

Inaudible High-Frequency Sound Affects Frontlobe Brain Activity

Shim Han-Moi¹, Cho Ok-Hue¹, Jang Seok-Woo², Choi Ji-Hyang², Choi
Hyun³ and Lee Won-Hyung^{4*}

¹Chungang University, Heukseok-dong, Dongjak-gu, Seoul, Korea, South Korea

²Korea Mindtraining Institute , Bongcheon-dong, Gwanak-gu, Seoul, Korea

³National Rehabilitation Center Research Institute, 58, Samgaksan-ro
Gangbuk-gu, Seoul, Korea

⁴ Chungang University, Heukseok-dong, Dongjak-gu Seoul, Korea

*Corresponding Author

Copyright © 2014 Shim Han-Moi, Cho Ok-Hue, Jang Suck-Woo, Choi Hyun and Lee Won-Hyung. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

High-frequency is sound produced in non-audible area, which couldn't be heard in daily life. The frequency range above 22 KHz is called 'high-frequency' and its components are called 'HFC (High-Frequency Components)'. It is known that ocean wave sound is rich in HFC, because it brings serenity and causes α -waves in human mind. When this natural sound is combined with high-frequency, it seems to give a pleasurable feeling, indicated by a α -wave increase and a β -wave decrease. We call this phenomena "the hypersonic effects". In this experiment, subjects listened to the ocean wave sound simultaneously with corresponding frequencies similar to ocean wave frequency components created artificially in a electric circuit. Brain waves were measured by an EEG system with 8 channels using 2 electrodes on Fp1, Fp2. The results showed that α -wave increase and β -wave decrease were statistically significant while subjects were listening to ocean wave sound along with the high frequency components, reflecting the hypersonic effect.

Keywords: High-frequency, HFC (High-frequency components), hypersonic effects, brain wave, α -wave, β -wave

1 Introduction

Frequencies above 22 KHz are often called high-frequencies and their components are called HFC (High-Frequency Components). The coastal wave sound is one example of natural high-frequency sound (Tsutomu et al. 2000). In fact, the effects of high-frequency on the human body and the brain have rarely been studied in Korea. Should the effects of high-frequency sounds on the brain activities be proven to be meaningful, the results can be utilized in the development of various applied products and also in such fields as medicine and education. Generally, ocean wave sounds recorded and reproduced through media devices are delivered in audible frequency ranges under 22Khz; however, in the process of being converted to digital signals, their original sound characteristics become considerably distorted.

Fig.1 shows the characteristics of coastal wave sound frequency. The frequency ranged broadly from about 20 kHz through 60 kHz, which was way out of audible frequency range. Wave sound's acoustic pressure is highest (about 80-100db) in the audible frequency range (within 20kHz) Even if the ocean waves of their frequencies beyond 20kHz become inaudible to humans but its intensity continues to exist between 20kHz and 50kHz with its highest intensity about 60dB. This indicates that the High Frequency Components of ocean wave sound are concentrated in the frequency range between 20-50 kHz.

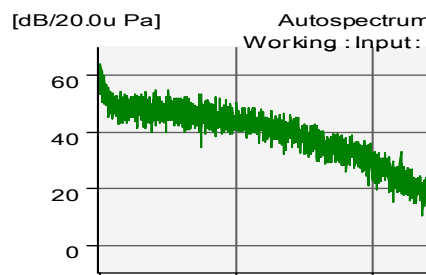


Fig.1 Characteristics of coastal wave sound frequency.

Theta waves occur in a sleeping state or in a deeply relaxed state. As for Alpha waves, a variety of studies have shown that it occurred when subjects were in a relaxed arousal state especially with their eyes closed or in a state of clear mind and attention; they were also related to performance enhancement. Alpha waves were increased when people were performing memory tasks. In addition, increasing Alpha waves through a neurofeedback training resulted in the enhancements of memory and attention (Jang, S,W 2003).

The purpose of the study was to examine how the certain high frequencies generated by the natural ocean wave sound affected the brain. Instead of using the

existing methods, we separately manufactured a high-frequency generating device for our experiments. The previous high-frequency device separated the high-frequency section by a filter, then amplified and delivered it through a speaker. Our device, however, generated and amplified specifically 40 kHz high-frequency and the audible wave sound was delivered through a speaker separately. In other words, unlike the previous studies, the present study attempted to look at the effect of the high-frequency sound on EEG when the high frequency components were presented using the high frequency generating device separately from the audible ocean wave sound presented through a ordinary speaker.

2 Methods

2.1 Apparatus

2.1.1 High-frequency generator

We developed a separate high-frequency generator to produce the specific frequency that showed an Alpha wave enhancement effect in the previous experiments, and the generator was made directional so that the generated high frequency could be delivered directly through the ears. We wanted to look at how the high-frequencies generated this way would affect the ocean wave sound and eventually the human body. The high-frequency generating device used a Dr. Schuwen ultrasound generator made by Innochip Technology® and had a separate power supply (Fig 2).

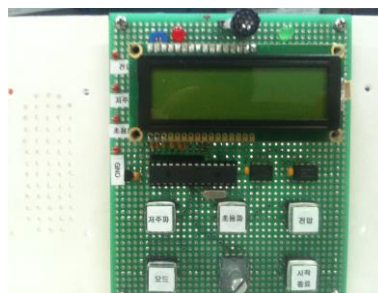


Figure 2. High-frequency generating device

As shown in Figure 2, the device comprised of a power supply, a high-frequency generator, an amplifier and an LCD screen indicating current output in real time. 5-volt power was used and the maximum output was 0.001 Watt (1mW).

Figure 3 represents the response characteristics of its module showing that the central frequency was around 40 kHz. The device was designed to give out a sound pressure level of 85dB for 40 kHz and 60dB for 35 kHz and 45 kHz at around 1meter in front of the sound source.

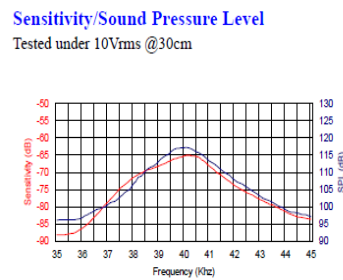


Figure 3. Frequency response of hypersonic device module

2.1.2 EEG system

A QEEG-8(Laxtha, Inc, Korea) was used to measure the brain waves of the participants.

According to the international 10-20 electrode placement system, 2 electrodes were placed at Fp1, Fp2

2.2 Sound materials

There were four stimuli conditions in the experiment. First, high-frequency sound combined with natural waves sound (full range sound condition), second natural sound wave, third, high-frequency alone (high frequency component condition), and last, no sound condition (baseline condition).

1) Stimulus condition 1: FRS (full range sound)

Participants listened to the natural sound of ocean waves and simultaneously to the high-frequencies artificially generated by the high-frequency generating device.

2) Stimulus condition 2: natural ocean wave sound

A recorded ocean wave sound was presented via a general digital displayer or speakers.

3) Stimulus condition 3: HFC

The artificially created high-frequency single tone around 45 kHz was designed to simulate the high-frequency components of natural ocean waves.

4) BASELINE

No stimulus was given to participants.

2.3 Subjects

Korean 50 volunteers aged from 19 years to 59 years participated in the experiment. Subjects were divided into two groups with one of them being the experimental group that heard the stimulus conditions 1 (natural sound + high-frequency) and 3 (high-frequency alone) and the other being the control group that heard the stimulus condition 2(natural ocean wave sound) and 4 (no sound condition). Each subject was randomly assigned to one of the two groups.

2.4 Procedures

Table 1 shows the experimental procedure in detail. 50 men and women are randomly placed in each group (25 in each group). The participants in the experiment group (EG) heard the stimulus conditions 1 and 3 for 5 minutes each whereas those in the control group (CG) heard the stimulus conditions 2 and 4 for 5 minutes. EEG signals from the subjects' surface brain were measured before and during the stimulus presentations separately.

Table 1. Method of Experiment (EG -Experimental group, CG -Control group)

	Members	Stimulus	Before	After
EG	25	1.Hypersonic wave (5min) 2.Hypersonic wave + Ocean wave(5min)	EEG 2ch	
CG	25	1.Silence(5min) 2.Ocean wave (5min)		

3. Result

Table 2. Alpha relative power; Ocean wave (1. Control group) vs Ocean wave + hypersonic wave(2. Experimental group)

ch	group	Average	SD	n	F	p
Fp1	1	30.52	6.48	25	26.09	.000**
	2	34.27	2.80	25		
Fp2	1	31.482	7.843	25	12.46	.001**
	2	34.483	5.133	25		

Table.2 shows ANOVA analyses results between the experimental group (that heard the ocean wave sound and the high-frequency component simultaneously) and the control group (that heard the ocean wave sound only). All of the 2 EEG channels were analyzed. The relative powers of Alpha and Beta brain waves At Fp1 and Fp2 were significantly different between the two groups (Fp1 < 0.01, Fp2 < 0.01). This result was consistent with Tsutomu (2000)'s study results in which alpha waves were also increased at the occipital cortex.

Table 3 Beta relative power; Ocean wave (1. Control group) vs Ocean wave + hypersonic wave (2. Experimental group)

ch	group	Average	SD	n	F	p
Fp1	1	17.61	1.54	25	5.82	.020*
	2	16.07	2.81	25		
Fp2	1	17.84	2.44	25	11.10	.002**
	2	15.40	2.73	25		

As shown in Table 3, Beta waves were also decreased significantly at Fp1 and Fp2 (Fp1 < 0.05, Fp2 < 0.01). Beta waves regarded as the signs of tension and arousal were decreased at the pre-frontal lobes when people heard the ocean wave sound and the high-frequency component at the same time.

Table 4. Alpha relative power; Silence (1. Control group) vs. Hypersonic wave (2. Experimental group)

ch	group	Average	SD	n	F	p
Fp1	1	30.52	6.48	25	7.082	.001**
	2	34.27	2.80	25		
Fp2	1	31.482	7.843	25	4.23	.045*
	2	34.483	5.133	25		

Table 5. Beta relative power; Silence (1. Control group) vs. Hypersonic wave (2. Experimental group)

ch	group	Average	SD	n	F	p
Fp1	1	18.71	1.87	25	16.62	.000**
	2	14.07	4.62	25		
Fp2	1	31.482	7.843	25	12.06	.001**
	2	34.483	5.133	25		

The high frequency component vs. no sound conditions were also compared (See Table 4 for alpha waves, Table 5 for beta waves). Even if subjects did not hear

any sound in both conditions, the subject group in the high frequency condition showed an increase in alpha waves and a decrease in beta waves at both Fp1 and Fp2, compared to the no sound condition. It may be said that the high-frequency component combined with the audible ocean wave sound would had a greater effect on alpha increase at both the pre-frontal and occipital lobes in comparison with the high-frequency component alone.

3. Discussion and conclusion

Generally the high frequency induced EEG changes featured by an increase in alpha waves and a decrease in beta waves. As a low quality ocean sound is different from a high quality 3D surround sound, a high-frequency ocean wave sound seems to be different from a simple low frequency ocean wave sound in its effectiveness. In other words, when a ocean wave sound is heard with the high frequency component, the listener feels more pleasure, pleasantness, and feels less tension and more relaxed. Some researchers including Oohashi(1991,2002) and Tsutomu (2000,2006) investigated this phenomenon called 'the hyper sonic effect' but the exact causes of this phenomenon has not been clearly revealed. One possible explanation is that the vibration of the air is delivered through the auditory route to the deeper brain structures and the autonomic nervous system. The advocates of this hypothesis recognized the high frequency vibration of the human voice as stimulating the auditory cortex (Hosoi e al 1998). If this hypersonic effect can be utilized in everyday life, to our great expectation, we may be able to enhance attention and relaxation and reduce tension and stress using the high frequency generator. The results of the present study confirmed the hypersonic effect occurring when ocean wave sound was combined with the high frequency component. We examined how the high frequency sound affect throughout the brain using the EEG at frontal brain areas. The present study differed from the previous studies in that it did not need an expensive speaker or high frequency CD player and that it was very simple and useful to be applied in developing a device to have the hypersonic effect However one of the weaknesses of the high frequency component is that it loses its power abruptly specially as the distance from the sound source increases so that it should be placed very close if it is to be effective. Also, various high frequency generating equipment will be developed to utilize the hypersonic effect.

Acknowledgements. This research was supported by Innochip Technology® & Chung-Ang University's Cross Functional Team (CFT) Program under Brain Korea 21 PLUS Project in 2014.

References

- [1] Hosoi H, Imaizumi S, Sakaguchi T, Tonoike M, and Murata K. (1998). Activation of the auditory cortex by ultrasound. *Lancet* 351: 496–497

- [2] Jang, S. W (2011). A study of personality type & evoked potentials. Korean Journal of the science of Emotion & sensibility, Vol.14.No.1, 137-146.
- [3] Lee, Y, H (2003). The effect of attention and memory on alpha wave - Relax training program in students with cerebral palsy. University of Daegu Press.
- [4] Oohashi, T., Nishina, E., Kawai, N., Fuwamoto, Y., Imai, H., (1991). High-frequency sound above the audible range affects brain electric activity and sound perception. Proceedings of 91st Audio Engineering Society convention. Audio Engineering Society, New York.
- [5] Oohashi, T., Nishina, E., Honda, M., (2002). Multidisciplinary study on the hypersonic effect. In: Shibasaki, H., Fukuyama, H., Nagamine, T., Mima, T. (Eds.), *Inter-Areal Coupling of Human Brain Function*. Elsevier Science, Amsterdam, 27–42.
- [6] Tsutomu, Oohashi, Emi Nishina et al. (2000). Inaudible High-Frequency Sounds Affect Brain Activity: Hypersonic Effect, *The American Physiological Society, J Neurophysiol* Vol 83: 3548–3558.
- [7] Tsutomu Oohashi, Norie Kqwai, Emi Nishina et al. (2006). The role of biological system other than auditory air-conduction in the emergence of the hypersonic effect. *Brain Reserch*, 1073-1074, 2006, 339-347

Received: August 1, 2014