and 120 minutes for a total of 8 times overnight. Subjective feelings just after awakening were measured with three psychological questionnaires. The differences between the subjective data with music and with an alarm tone were calculated and analyzed. The results indicate that awakening with music was more comfortable than awakening with an alarm tone. Additionally, differences in comfort levels between awakening with music and awakening with an alarm tone were smaller at 30 and 90 minutes than at 60 and 120 minutes, suggesting the effects of the circadian rhythms.*

Keywords *Awakening, Nap, Effect of Music, Circadian Rhythm, Sleep Rhythm*

1. Introduction

1.1 Research theme

This study is an initial step toward the goal of our research to quantify the response of a human when he/she hears music. Fig. 1 is a scheme of our research goal; first, we hypothesize the human as a black box with inputs and outputs, and then we analyze the human as a function of the inputs onto the outputs.

In this study, the input is music and the output is human subjective responses. Based on this scheme, we discuss comfortable awakening by music in this paper.

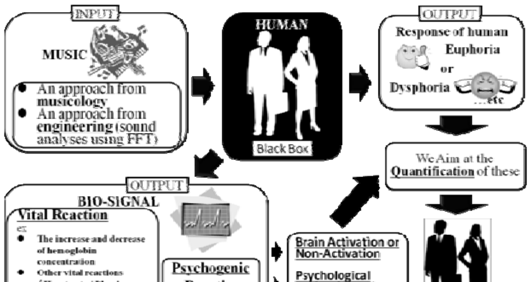

Fig.1 Research goal

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1.2 Background

Sleep and awakening are critical issues for people under high levels of stress in modern society. Many people work under circumstances in which they do not have good sleep conditions or they have to sleep against their circadian rhythms: for example, factory workers and healthcare workers who switch shifts or police officers or firefighters who work overnight. It is important to reduce physical fatigue through comfortable awakening to improve these job circumstances.

In this study, we performed quantitative analyses of the feelings that occur when awakened from a nap (short-term sleep). This paper is the first to analyze the comfort of forced awakening relative to music and the brain.

1.3 Two Hypotheses

We propose two hypotheses regarding comfortable awakening. The first hypothesis states that awakening by music is more comfortable than awakening by only alarm tone sounds. The second hypothesis states that the comfort of awakening is determined by the sleep cycle and the circadian rhythm.

1.4 Conventional Research Details

Various studies on sleep have been conducted. Previous study was classified into eight different patterns according to their research themes.

The first research patterns focuses on the relationship between mortality and sleep time or sleep rhythm [1, 2]. Research in this area has found that the sleep length that causes the lowest mortality is 7 hours [1] and that mortality is high among those who are dissatisfied with the feeling of awakening [2]. The second research pattern measures the correlation between sleep rhythm and brain activity [3-7] using NIRS [3], polysomnography [4, 5], EEG [6] and blood pressure [7]. The third research pattern measures circadian rhythm [8] and concludes that circadian rhythm is related to the timing of REM sleep. The fourth research pattern examines the relationship between sleep and a physiological mechanism [9, 10], including a number of studies that focus on reduced leptin [9] or melatonin [10]. The fifth research pattern examines the physiological effect of naps or short-time sleep [11-16], measuring sleep characteristics using blood pressure [11, 12], modeling of the pattern of nap [13, 14], and investigating the relationship between naps and mortality [15, 16]. The sixth research pattern examines the sleep of sick patients or the relationship between the mortality of sick patients and sleep [17-21], including the effect of sleep on the mortality of insomnia or cancer patients [17, 18], the effect of sleep on memory in schizophrenia patients [19] and the sleep patterns of narcolepsy patients [20]. The seventh research pattern analyzes the effect of sleep quality on happiness in everyday life and on job performance [21-23], including measurements of sleepiness and its importance in everyday life [21] and the influence of sleep shortages [22, 23]. The final research pattern examines the influence of music on sleep [24, 25], including the efficacy of music for the initiation of sleep [24] and the excitatory effect of music on sleep [25]. Additionally, a number of studies investigate the psychological effect of music through non-invasive physiological measurements [26, 27]. Finally, some studies show that music affects the relaxation of stress [28].

We would like to emphasize that none of the previous studies focused on awakening. Many of the previous studies focused on "during sleep", "effect of sleep" or "initiations of sleep". However, only a few studies have been conducted on awakening from sleep, and none have been conducted on the effect of music on awakening..Given the lack of research in this area, we focus on comfortable awakening from sleep with music.

2. Method

2-1. Subject

The subjects were ten healthy Japanese volunteers: five men and five women. The average age was 28.3 (+-8.43) years. All of the subjects provided informed consent.

Table 1 Subjects

Subjects	Men	Women	Total
Number	5	5	10
Age	30.8±9.58	25.8±7.26	28.3±8.43

2-2. Questionnaires

We measured the subjective feelings of the subjects using three psychological questionnaires: the VAS (Visual Analogue Scale), the ALQ (Affective Level Questionnaire) and the POMS (Profile of Mood States). We chose three different types of tests because we did not want to trust only one psychological test, and we verified the reliability of each test.

A. VAS

Please indicate odor offensiveness upon awakening.

✧ How do you feel now? Please rate on a scale of one to ten. “5” is neutral.

	1	2	3	4	5	6	7	8	9	10	
Elation	○	○	○	○	○	○	○	○	○	○	Discomfort

B. ALQ

Are you feeling relaxed? or Are you feeling tense?

✧ Please choose the near feelings. “3” is neutral.

	1	2	3	4	5	
feeling of relaxation	○	○	○	○	○	Feeling of tense

C. POMS

Please choose the feeling that is closest to your current mood

Convivial mood

✧ Please choose the near feelings. “3” is neutral.

	1	2	3	4	5	
Great many	○	○	○	○	○	Strikingly absent

Fig.2 Samples of three questionnaires: (A) VAS, (B) ALQ and (C) POMS.

Figure 2 shows sample items from each of the three tests. VAS has 1 question, ALQ has 12 questions and POMS has 58 questions that are divided into attributes: 8 questions are about vigor (+), 15 questions are about vigor (-), 12 questions are about anger – hostility, 7 questions are about fatigue, 8 questions are about strain – uneasiness (+), 1 question is about strain – uneasiness (-), 6 questions are about confusion (-) and 1 question is about confusion (+).

2-3. Use Instrument and Measurement Location

We used an *IntelliAlarm "TSX-80"* that is a product of YAMAHA Corporation (Fig. 3).

Fig. 3 Instrument

IntelliAlarm has 2 modes; (1) normal alarm mode using alarm tone sounds and (2) *IntelliAlarm* mode using music and alarm tone sounds. Figure 4 shows the distinctive features of *IntelliAlarm* mode, including volume and frequency. In *IntelliAlarm* mode, the volume of the sound source rises progressively starting three minutes before the preset time, and the alarm tone rings at the preset time.The frequency band rises progressively before the alarm tone sounds from 500 Hz to 20 kHz.

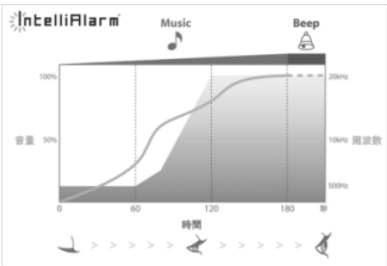


Fig. 4 Volume and Frequency band of *IntelliAlarm*

2-4. Musical pieces

We used jazz music from France because it would be unfamiliar to subjects. Subjects heard the music once before the start of the experiment. The reason using the jazz is because a base sounds being always played in one music.

2-5. Experiment environment

We prepared a private room for each subject. Every room was equipped with shading curtains to eliminate the effect of sunlight, as the experiment was conducted from 9:00 pm to 9:30 am. The *IntelliAlarm* was placed on the left side of the bed for each subject. Subjects turned off the light source in the room, except for the watery backlight of the *IntelliAlarm*.

2-6. Time protocol

We conformed to the following time protocol:

① Subjects were made awake with the IntelliAlarm mode (music and alarm tone sounds) or the normal alarm mode after naps lasting 30, 60, 90 and 120 minutes. The time schedule was randomized to ascertain whether the absolute timing in a day of sleep initiation and awakening influenced the response of the subjects.

② Subjects rested for 20 minutes following the nap to ensure that they were completely awake.

③ Subjects measured their subjective feelings during each rest time with psychological questionnaires. The psychological questionnaires were VAS, ALQ and POMS.

Some data are missing for subject number 3 due to trouble experimenting.

2-7. Calculation

To estimate the difference in subjective data for awakening with music and with an alarm tone, we defined the difference in the subjective data (ΔSD) as

$$\Delta SD = SD_{\text{awakening by music and alarm tone}} - SD_{\text{awakening by normal alarm}}$$

for each test. In addition, we compared the average of all the questions in ΔSD of ALQ and the average for each attribute of questions in ΔSD of POMS

We compared ΔSD awakening by music and alarm tone with ΔSD awakening by normal alarm tone sounds for each nap length with a t-test, and we examined the data for significant differences ($p<0.05$).

2-8. A hypothesis regarding awakening with music

We propose a hypothesis for a mechanism for the subject's responses to awakening with music

Figure 5 shows a visual representation of our hypothesis. In Fig. 5, sound enters through our ears and is changed into corresponding electrical signals, which are first processed in the audiopsychic area and then in the prefrontal lobe, where we judge "It's time for me to wake up!" During this process, the comfort of awakening depends on whether the brain cortex is working (REM sleep) or not working (non-REM sleep). According to our hypothesis, the awakening effect of music should show better performance at the time of non-REM sleep than REM sleep. At the time of non-REM sleep, the music is assumed to stimulate cerebral cortex, and to make forced half awakening level resembling a state of REM sleep. After this half-awakening level is achieved, the alarm should lead people to wakefulness. According to this hypothesis, awakening by both music and alarm tone sounds should be more comfortable than with only normal alarm tone sounds.

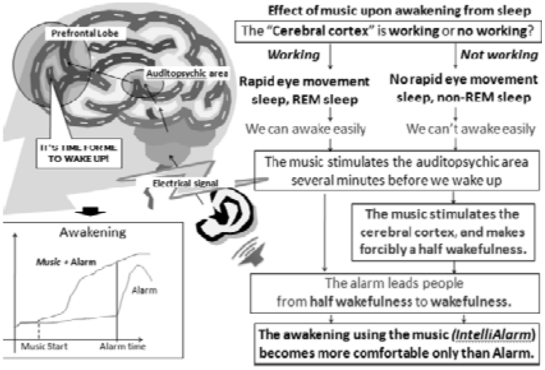


Fig.5 A hypothesis for awakening by music

3. Result

3-1. No time adjustment

Fig. 6, Fig. 7, and Fig. 8 show the relationship between nap length and ΔSD according to the three questionnaires

Fig. 6 shows the result of ΔSD of VAS: the vertical axis representing the ΔSD and the horizontal axis representing nap length. In Fig. 6, awakening with music is more comfortable than awakening with an alarm tone, as ΔSD is positive. Additionally, in Fig. 6, ΔSD shows positive values for all nap lengths, with positive values of ΔSD being higher at 60 and 120 minutes than at 30 minutes and 90 minutes

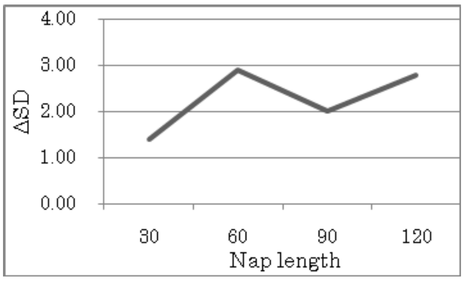


Fig. 6 ΔSD of VAS

Fig.7 shows the result of ΔSD of ALQ: the vertical axis representing the ΔSD and the horizontal axis representing nap length. As shown in Fig. 7, awakening with music is more comfortable than awakening with an alarm tone, as ΔSD is positive. Additionally, ΔSD shows

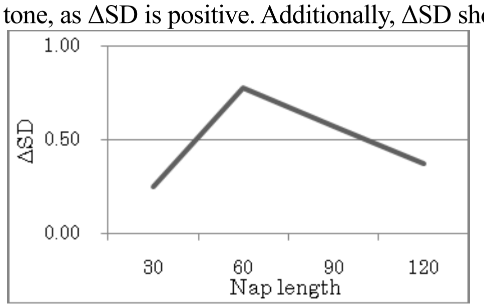
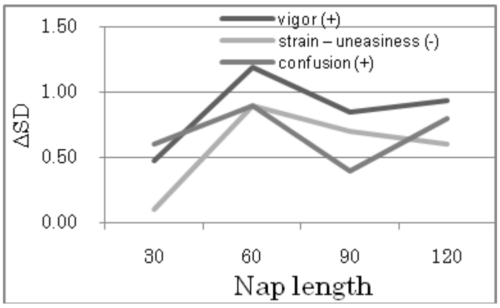


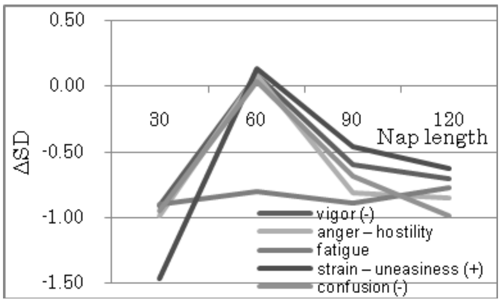
Fig. 7 ΔSD of ALQ

positive values for all nap lengths, and ΔSD had the highest value at 60 minutes.

Figure 8 shows the results of ΔSD for POMS. Fig. 8(A) shows the results for the positive questions in POMS: the vertical axis representing ΔSD and the horizontal axis representing nap length. In Fig. 8(A), awakening with music is more comfortable than awakening with an alarm tone, as ΔSD POMS $_{\text{positive question}}$ is positive. Fig. 8(B) shows the results for the negative questions in POMS: the vertical axis representing ΔSD and the horizontal axis representing nap length. In Fig. 8(B), awakening with music is more comfortable than awakening with an alarm tone, as ΔSD POMS $_{\text{negative question}}$ is negative. With regard to POMS positive questions (Fig. 8(A)), ΔSD had positive values for all nap lengths, and the positive values of ΔSD were highest at 60 and 120 minutes. With regard to POMS negative questions (Fig. 8(B)), ΔSD had negative values except at 60 minutes.



(A) Positive questions in POMS



(B) Negative questions in POMS

Fig.8 ΔSD of POMS

Table 2 shows the *p* values for the t-tests between nap length and the subjective data. We calculated *p* values using bilateral t-tests, assuming that each of the two groups was equally dispersed. With regard to VAS, we found significant differences ($p<0.05$) for all nap lengths, and greater significant differences ($p<0.005$) for 60 minutes and 120 minutes. The results of ALQ indicated significant differences for all nap lengths ($p<0.05$) except for 120 minutes. The results for the POMS indicated significant differences ($p<0.05$) for vigor (+) for all nap lengths.

Table 2. *p* **values for nap length and subjective data**

		30	60	90	120
VAS		0.008	0.000	0.017	0.004
ALQ		0.045	0.032	0.007	0.119
POMS	vigor (+)	0.044	0.006	0.002	0.005
	vigor (-)	0.098	0.287	0.105	0.027
	anger – hostility	0.110	0.313	0.016	0.034
	fatigue	0.211	0.010	0.072	0.078
	strain – uneasiness (+)	0.003	0.384	0.276	0.034
	strain – uneasiness (-)	0.147	0.190	0.119	0.151
	confusion (-)	0.105	0.328	0.126	0.002
	confusion (+)	0.110	0.180	0.324	0.115

* The filled cells represent p<0.05

3-2. Adjustment by the time (data analysis except data from 3:00 am to 5:00 am)

An analysis of questionnaires between 3:00 am and 5:00 am found that all subjects reported negative feelings. Therefore, we performed a data adjustment to exclude the data during this time period. Figure 9, Figure 10, and Figure 11 show ΔSD for the 3 questionnaires excluding data from 3:00 am till 5:00 am.

Fig. 9 shows the results of ΔSD of VAS, with the vertical axis representing ΔSD and the horizontal axis representing nap length. Awakening with music is more comfortable than with alarm tones, as ΔSD is positive. Additionally, Δ SD is positive for all nap lengths, and the positive values of ΔSD are highest at 60 and 120 minutes.

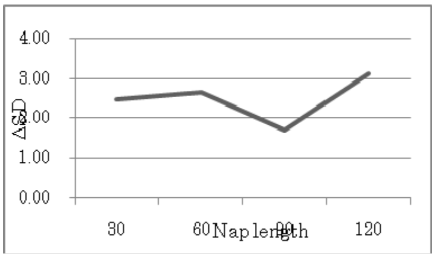


Fig.9 Δ SD of VAS excluding 3:00 am until 5:00 am data

Fig. 10 shows the results of ΔSD of ALQ excluding 3:00 am until 5:00 am data: the vertical axis

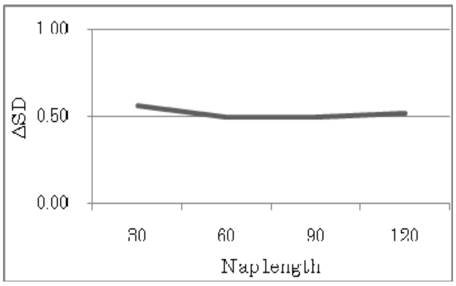
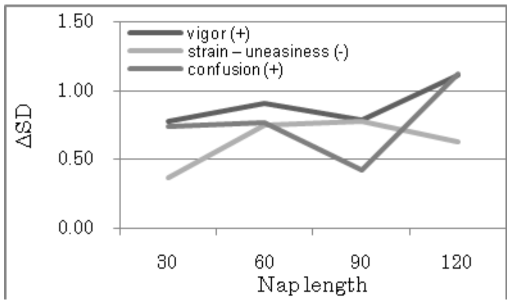


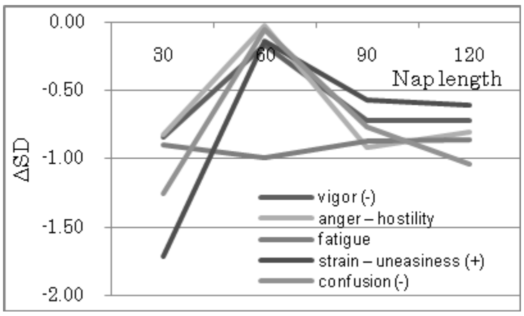
Fig.10 Δ SD of ALQ excluding 3:00 am until 5:00 am data

representing ΔSD and the horizontal axis representing nap length. Awakening with music is more comfortable than with alarm tones, as ΔSD is positive. ΔSD is positive for all nap lengths.

Fig. 11 shows the results of ΔSD of POMS excluding 3:00 am until 5:00 am data: the vertical axis representing ΔSD and the horizontal axis representing nap length. Fig. 11(A) shows the results for the positive questions in the POMS. Awakening with music is more comfortable than with alarm tones, as ΔSD is positive. Fig. 11(B) shows the results for the negative questions in the POMS. Awakening with music is more comfortable than with alarm tones, as ΔSD for negative questions is negative. The results for the POMS $_{\text{positive questions}}$ shows that ΔSD is positive for all nap lengths, and the positive values of ΔSD are highest at 60 and 120 minutes.



(A) Positive questions in POMS



(B) Negative questions in POMS

Fig.11 Δ SD of POMS excluding 3:00 am until 5:00 am data

Table 3 shows the *p* values for the t-tests between nap length and the subjective data We calculated *p* values using bilateral t-tests, assuming that each of the two groups were not equally dispersed because some data revealed a significant bias.

The results of VAS indicate significant differences (p<0.05) for all nap lengths, and greater significant differences (p<0.005) were found at 60 minutes and 120 minutes. Comparisons between the raw data in Fig. 6 and the adjusted data in Fig. 9 for all nap lengths revealed that ΔSD of adjusted data decreased for the 90 minute length and increased for the 30 minute length in the adjusted data as compared to the raw data. The results of ALQ indicate significant differences ($p<0.05$) for all nap lengths. Comparisons between the raw data in Fig. 7 and the adjusted data in Fig. 10 revealed that ΔSD of ALQ fluctuated less in the adjusted data. The result of POMS showed number of time which shows significant difference ($p<0.05$) at vigor (-) increases compared with corresponding rows in Tables 2.

Table 3. *p* values for nap length and subjective data excluding 3:00 am till 5:00 am data

		30	60	90	120
VAS		0.011	0.000	0.028	0.001
ALQ		0.083	0.044	0.013	0.023
POMS	vigor (+)	0.092	0.002	0.003	0.003
	vigor (-)	0.028	0.329	0.036	0.024
	anger – hostility	0.064	0.468	0.007	0.040
	fatigue	0.098	0.033	0.056	0.053
	strain – uneasiness (+)	0.001	0.341	0.114	0.030
	strain – uneasiness (-)	0.184	0.057	0.051	0.115
	confusion (-)	0.005	0.449	0.062	0.003
	confusion (+)	0.196	0.079	0.172	0.022

* The filled cells represent $p<0.05$

4. Discussion

The results of ΔSD show that awakening by music was more comfortable than awakening by alarm tone sounds for all nap lengths, except in the $\text{POMS}_{\text{negative questions}}$ in the raw data for the 60 minute nap length. Given this finding, we conclude that awakening with music is more comfortable than awakening with alarm tone sounds.

The difference of comfort between awakening with music and awakening with alarm tone sounds was smaller at 30 and 90 minutes than at 60 and 120 minutes, except for POMS negative questions in both the raw and adjusted data and also for the ALQ in the adjusted data. We presume this phenomenon is caused by sleep cycles, in which humans are in REM sleep states at 90 minutes and in non-REM sleep states at 30 minutes, because the past studies prove that the stage of the sleep changes with time and REM occur every 90 minutes [6].

The results of POMS show contradictions between the $\text{POMS}_{\text{positive questions}}$ and the $\text{POM}_{\text{S negative questions}}$ at the 60 minute nap length. We assume that this contradiction is caused by the confused consciousness of the subjects, causing a lower increase of consciousness at this time due to human sleep cycles: humans are in non-REM sleep state at 60 minutes, because the past studies prove that the stage of the sleep changes with time and around the sleep of 60 minutes is shallow stage of sleep [6]. In this study, we supported that the clear fact that the feelings of awakening depend on a stage of the sleep in past studies [29] and an everyday sense.

Exclusion of the data from 3:00 am until 5:00 am strengthened the significant differences between music and alarm tones. This result reveals that subjects felt negative when awakened in the 3:00 am until the 5:00 am window, regardless of the presence of music. We speculate that this negative feeling was caused by the circadian rhythm.

In addition, we think about the future prospects as follows. By this experiment, we think that we have to compare subjectivity data at awakening with objectivity data of the depth of the sleep, and we think that we have to increase the subjects. In this experiment, we considered the psychology experimental data by support of past studies, but we think our study have to be backed up by objective data. And we provided jazz music for the reason of base sounds being always played in one music at this experiment, but we think that we have to pursue optimal "music" at awakening. Moreover, we experimented on the awakening from a nap at this experiment, but we think that we have to experiment the awakening from normal sleep.

5. Conclusion

In this paper, we discussed comfortable awakening with music because comfortable awakening is a critical issue for people under high levels of stress. We proposed a mechanism for comfortable awakening with music that is irrelevant of the stage of sleep. We assume that music stimulates the cerebral cortex and forces a half-awake level that resembles a state of REM sleep during non-REM sleep. We measured the subjective feelings of 10 healthy volunteers using 3 psychological questionnaires: the VAS, ALQ and POMS. The results suggest the following 3 conclusions: (A) awakening with music is more comfortable than awakening with alarm tone sounds because ΔSD (the difference in the subjective data between awakening by music accompanied by an alarm tone and awakening with only the normal alarm tone) is positive in almost every questionnaire; (B) sleep rhythm causes confused consciousness in subjects because ΔSD for the POMS showed contradictions between the $\text{POMS}_{\text{positive questions}}$ and the $\text{POMS}_{\text{negative questions}}$ for the 60 minute nap length in the non-REM sleep state; and (C) circadian rhythm affects awakening comfort, as the subjects reported feeling negative from 3:00 am until 5:00 am regardless of the presence of music.

In conclusion, we summarize our results as follows:

1) Awakening by music feels more comfortable.
2) Sleep rhythm and the circadian rhythm influence awakening comfort.

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