On the Mechanism of "Hypersonic Effect"

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Abstract

The authors found that high frequency above the audible range can affect brain electric activity and sound perception using close-eyed subjects and named the effect "Hypersonic Effect". Here we report on Hypersonic Effect of open-eyed subjects.

1. Introduction

The authors found that there were rich high frequency components above the audible range (20kHz) in some kinds of natural environmental sounds and instrumental sounds [Oohashi *et al.* 1989]. In our former research [Oohashi *et al.* 1991], we have developed a new system for sound recording and presentation and a novel technique to measure brain electric activity. We used them to determine if high frequency components above the audible range can influence sound perception.

As a result, when we presented full-range Gamelan music of Bali, Indonesia with rich high frequency components above 30 kHz to the subjects, many of the subjects showed a clear increase in α-EEG (electro-encephalogram) power. When we cut the high frequency components above 26 kHz of the same Gamelan sound and presented, power of α-EEG decreased. In addition, the result from a subjective sound quality evaluation experiment indicated at a high level of significance that the music containing high frequency components was perceived as more pleasant than music from which high frequency components were eliminated. This is consistent with the numerous reports that α-EEG is increased by pleasant sounds and inhibited by unpleasant ones. We named this effect "Hypersonic Effect."

Based on these results, we proposed a "two dimensional sound perception model" to explain its mechanism. In this hypothesis, frequencies in the range from 20 Hz to 20 kHz act as a message carrier dimension through auditory receptors, and frequencies in the range above 20 kHz represent a modulation dimension that influenced the way audible sounds are perceived through some kind of somatic sensory receptor. It could be considered that the increase of α-EEG power was

observed as a reflection of the modulation of some function in brain.

However, in ordinary studies on EEG, it is an established theory that α-EEG disappear when the subject opens his/her eyes. In our former experiments, subjects were asked to close their eyes. And it is relatively uncommon for us to close our eyes when we listen to sounds or music. So, we determined whether our method, using α-EEG as an index, would be successful when the subject is open-eyed as the first step to examine on the mechanism of "Hypersonic Effect".

2. Method

Gamelan music was reproduced and presented repeatedly using the bi-channel reproduction system [Oohashi *et al.* 1991]. Full-range sound or high-cut sound were reproduced without the subjects' prior knowledge. Full-range sound contains high frequency components above 26 kHz, but high-cut sound does not. Subjects were asked to open their eyes. At 11 scalp points, EEGs were recorded based upon the international ten-twenty electrode system. To minimize stress, we investigated the use of telemetric system to avoid restraint of the subject, improvement of the affixing method of electrodes and adaptability of the measuring environment. EEGs were delivered over 30 minutes (including before and after the sound presentation), and recorded on magnetic tapes.

For data analysis, we used the brain electric activity mapping (BEAM) based on FFT. To evaluate with high reliability, we investigated the condition of measurement and the method for data analysis in detail.

3. Result

From our experiment, it is shown that we are able to observe the Hypersonic Effect in more than half of the subjects, if certain condition for experiment and method for data analysis were settled.

Table 1. Effect of high frequency components on α-EEG power (open-eyed condition)

Subject	Change of α-EEG power
1	25.6%
2	21.8
3	8.2
4	8.0
5	7.9
6	5.3
7	5.0
8	3.8
9	1.6
10	−3.3
Average	8.4
t	5.02
Reliability	(%) 99.95

In this experiment, when full-range sound was presented, 7 subjects out of 10 showed a clear increase in α-EEG power compared with high-cut sound, and only one subject showed a little decrease as shown in Table 1. This result shows that high frequency components above 26 kHz are able to induce increase of α-EEG with 99.95% reliability. The reliability in this experiment is higher than in another experiment we conducted using close-eyed subjects (Table 2) [Oohashi *et al.* 1991]. In the measured α-EEG maps after 20 second intervals, when the full-range sound was presented, α-EEG power

Table 2. Effect of high frequency components on α-EEG power (close-eyed condition)

Subject	Change of α-EEG power
1	134.9%
2	122.1
3	98.5
4	55.7
5	40.6
6	35.4
7	17.7
8	13.2
9	12.3
10	10.9
11	10.2
12	8.3
13	-0.8
14	-2.5
15	-3.1
16	-3.3
Average	34.38
t	2.83
Reliability	(%) 99.0

increased, and when the high-cut sound was presented, the power decreased. For all subjects, there was an initial time delay, α blocking effect and artifact caused by eye movement in frontal area were observed. We found that 20 to 40 seconds were needed to get stable data. These result showed that this new method of experiments would be able to explain the mechanism of Hypersonic Effect.

References

[Oohashi *et al.* 1989] T.Oohashi et al., High frequency sound on "Trance Induction Music, Tech,Rep.Musical Acoust. Acoust.Soc.Jpn, ES88-77, pp.11-15.

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