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# Psychophysiological Experiments on Extent of Disturbance of Noises Under Conditions of Different Types of Brain Works

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## 1. Introduction

For quantitative evaluation of human conditions, subjective evaluation obtained through psychological measurements is generally used for assessment of an acoustic environment. It is also important that human reactions to surrounding environments be objectively evaluated from physiological aspect.

In the field of architectural environment, Authors reported that auditory information processing was affected by the priority of processing in the brain (Akita et al., 1995). From this finding, it was demonstrated that the Electroencephalogram (EEG) was effective for objective evaluation as a physiological index. In the field of psychophysiology, the distinct EEG theta rhythm from the frontal midline area observed during performance of mental tasks such as continuous addition was defined as the frontal midline theta rhythm (Fmθ) (Brazier et al., 1952; Ishihara et al., 1972). In the studies on Fmθ, it was found that Fmθ was associated with concentration on the task, with higher Fmθ values indicating higher concentration (Ishihara et al., 1975; Ishihara et al., 1976; Ishihara et al., 1991; Suetsugi et al., 2002). As the previous studies on the influence of various noises on task performance, for example, Hashimoto et al. investigated the effects of familiar noises with a moderate sound level of 60 dB $L_{\mathrm{Aeq}}$ on physiological responses, task performance and psychological responses (Hashimoto et al., 1999). From the results, it was shown that the effect of noise on task performance depended on the kind of noises, it strongly influences the task performance as the task became increasingly more complex.

Author has studied relationships between extent of disturbance caused by sounds and EEG during simple calculation task up to now (Tsujimura et al., 2006; Tsujimura et al., 2008). As the finding in the paper, information processing mechanism of cerebral cortex relevant to disturbance was reported (Figure 1) (Tsujimura et al., 2006). Moreover, to clear an effect of meaning of noise on task performance or extent of disturbance, we have investigated the effect of meaningless and meaningful noises on extent of disturbance caused by noises and task performance of two kinds of brain works (Tsujimura et al., 2007).

In this paper, in order to find influence of noise including verbal information on the extent of disturbance or EEG during different types of brain works, the psychophysiological experiment was conducted. The relationships between extent of disturbance and EEG were examined during each brain work.

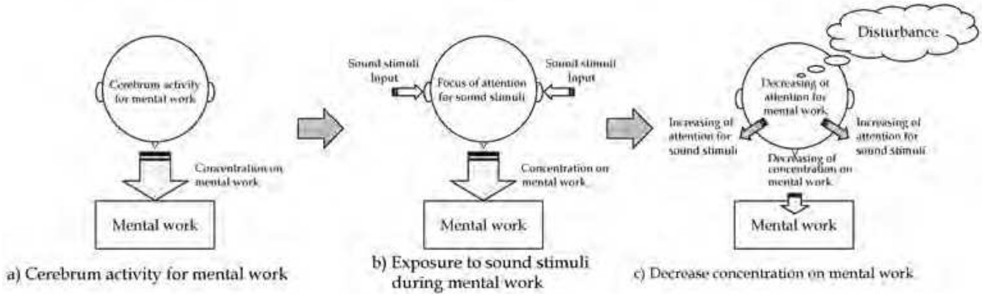



Fig. 1. Information processing mechanism of cerebral cortex relevant to disturbance (Tsujimura et al., 2006)

## 2. Subjective experiment

In a hemi-anechoic room, the subject performed two kinds of brain works during exposure to three kinds of noises. The EEG was measured, and extent of disturbance was judged by him/her under each experimental condition.

### 2.1 Experimental system

The experimental system was constructed in a hemi-anechoic room. The block diagram of the experimental system is shown in Figure 2. The distance between a loudspeaker and subject was 2.0 meters. In this experiment, the 8-channel bioelectrical amplifier (DIGITEX Lab., BA1008) was set up under following conditions: The sensitivity was 50 microvolt. The time constant was 0.1 second. The 30 Hz treble cutoff filter was used.

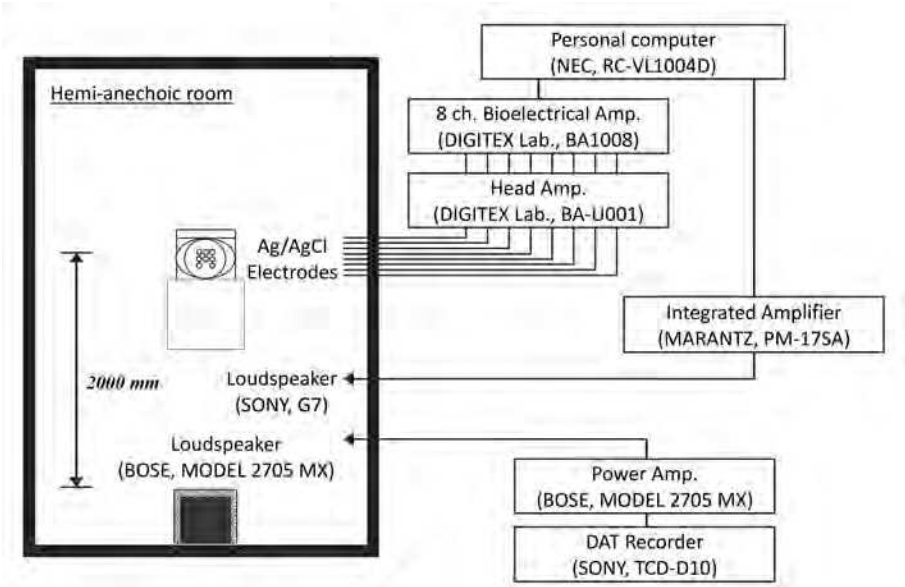



Fig. 2. Block diagram of experimental system

## 2.2 Mental works

Two kinds of brain works used in this experiment were described as follows. Mental arithmetic manipulation of double digits and memorization of Chinese characters were used in this experiment as brain works (Yoshida et al., 2007). In the mental arithmetic manipulation of double digits, subject was instructed to continue mental arithmetic of double digits (arithmetic addition and subtraction of double digits) for 5 minutes. In the memorization of Chinese characters, subject was instructed to memorize as many Chinese characters as he/she could in 2 minutes, and then write the answers on answer sheets in 3 minutes. The examples of brain works were shown in Figure 3-a) and b). The subject was given an instruction that he/she does not move his/her heads during the experiment.

| | | | |
|---|---|---|---|
| 62+39 | 33+78 | 93-58 | |
| 98-76 | 47-69 | 62+53 | … |
| 91-81 | 75+73 | 39+81 | |

a) Mental calculations (arithmetic addition and subtraction of double digits)

| | | | | |
|---|---|---|---|---|
| 合 | 業 | 覚 | 憲 | 間 |
| 乗 | 解 | 首 | 殺 | 戸 |
| 宗 | 修 | 兄 | 告 | 囲 |
| 右 | 暑 | 急 | 青 | 共 |
| 机 | 衣 | 回 | 京 | 結 |

b) Memorization of Chinese characters

Fig. 3. Examples of brain works in this experiment

### 2.3 Noise

In this experiment, news broadcast was used as meaningful noise, and white noise was used as meaningless noise. These noises were presented to the subject at 50 dB $L_{\mathrm{Aeq,\ 5min}}$. This experiment consisted of three experimental conditions – two kinds of noises and one with pink noise as a background noise (The pink noise was presented to the subject at 30 dB $L_{\mathrm{Aeq,\ 5min}}$). The experimental conditions in this experiment are shown in Table 1.

| Meaning of noises | The kinds of noises | $L_{\mathrm{Aeq,\ 5min}}$ [dB] |
|---|---|---|
| Meaningful noise | News broadcast | 50 |
| Meaningless noise | White noise | |
| | Pink noise (BGN) | 30 |

Table 1. Noises were used in this experiment

### 2.4 Experimental procedure

19 subjects participated in this experiment; 11 males and 8 females. They were Japanese university students with normal hearing ability. Firstly, in a hemi-anechoic room, subject was asked to sit on chair. The subject was instructed to concentrate on the brain work, and performed the work during exposure to noise described above Table 1. The EEG of each subject was measured with or without noise during brain work. In order to keep a constant background noise in hemi-anechoic room, the pink noise was presented to subjects at $L_{\mathrm{Aeq,\ 5min}}$ 30 dB during this experiment. The measurement of EEG was based on the ten-twenty electrode system (Jasper, 1958). The ten-twenty electrode system is shown in Figure 4. Inoue et al. reported that there was a part of the generation mechanism of Fmθ in the paramedian line area of cerebral cortex of frontal lobe in each cerebral hemisphere, firstly, Fmθ occurred at the paramedian line of frontal lobe ($F_{p1}$, $F_{p2}$, $F_3$, $F_4$, $C_3$, $C_4$, $P_3$, and $P_4$ positions) (Inoue et al., 1984). From these findings, in our study, EEG was measured by electrodes at $F_z$, $C_z$, $F_{p1}$, $F_{p2}$, $F_3$, $F_4$, $C_3$ and $C_4$ positions using $A_1$ and $A_2$ as references. A measured EEG passed through a 30 Hz treble cutoff filter, and then it was amplified by an 8ch bioelectrical amplifier.

After the measurement of EEG, the subject was asked to evaluate the extent of disturbance in performing the brain work caused by each of noise shown in Table 1 except for background noise condition by the rating scale method using ten-step category. Thus, they evaluated the extent of disturbance four times in all. This category scale used in the evaluation of extent of disturbance is shown in Figure 5. The extent of disturbance was evaluated throughout the brain work.

### 2.5 Analysis of EEG

In the field of psychophysiology, Ishihara, et al. have defined the distinct theta rhythm (6-7 Hz) of EEG observed at frontal midline area ($C_z$ position described above Figure 4) during performance of mental tasks such as continuous addition and taking an intelligence test as frontal midline theta rhythm (Ishihara et al., 1976; Inoue et al., 1984). It was found that frontal midline theta rhythm was associated with concentration on a mental task (Ishihara et al., 1996). From these findings, in this study, potentials of EEG of 6-7 Hz (in what follows "Fmθ" was described) was analyzed by use of FFT .

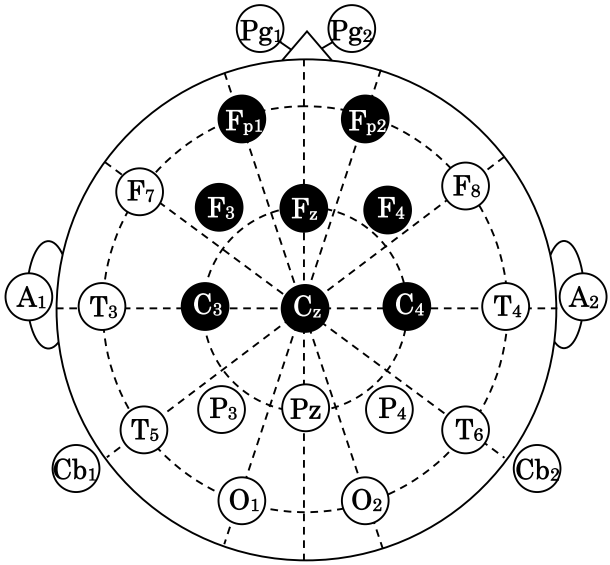



Fig. 4. Points of measurement based on the ten-twenty electrode system (Jasper, 1958)

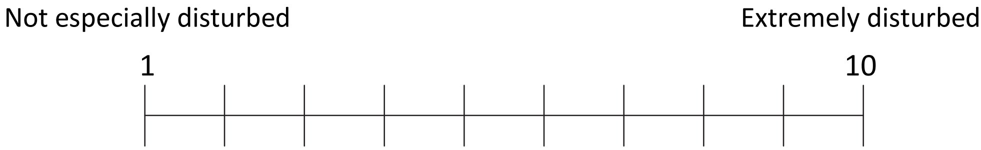


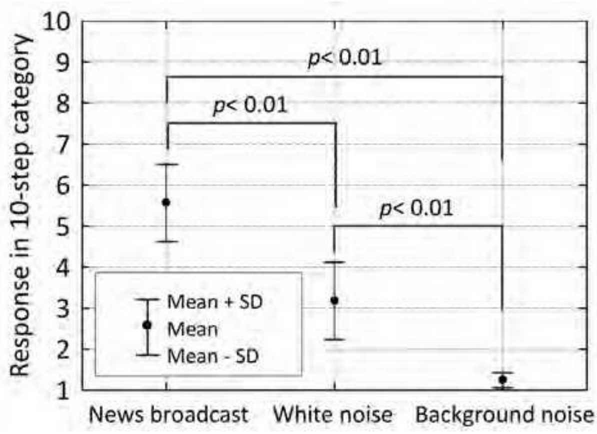

Fig. 5. Category scale of extent of subjective disturbance used in this experiment

## 3. Result and discussion

### 3.1 Effect of noise on extent of disturbance

The relationships between noise conditions and extent of disturbance for each brain work are shown in Figure 6. The averaged evaluation of extent of disturbance for 19 subjects is used in Figure 5. Two-way ANOVA in which the kind of brain work and noise were used as factors was calculated. From the results, a main effect of noise was significantly different in both works (Mental arithmetic manipulation of double digits: $F (2, 54) = 35.52$, $p<0.01$, Memorization of Chinese characters: $F (2, 54) = 37.94$, $p<0.01$). In both works, multiple comparison (Tukey's HSD test) was calculated. The extent of disturbance showed significant differences between each noise conditions in both works ($p<0.01$).

In both works, the extent of disturbance obtained on exposure to news broadcast was higher than that of white noise. In regard to news broadcast, the extent of disturbance in memorization of Chinese characters was higher than that of mental arithmetic manipulation of double digits. From these results, it was suggested that noise including verbal information have effects on extent of disturbance more than that of nonverbal information during brain works. The effects of noise including verbal information such as news broadcast varied according to the kinds of brain works.



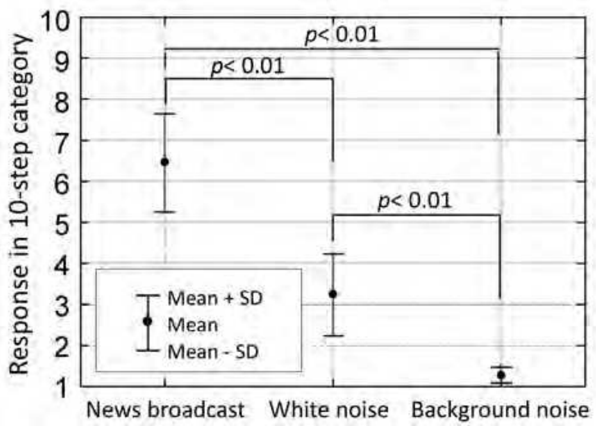
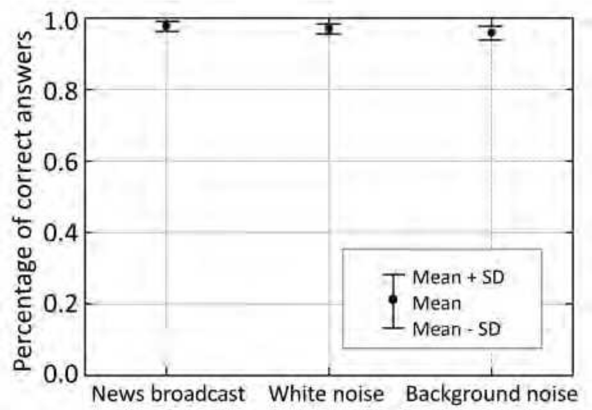




Fig. 6. Relationship between noise conditions and extent of disturbance for each brain work. a) Mental arithmetic manipulation of double digits, b) Memorization of Chinese characters. The y-axis ranges from 1 = 'not especially disturbed' to 10 'extremely disturbed'. The extent of disturbance of noise was not evaluated in the condition of no noise (background noise condition) because there was no noise targeted for evaluation.

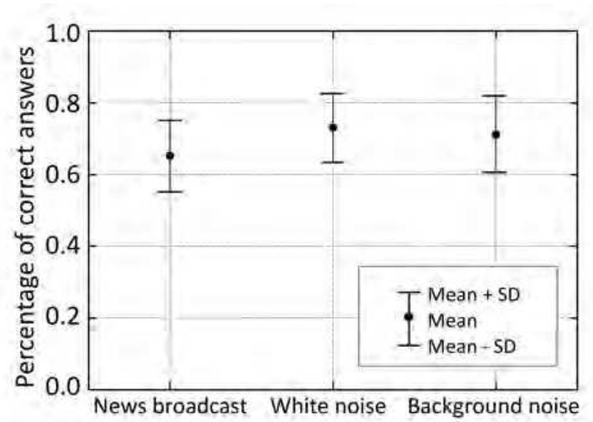
### 3.2 Effect of noise on task performance

The relationships between noise conditions and task performance for each brain work are shown in Figure 7. From the results shown in Figure 6, in memorization of Chinese characters, task performance of exposure to news broadcast seemed to be lower than those of white noise and background noise. Two-way ANOVA in which the kind of brain work and noise were used as factors was calculated. From the results, in regard to task performance, a main effect of the kind of works and noise conditions were not significantly different.

These results show that noises used in this experiment have no influence on task performance of mental arithmetic manipulation of double digits, and they have some effect on that of memorization of Chinese characters. The news broadcast influence on task performance of memorization of Chinese characters to a greater degree than white noise. It was suggested that noise including verbal information adversely affected task performance of work containing verbal information such as memorization of Chinese characters.




(a) Mental arithmetic manipulation of double digits




(b) Memorization of Chinese characters

Fig. 7. Relationship between noise conditions and task performance for each brain work. (a) Mental arithmetic manipulation of double digits, (b) Memorization of Chinese characters.

### 3.3 Effect of noise on EEG

The relationships between noise conditions and Fmθ power for each brain work are shown in Figure 8 and Figure 9. The mean of Fmθ power for 19 subjects was used in Figure 8 and 9. Two-way ANOVA in which the kind of brain work and noise were used as factors was calculated. From the results, in mental arithmetic manipulation of double digits, a main effect of noise conditions showed significant differences ($F(1, 36) = 5.22$, $p<0.05$). Also, in the case of writing in the answers for memorization of Chinese characters, a main effect of noise conditions showed significant differences (F (1, 36) = 6.64, $p< 0.05$) however a main effect of the kind of works and the interaction of the kind of brain work and noise were not significantly different. In these works, Tukey's HSD test was calculated. Fmθ power showed significant differences between the conditions of exposure to news broadcast and white noise ($p<0.01$).

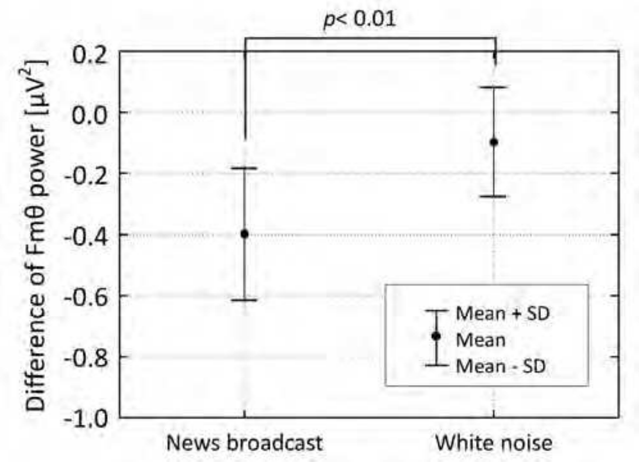
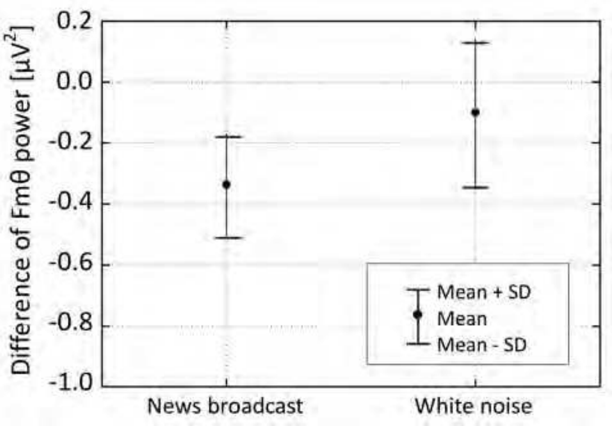


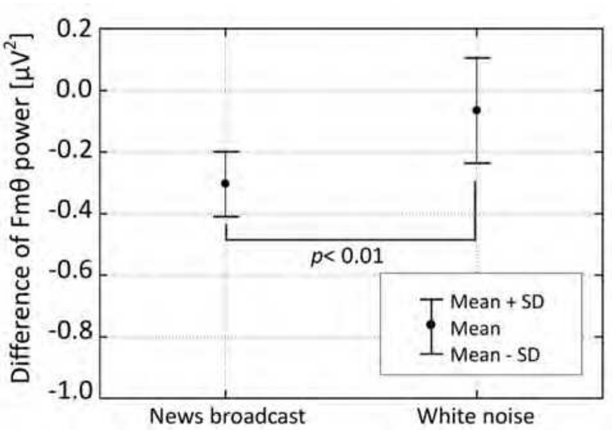

Fig. 8. Difference of Fmθ power between the condition of background noise and each noise condition (Mental arithmetic manipulation of double digits).

These results showed that there was a tendency to decrease Fmθ power when the subjects were exposed to noise. It was found that Fmθ power more decrease especially when the subjects were exposed to news broadcast. In the results of Two-way ANOVA and Tukey's HSD test, for memorization of Chinese characters, a main effect of noise conditions showed significant differences under the experimental condition which subjects wrote in the answers. This means that noise generated during the writing in the answers have an effect on Fmθ power more than that of during memorization of Chinese characters, from the result, it was suggested that memorization take more concentration than remembering.

The relationships between Fmθ power and extent of disturbance in performing each brain work are shown in Figure 10. As the result of Figure 9, it was indicated that Fmθ potentials decrease as the extent of disturbance becomes large. Ishihara, et al. reported that Fmθ was easily detected when the subjects were able to concentrate on a task (Ishihara et al., 1996). This means that Fmθ power was strongly associated with intensity of concentration on the task. The extent of disturbance increases as Fmθ power determined concentration on a task decreases. Therefore, it was found that concentration was one of factors that triggered the extent of disturbance for task. Additionally, it was suggested that there is a possibility that extent of disturbance was estimated from Fmθ power.

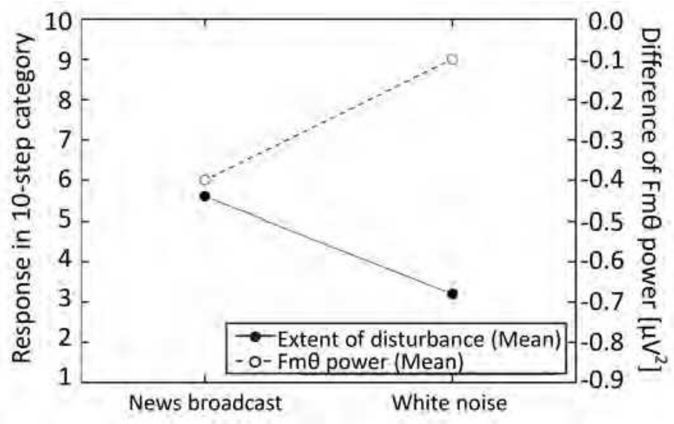



(a) Memorization

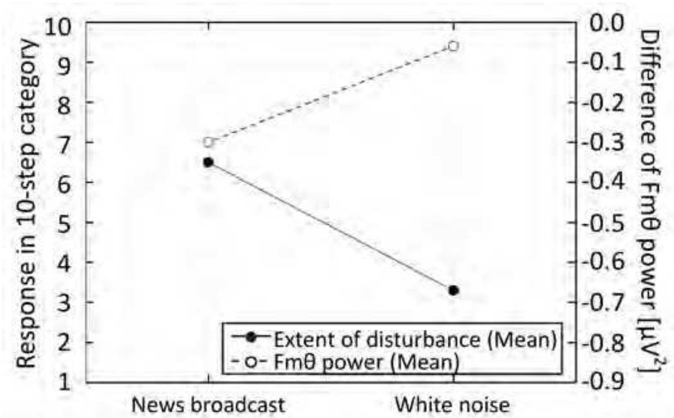



(b) Writing in the answers

Fig. 9. Difference of Fmθ power between the condition of background noise and each noise condition (Memorization of Chinese characters). (a) Memorization of Chinese characters, (b) Writing in the answers. The y-axis shows the difference (variation) between the Fmθ potentials measured on the condition of no noise (background noise condition) and each noise condition.




(a) Mental arithmetic manipulation of double digits




(b) Memorization of Chinese characters (Writing in the answers)

Fig. 10. Relationship between difference of Fmθ power and extent of disturbance.

## 4. Conclusion

In this paper, in order to find an influence of noise including verbal information on extent of disturbance or EEG under different types of brain works, we investigated: (1) effects of news broadcast and white noise on the extent of disturbance or EEG; (2) differences of them due to kinds of brain works; (3) relationship between difference of Fmθ power and extent of disturbance. From their results, it was suggested that: (1) noise including verbal information have effects on extent of disturbance more than that of nonverbal information; (2) noise including verbal information adversely affected task performance of work containing verbal information such as memorization of Chinese characters; (3) noise generated during the writing in the answers have an effect on Fmθ power more than that of during memorization of Chinese characters, memorization take more concentration than remembering; (4) there is a possibility that the extent of disturbance was estimated from Fmθ power.

These findings in our study are useful in the improvement of sound environment for office and classroom of school in the field of noise control. Furthermore, they could help to propose the development of environmental design method to upgrade creativity in office environment and the effective improvement method of sound environment for open-plan classroom. As the study applied to learning environment these findings in this report, authors have investigated the effect of indoor sound environment in a classroom on learning efficiency. In the study, the percentage of correct answers of each task, subjective judgment on degree of disturbance and the power level of frontal midline theta rhythm (Fmθ) were measured under the three types of sound environmental conditions (no-noise, air-conditioning noise, talking noise) in anechoic room (Tsujimura et al., 2010). From the results, it was confirmed that there is a negative correlation between Fmθ power and extent of disturbance, it was shown that Fmθ power was applicable to measurement of evaluation of learning efficiency as physiological index. Furthermore, it was found that noise generated during the writing in the answers have an effect on Fmθ power more than that of during memorization. It was very important findings that noise generated during unspread of idea interfere with that work in the field of noise control.

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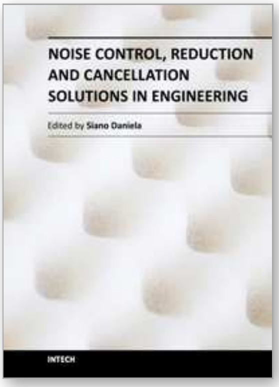


**Noise Control, Reduction and Cancellation Solutions in Engineering**

Edited by Dr Daniela Siano

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Noise has various effects on comfort, performance, and human health. For this reason, noise control plays an increasingly central role in the development of modern industrial and engineering applications. Nowadays, the noise control problem excites and attracts the attention of a great number of scientists in different disciplines. Indeed, noise control has a wide variety of applications in manufacturing, industrial operations, and consumer products. The main purpose of this book, organized in 13 chapters, is to present a comprehensive overview of recent advances in noise control and its applications in different research fields. The authors provide a range of practical applications of current and past noise control strategies in different real engineering problems. It is well addressed to researchers and engineers who have specific knowledge in acoustic problems. I would like to thank all the authors who accepted my invitation and agreed to share their work and experiences.



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