腦의 左半球와 右半球의 작용에 미치는 音의 서로 다른 影響

Different Effects of Sound Stimuli on Performing Left-and Right-Hemispheric Tasks

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요 약

소음과 음악이 정신작업에 어떠한 영향을 미치는가를 검토하기 위해, 국민학생을 대상으로 소음그룹과 음악그룹으로 나누어 左半球作業으로서 數의 加算테스트를, 右半球作業으로서 그림의 패턴찾기 테스트를 실시하였다. 그 결과 소음과 음악의 작업에 미치는 영향은 매우 달랐다. 음악그룹의 피험자가 加算作業을 한 경우의 작업량은 평균 작업량보다 다 적은 주기를 나타내는 경향이 있다. 이것은 左半球에서 加算作業과 음악처리간의 간섭때문이다. 한편, 소음下에서의 의 加算作業은 소음과 加算作業이 左右 다른 半球에서 처리되므로 소음의 영향은 나타나지 않았다. 소음下의 패턴 찾기테스트에서는 피험자가 작업중에 동요를 나타내는 경향을 보였다. 의미없는 소음은 右半球에서 처리되기 때문에 이것은 右半球에서의 간섭효과로 설명될 수 있다.

ABSTRACT

In order to examine the different effects of noise and music on mental tasks, an addition of figures as a left-hemispheric task and a pattern search as a right-hemispheric task were given to elementary school pupils under conditions of jet noise stimulus, music stimulus, and no-sound stimulus, respectively. Results

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showed that effects of music and noise stimuli during these tasks were significantly different. The subjects under music stimulus tended, when performing additions, to show occasional short periods in which they produced substantially less than their own average rate of work. This is due to interaction between calculation and hearing music in the left hemisphere, whereas there was no detrimental effects on the task of addition under noise stimulus as well as no-sound stimulus because the addition and the noise may be separately processed in different cerebral hemispheres. As effects of noise on performing search task, the subjects tended to show instantaneous agitations in their working curves. Since noise with no-meaning is processed in the right hemisphere, it may be explained as an interacting effect in this hemisphere.

I. INTRODUCTION

A number of researches on the sound effect upon mental tasks have been reported. Some authors have reported detrimental effects on the performance of mental tasks under noise, while others have pointed out no particular effects of noise upon task performance. There seem to be variables that account for these conflicting results: (1) kind of task (2) sequential pattern of sound (periodic or aperiodic, noise or music), and (3) intensity level of sound. Methods of measuring task efficiency seem to have led to these conflicting results. On the other hand, an attempt has been made to explain the arousal level by measuring the physiological responses such as heart rate, pulse amplitude, and peripheral blood volume during task performance under noise. However, no significant change in arousal level was observed anywhere [1],[2].

In the experment reported here, it is intended to investigate different effects of noise and music on mental tasks in relation to the hemispheric specialization of the human brain, which may unequivocally demonstrate why effects depend on the kind of task, even at the same intensity level. In order to examine the effects, the "Krapelin-Uchida Test" was applied to 559 elementary school pupils, under the condition of jet noise stimulus (90±5 dBA), music stimulus (90±5 dBA), and no-sound stimulus, respectively.

It is well known that the two cerebral hemispheres of the human brain have different functions. The left hemisphere tends to process complex thought, language, and calculation in logical sequence. On the other hand, the right hemisphere performs nonverbal data processing, spatial processing, and pattern recognition [3-7]. By the physiological measurement technique, it was revealed that meaningless signals such as noise and click are processed in the right hemisphere [8-11]. For example, larger auditory evoked potentials and more prominent evoked waveform components of noise stimulus were observed in the right hemisphere as compared with the left hemisphere [9]. Lateralization of musical functions has not been well demonstrated so consistently as for noise, because of its complex combination of pitch, rhythm, harmony, intensity, timbre, and spatial chracteristics. Musical functions may also vary according to the subjects musical experiences, whether they are musicians or nonmusicians [12-15]. Many of these lateralizations have been summarized by Gates and

Bradshaw[26]. Laterality difference in music seems to depend on the kind of processing required. Therefore, in a normal musical situation, processing is not restricted to one specific hemisphere but involves both hemispheres[6], [16].

In this context, it is supposed that effects of noise and music depend on what kind of task is performed, left-hemispheric task or right-hemispheric task. When one adds figures, detrimental effects of music is supposed to appear more compared with noisy condition, because of an interaction in the left hemisphere. When the subjects perform a pattern search, it is assumed to be influenced by noise.

II. PROCEDURE

1. Subjects

The pupils of two elementary schools in a quiet residential area were chosen as subjects. The subjects were 280 second-grade pupils 7 or 8 years old for simple search, and 279 fourth-grade pupils 9 or 10 years old for adding figures, as shown in Table 1. In Japan, first through sixth grade pupils from 6 to 12 years of age usually attend the elementary school.

2. Music and noise stimuli

The tests were carried out in the classroom of each school. Each class was divided into three groups as shown in Table 1. The "no stimulus" group was in the usual condition below 25 dB(A) without any sound stimulus. The "noise group" was given a jet noise which was recorded at a distance of 1.5 km from an airport when a jet air plane (Boeing-727) was taking off. During alternate periods l=2n (n=1,2.....N/2) during the task, the stimulus noise was reproduced through two loudspeakers which were set in front of the classroom. The "music group" was given an excerpt of music (Beethoven's Symphony No.9, fourth movement) in a way similar to the noise group.

The time patterns of the noise and music are shown in Figs. 1(a) and 1(b), respectively. The spectra at the maximum sound pressure level are shown in Figs. 2(a) and 2(b), respectively. These spectra indicate almost the same pattern. The peaks of noise and music levels reproduced in the classrooms were controlled within 90±5 dB(A). The reverberation time of all test rooms was not very different, 0.5 to 0.9 s for the audio frequency range.

3. Left- and right-hemispheric tasks

The two cerebral hemispheres process their own specialized information: the left hemisphere is superior for language, writing, and calculation (*verbal or sequential aspects*), while the right hemisphere is superior for visual pattern recognition, spatial ability, and drawing figures

Table 1. Number of subject

Task	Age (years)	Music group	Noise group	No-stimulus group	Total
Adding figures	9-10	36	123	120	279
Simple search	7-8	38	119	123	280

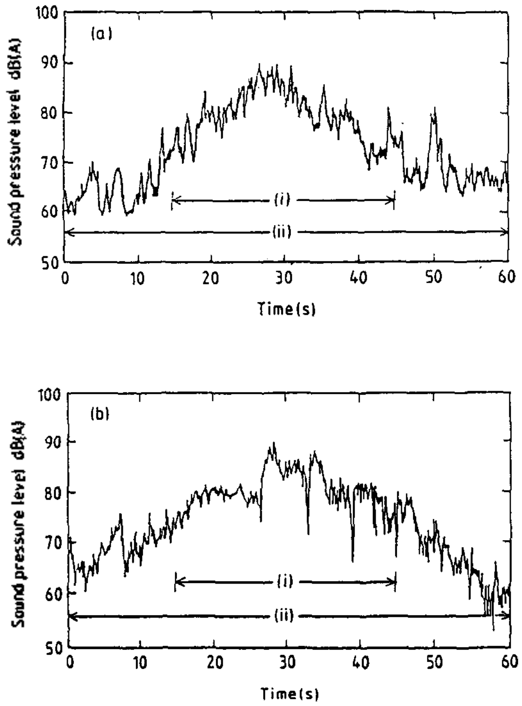

Fig. 1 (a) Jet Our Plane stimuli, (b) music stimuli during every alternate period of simple search task (i) and of adding task (ii).

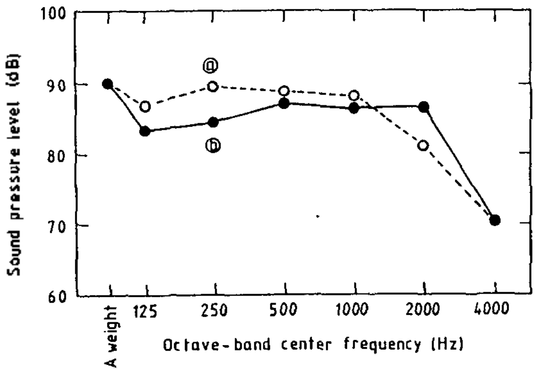

Fig. 2 (a) Spectrum of jet air plane noise, and (b) spectrum of music at the maximum sound pressure level.

(*nonverbal or spatial aspects*)[3-16]. In this investigation, an adding test was chosen as a left-hemispheric task and a simple search test was chosen as a right-hemispheric task.

(1) Left-hemispheric task

The task for the 9- and 10-year-old pupils was to add two figures, as shown in Fig. 3(a). The total values added were adjusted to be smaller than nine.

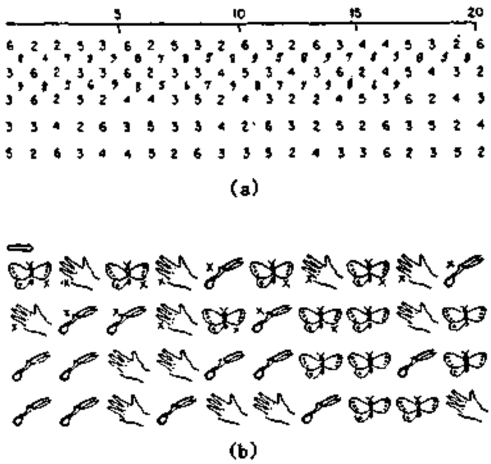

Fig. 3 Examples of task during a test period, (a) adding task, (b) simple search task.

(2) Right-hemispheric task

The mental task for the 7- and 8-year-old pupils was to find something lacking in each picture and drawing the symbol "X" on it, as in the example shown in Fig. 3(b).

The subjects were told to perform the task as fast as possible in each period and to start from the first period (i=1) when the signal "start" was given and start a new set of problems (i=2,3,4,...,N) as soon as the signal "next" was given. The procedure is shown in Table 2. The total time was 35 minutes for the adding

Table 2. Procedure of tasks

Task	First half of test Time(s)X Period(N)	Interval (s)	Second half of test Time(s)XPeriod(N)	Total (s)
Adding figures	(60X15)	300	(60X15)	2100
Simple search	(30X10)	120	(30X10)	720

task (N=30) and 12 minutes for the search task (N 20). Each task was divided into a first and a second half and there was also an interval for rest in between (5 minutes for the adding task and 2 minutes for the search task). This test method is called the "Krapelin-Uchida Test" and has been developed as a standardized mental test[17].

4. Evaluation of mental task

First, the individual work produced in each period, which is called the "working curve", was drawn for all test results as shown in Fig. 4. In this investigation, the following scores were calculated, based on the working curve.

(1) Mean working amount

$M_1=(1/N)\sum_{i=1}^{N} M_i$, $M_2=(1/N)\sum_{i=N+1}^{2N} M_i$, where N=15 for the adding test and N=10 for the search test. Taking the test. Taking the effect of training into account, the mean working amount of the second half is considered to show

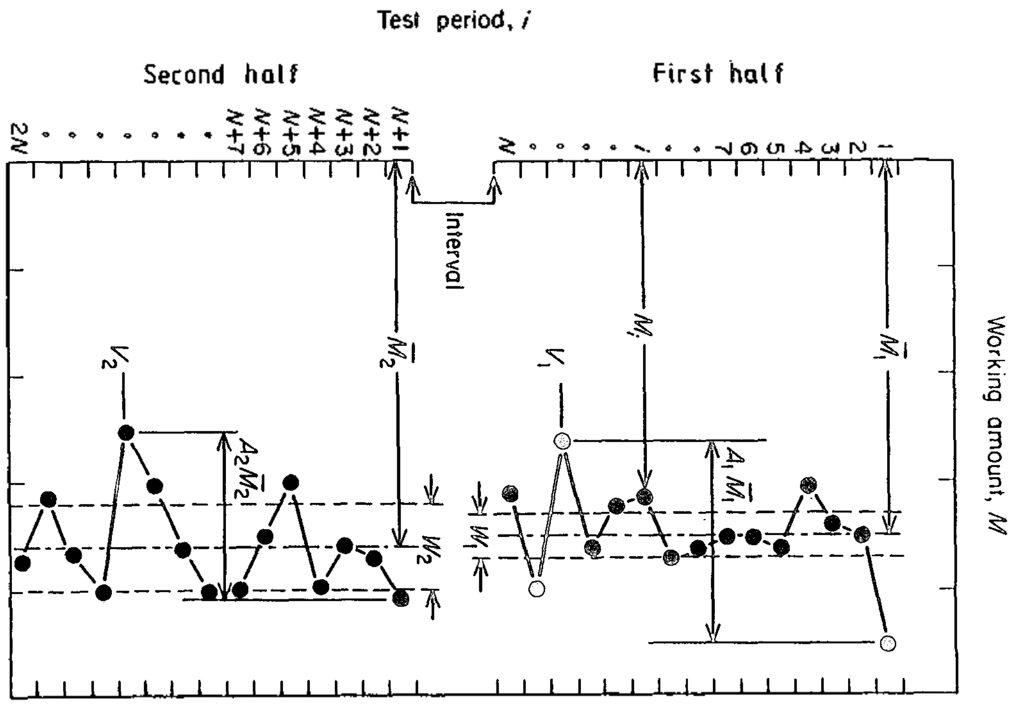

Fig. 4 Evaluation of "working curve" obtained by the test.

mental ability and to be greatly dependent on the intelligence quotient. However, it is not discussed in the present paper because no fundamental difference was observed.

(2) Agitation

$A_1 = \{M_i(Max) - M_i(Min)\}/M_1$ $(i=1, 2, \cdots, N)$, $A_2 = \{M_i(Max) - M_i(Min)\}/M_2$ $(i=N+1, N+2, \cdots, 2N)$. As the degree of variation changes according to the working amount , the basis of judgment was adjusted as shown in Table A.1 of Apendix[17]. This score is classified into two categories. It is hypothesized that an agitation or fluctuation would be found when the subject simultaneously performs two right-hemispheric tasks. Because the stimulus was exposed during every alternate period of tasks, this score is thought to be the instantaneous effect of sounds.

(3) V-type relaxation

This socre is classified into two categories according to the occurence of a sudden large fall in the working curve during each half of the task. This is very important along with the scores of the standardized test to judge mentality. V-type relaxation was assessed by

$$V_1 : M_i < M_1 - \frac{3}{2}W_1 \ (i=1, 2, \cdots, N),$$

$$V_2 : M_i < M_2 - \frac{3}{2}W_2 \ (i=N+1, N+2, \cdots, 2N),$$

the same hemisphere.

where W_1 and W_2 which are the average variations of the curve excluding the periods of i=1 and N+1 which usually give a larbe working amount, may be measured by the working curve (Note that $V_1 : M_i < \frac{3}{2}W_1$ and $V_2 : M_i < \frac{3}{2}W_2$ indicated in reference [25] should be read as defined above). Thus a subject was regarded as showing relaxation if any period showed a fall in output below $\frac{3}{2}W_j$ $(j=1,2)$. Such relaxation is thought to be caused by an abandonment of effort when mental functions are unbalanced or disordered. It is supposed that the left-hemispheric dominant or meaningful sound exposed during such left-hemispheric task may affect the mental function, because of interaction in

III. RESULTS

Before analyzing the data, no difference in the test results between the two elementary schools was found. Therefore, the data were combined to compare the results of pupils in the two elementary schools, as shown in Table1.

All the data were analyzed, but only thee results of the first-half of the test will be reported here, because no significant differences were found in the second-half results. Significant

Table 3. Significant differences obtained by the two-tailed test of Kolmogorov-Smirnov for each evaluation score in reference to that of no-stimulus group

Task	Music group	Noise group
Adding figures (Left-hemispheric)	Agitated(- -) Relaxd (<0.01)*	Agitated(- -) Relaxed (- -)
Simple search (Right-hemispheric)	Agitated(- -) Relaxed (- -)	Agitated(<0.1)* Relaxed (- -)

* Figures indicate the significance level.

differences obtained by the two-tailed test of Kolmogorov-Smirnov (KST)[18],[19] for each evaluation score in reference to that of the no-stimulus group are shown in Table 3. If no figure is printed in the table, it means that KST gave a significance level of more than 10%, showing no significant differences compared with the no stimulus group.

For the figure adding test as a left-hemispheric dominant task, the percentage of relaxed pupils showed a great significance level for the music group as compared with the no stimulus group as shown in Fig. 5(a) ($p<0.01$). However, the percentage of relaxed pupils showed no difference between the noise group and the no-stimulus group as can be seen from Fig. 5(a). It is remarkable that the music group differed significantly from the noise group ($p<0.01$) in the case of adding tasks. On the other hand, for agitation, no significant difference was found in any group as shown in Table 3 and Fig. 5(b).

For the simple search test, which is a right-hemispheric task, the percentage of "V-type relaxed" pupils i shown in Fig. 6(a). Little difference can be foundin the result. For agitation, only the noise group approached the significance level ($p<0.1$), as shown in Table 3 [see also Fig. 6(b)]. Although the agitated proportion of the music group was greater than that of the noise group, it did not reach the significance level partly due to the small number of subjects in the music group, as shown in Table 1.

IV. DISCUSSION

As was assumed, the effects of environmental sound during mental tasks are closely related to the content of the task being performed. Referring to the results, we assumed brain models involving the pattern of interaction in each hemisphere when a mental task is performed under noise and music, as shown in Fig. 7.

In the case of the figure adding task, there

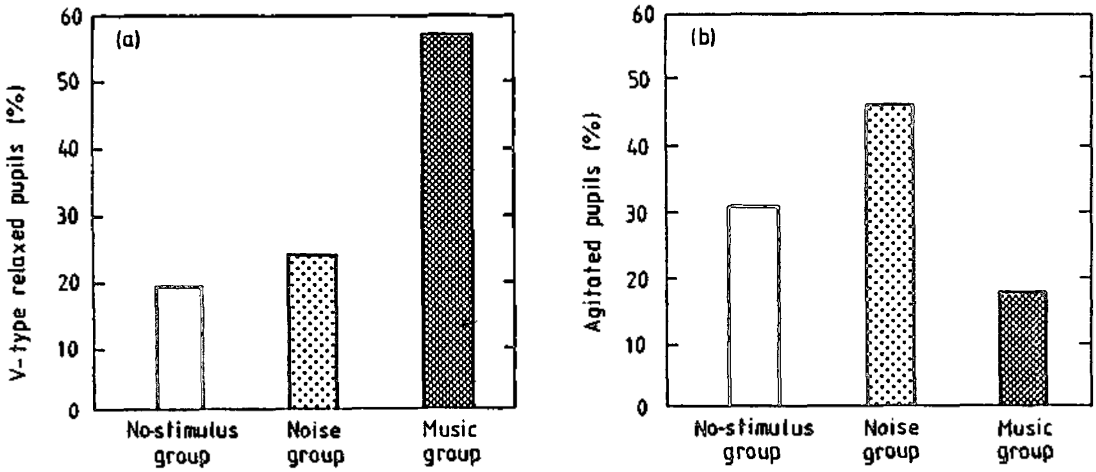

Fig. 5 (a) Percentage of "V-type relaxed" pupils during adding task, (b) percentage of "agitated" pupils during adding task.

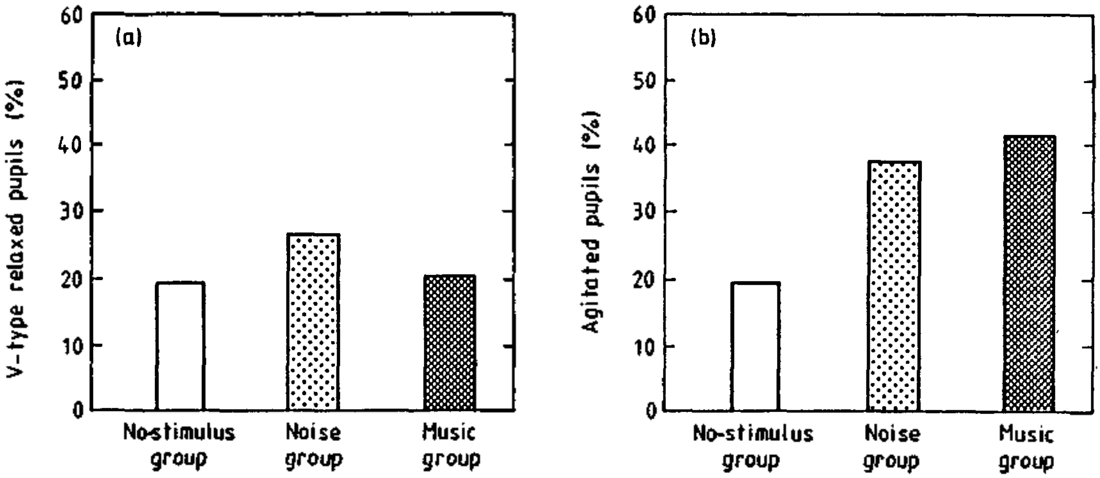

Fig. 6 (a) Percentage of "V-type relaxed" pupils during simple search task.

was no significant difference between the noise group and the no-stimulus group in the percentage of V-type relaxed pupils. This result may support the fact that noise and calculation tasks are separately processed in each different cerebral hemisphere [see Fig. 7(b)]. However, the percentage of relaxed pupils in the music stimulus group differs significantly from that of the noise stimulus group and the no-stimulus group. It can be explained from the fact that music perception and calculation are processed one after the other in the left hemisphere [see Fig. 7(a)]. In other words, the V-type relaxation in left-hemispheric tasks is considered to reflect the mode of the left hemisphere which processes information sequentially. Although we assumed that music was processed by both hemispheres, music did not appear to impair the process of search task in this investigation; a rather slight decrease of agitation in comparison with no-stimulus group occurred.

In the search task, V-type relaxation did not

APPENDIX

Table A.1

Judgment of "agitated" pupils

A	Categories of mean working amount M_2										
		1		2		3		4		5	
	0		15		20		25		30		(Simple task/30 s)
	0		15		25		35		45		(Addint task/60 s)
A_1		0.75		0.59		0.46		0.35		0.26	
A_2		0.66		0.46		0.33		0.29		0.26	

If A_1 or A_2 is larger than this standard value, the subject is judged as agitated in the first half of the task or in the second half of the task, respectively.

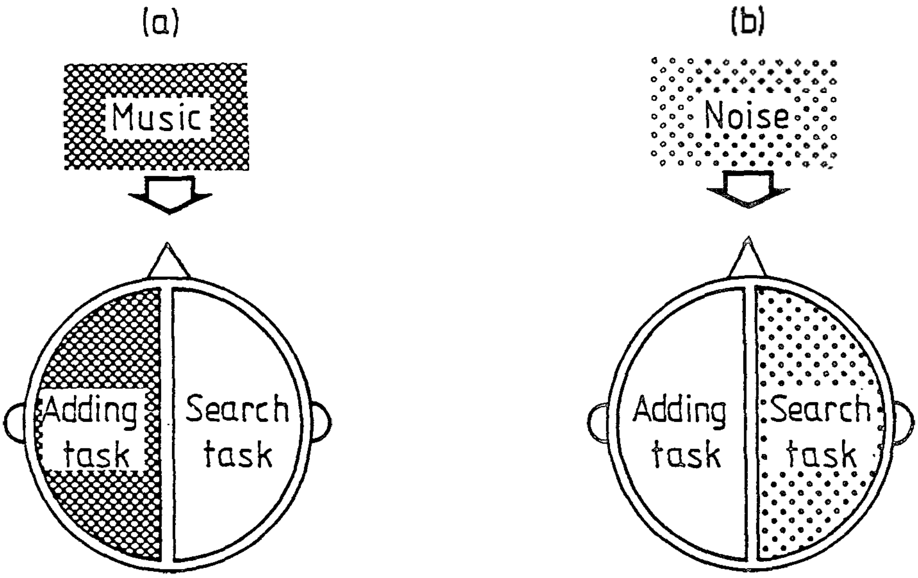

Fig. 7 Hemispheric interaction models performing mental tasks, (a) under music stimulus, and (b) under noise stimulus.

appear under both stimulus conditions. Interactions in the right hemisphere seemed to have occurred, but a significance level existed only for agitation. The observation of agitations or fluctuations as instantaneous effect of sound results presumably from the interaction between noise processing and pattern recognition in the right hemisphere [see Fig. 7(b)].

From this point of view, we can also explain the results of several other investigations well, although not exactly same experiemental results. For example, Kumagai et al.[20], who also applied the Krapelin test of adding figures, to subjects in noisly and quiet school rooms, reported that there were no significant differences in the work amount between the tests in noisy and quiet school rooms . Broadbent[21], who gave subtraction tasks to subjects in a 100 dB noise, reported that intellectual tasks were affected by noise, which seems to be in conflict with our result. However, his task involved immediate memorization as well as intellectual tasks. It required the subjects to memorize a number from a visual display of the right hemispheric dominance[22]. The effect of noise during each memorizing period was investigated by Woodhead[23]. The result indicated that there were decremental effects of noise during memorization. On the other hand, noise occurring during calculations did not cause a variation in calculating time or their accuracy. Thus, when mental tasks involve a short-term memory load, they appear to become susceptible is the effects of noise[24].

V. CONCLUSION

Effects of music and noise stimuli during mental tasks were significantly different. The adding test (left hemispheric task) was not affected by meaningless noise. In contrast with noise effect, however, a significant decremental effect was observed with the adding task under music stimuli. Particularly, the number of V-type relaxed pupils remarkably increased when music was presented. The V-type relaxation did not appear with the search test tright hemispheric task) under noise and music stimuli, although instantaneous agitation under noise stimulus was observed.

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