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On the Signal Analysis of Two Waterfall Sounds in Australia's Broken Falls

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Abstract

More and more people are paying attention to the psychological pleasure and relaxation that sound hearing brings. In most cases, humans seem to have a special preference for natural sounds. Natural sounds are mainly white noise and pink noise such as wind, rain, waves, waterfall sounds, etc. All of these are often considered to be beneficial to human health, but in reality the same category of natural sounds is no different. It will be very different due to space, time and other factors. Each sound can be unique, so people's hearing experience is also different. This paper quantitatively analyzes the spectrum and brain waves to analyze the feeling of hearing the natural Broken Falls sound. In particular, we aim to objectively analyze the objective feeling of Broken Falls sound falling on the human auditory system through sound spectrum and brain waves..

Keywords: EEG, Spectral Analysis, Broken Falls sound, Health, Brain Wave, White sound, Grampians Mt..

1. INTRODUCTION

The human auditory organ perceives sound primarily in terms of three aspects: pitch, sound intensity and tone. Pitch is the frequency of sound, and the human hearing frequency is from 20Hz to 20KHz. The audible frequency band bandwidth gradually decreases over time. Humans have different objective perceptions of sounds of different frequencies in a frequency band. 20Hz-60Hz part: This section can give you a strong, deep and sensual feel. 60Hz-250Hz part: This part is the low frequency part of the sound that can show a sense of rhythm. The 50Hz-4KHz part is very close to the human voice, but it's a bit boring. If it is too high, the sound is similar to that of a phone. The human ear is more sensitive to this frequency band, but is prone to hearing fatigue. The 4kHz-5KHz part is a frequency band that affects the distance of the sound.

High volume makes people feel that the sound source is very close to the listener. If the volume is too low, the distance of the sound increases, indicating the energy part of the sound. The frequency band in the 6kHz-20kHz part mainly represents the tone, and the high volume makes the sound louder and brighter, but it is not clear. When the volume is low, the sound is clear but a little thin.[1] The human ear also perceives sound by frequency. The cochlea has a basement membrane that is often curved, and many auditory nerves are distributed under the basement membrane to receive sounds of various vibration frequencies. The basement membrane is divided into 25 frequency groups in the audible frequency band. Due to the masking effect, different frequency sounds of each same frequency group are superimposed together for frequency analysis.

Figure 1 shows the structure of an unfolded cochlea.[2] The intensity of sound is the intensity of the sound amplitude and the amount of sound energy. The volume range that the human ear can feel is $10^{-16} \sim 10^{2}$ W/cm^{2}. The sound intensity is too low to be heard, and if it is too high, the auditory organs are damaged. Humans have different perceptions of loudness at different frequencies. That is, they have different psychological perceptions of the same loudness and different frequencies.

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Voice is a unique feature of each sound. The brain distinguishes and recognizes sounds through tones that are represented by spectral envelopes in the frequency spectrum. Therefore, frequency spectrum analysis of sound can obtain the frequency spectrum component, sound intensity, and tonal characteristics of the spectrum envelope.[3] [4]

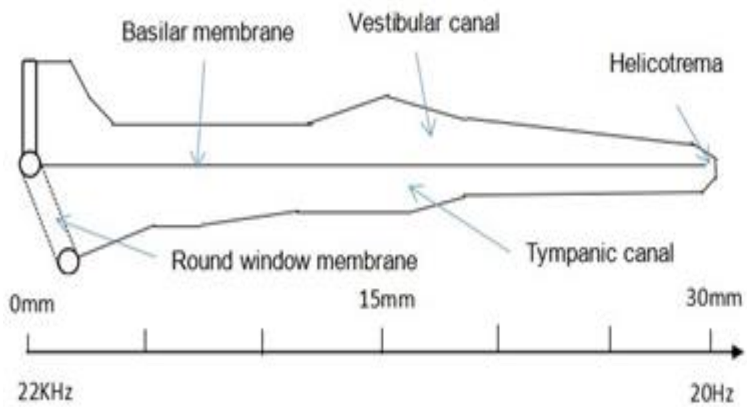

Figure 1. Flattened cochlear structure. [2]

This paper describes the sound characteristics of Broken Falls. Broken Falls is a very impressive, majestic yet broken J-shaped waterfall in Grampians Mt., Australia. This waterfall sits deep inside the Grampians National Park. The waterfall is over 50 meters high. Tourists can gaze at the majestic waterfall from a distant observation deck, or admire the sounds and shapes on the trails by the waterfall until they reach 100m below the waterfall. Down the stream of the waterfall is a beautiful natural pool that connects to the river. So visitors can appreciate its beauty and hear it from different angles.

This paper is divided into 5 parts. Chapter 1 is an introductory chapter, and Chapter 2 presents a spectrum analysis of the Broken Falls sound. Chapter 3 is the definition and analysis of brain waves. Chapter 4 is the result of the EEG measurement experiment and EEG analysis, and the conclusion is made in Chapter 5.

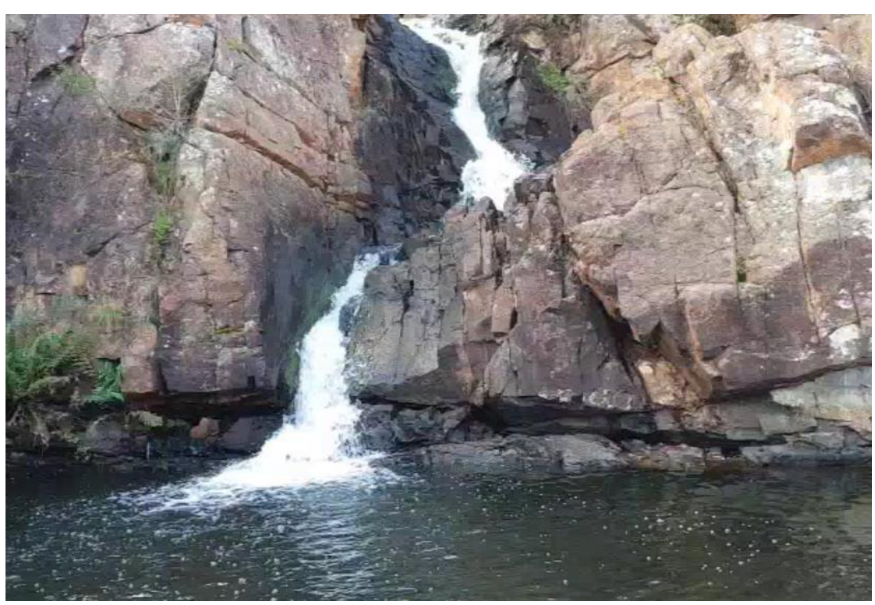

Figure 2. Broken Falls, Grampians Park, AU.

2. SOUND SPECTRAL ANALYSIS

The sound spectrum analysis tool is Adobe Audition CS6. The waterfall sound is taken as a sampling frequency of 44khz, and the FFT length is passed through FFT transformation with 1024 points, and the Hamming type is used as the window function. As shown in Figure 3, the spectral energy of sound is widely distributed over the entire audible frequency band. The low frequency energy is higher and the spectral energy gradually decreases with increasing frequency. The spectral energy distribution characteristic is similar to pink noise (-3dB/octave). Pink noise is considered a healthy sound preferred by humans.

The waterfall spectrum in Figure 3 consists of resonant peaks distributed in 500Hz, 4.5KHz and 12KHz, and each resonant frequency has two peaks. These three peaks determine the tonal character of the Broken Falls sound. The first low-frequency bimodal peak represents 400Hz and 600Hz in the F1 section, which becomes the sound of the waterfall flowing according to the topographic characteristics of the waterfall. As the name implies, the two waterfalls are bent and flow with different sound characteristics, and visitors can feel the mystery of the two Mokpo sounds that flow like fighting.

The second peak represents the sound of falling water flowing violently down the rock wall. In addition, 2.5KHz and 6.5KHz exhibit bimodal characteristics, so you can feel the sound of a water stream as if competing with each other. The third bimodal frequency is a sound component of 11KHz and 13KHz, which is the sound of water crashing against the surface or rocks, and these sounds irritate your ears and make you feel lively. The high-frequency, high-energy sound is high-pitched and clear, improving people's attention and concentration.[6][7]

Figure 3. Spectrum analysis of Broken fall Sound.

3. DEFINITION OF BRAIN WAVE AND SPECTRAL ANALYSIS OF EEG

For analysis of human brain activity and emotions, brain waves (EEG) are commonly used in the analysis. It is currently an electrophysiological monitoring method that records the electrical activity of the brain. [8] In other words, EEG records time-domain changes in translocations at different locations in the cerebral cortex. This time domain signal is the sum of the various chemical and electrical activation signals and it is difficult to analyze the time domain signal directly. Therefore, in frequency analysis, brain waves are finally defined according to different frequencies and functions through a number of observational experiments. Until now, brain waves are divided into five types: delta waves, theta waves, alpha waves, beta waves, and gamma waves.[9] However, gamma waves are not explained in this experiment. Table 1 is a classification of brain waves and brain functions.[10]

Table 1. Classification of brain waves.[10]

Types (Frequency)	Amplitude	Human brain activity
δ wave (1-3hz)	20 - 200μV	In most cases, it occurs in deep sleep. Neurons in the cortex are in a state of simultaneous relaxation, which is an unconscious brain wave.
θ wave (4-7hz)	100 - 150μV	It is a brain wave that appears between awake and sleep states, it is the performance of the central nervous system's inhibition state, and is related to the learning and memory processes.
α wave (8-13hz)	20 - 100μV	It is the main brain wave that appears in a normal quiet state, indicating that in a quiet state, the cerebral cortical nerve cells are in a state of relaxation and preparation for activity. The appearance of α Wave can make people feel relaxed quickly.
β wave (14-30)	5 - 20μV	It occurs when people perform behavioral actions and increase attention, such as thinking about problems or performing intellectual activities. However, the continuous emergence of a large number of β waves will give a lot of pressure and tension.

The EEG signal is an abnormal signal, but it is stable in a short time. Therefore, the windowing process must be performed before spectrum analysis, and the feature extraction of the EEG signal is also based on the analysis frame. Analysis methods for unsteady signals typically include short-time Fourier transform, wavelet transform, Hilbert-Huang transform, and linear prediction.[11] These all reflect the instantaneous spectral characteristics of the signal and can extract the characteristics of the signal. Then the extracted signals are classified and analyzed.

Commonly used classification methods include KNN (K-Nearest Neighbor) classifier and SVM (Support Vector Machine). This machine learning-based classification method is too complex because it requires a lot of learning data and a lot of calculations, and a table-based classification method is applied in this paper [12]. EEG components and their amounts can be obtained through frequency analysis of EEG, and finally, the emotional state of the subject can be judged by comparing the ratio of each EEG.

The spectrum analysis method used in this paper is a power spectrum density analysis based on linear prediction. The autocorrelation function (ACF) and the power spectrum density function are a pair of Fourier transforms. Here is the short-term autocorrelation function.

$$R_n(k) = \sum_{m=-\infty}^{\infty} x(m)W(n-m)x(m+k)W(n-m+k) \quad (1)$$

Here, the short-term autocorrelation function can be viewed as the output of the sequence x(m)x(m-k) through the hk filter. Where W(n) is a 256 point Hamming window. Since the autocorrelation function and the power spectral density function are Fourier transforms of each other, they must be passed through an AR filter to obtain the spectral envelope of the power spectrum. Where G is the gain and p is the order.

$$H(z) = \frac{G}{1-\sum_{i=1}^{p} a_i z^{-i}} \quad (2)$$

Gx(n) is called the prediction error and the difference equation of the linear predictor is defined as: Transfer function of the P-order predictor. [13]

$$\sum_{i=0}^{p} a_i r(|j-r|) = r(j) \quad 1 \le j \le p \quad (5)$$

$$E = r(0) - \sum_{i=1}^{p} a_i r(i) \quad (6)$$

Eventually, the prediction coefficient $a_i(.)$ can be obtained with the Levinson-Durbin recursive algorithm.[13]

4. EXPERIMENTAL AND RESULTS

First, record the sound source of Broken fall for 1 minute and save it in wave format. Then, 4 college students aged 20 to 25 years of age with normal hearing measured EEG, 2 men and 2 women. The test equipment used in the experiment is a two-channel 45Hz bandwidth EEG measurement equipment produced by Neuro Harmony S. The single channel sampling frequency is 256Hz. The testing site is a quiet laboratory.

The experiment is divided into two parts to compare the changes in brain waves caused by sound stimulation. The first part measures the recipient's brain waves in a quiet, silent environment. The second part measures the subject's brain waves when the sound of the waterfall is heard. The EEG measurement time for each part is 2 minutes and 30 seconds. All subjects quietly closed their eyes. In order to eliminate the psychological effects of physiological activity, tests were performed 1 hour after meals. And the EEG signal data is acquired.[14]

In the measurement experiment, the EEG signal with a frame length of 4 seconds per minute was blocked for spectrum analysis. Figure 3 shows the PSD and spectrogram of subject A's EEG. This figure shows the test result of the subject, and it can be seen that the α EEG of subject A is increasing when listening to the waterfall sound in the PSD diagram. In the case of β EEG, β EEG significantly increased in all subjects, and in the case of α EEG, subjects C and D increased. In particular, the difference before and after the waterfall sound was markedly decreased between the δ brain waves and the θ brain waves of all subjects.

Figure 4 shows the spectrogram of the four subjects as color codes. The four colors in each graph indicate the frequency of the EEG, and the color width indicates the intensity of the EEG. Here, the state of change before and after hearing the sound of the waterfall was compared for 4 people in pairs. When all four people heard the sound of the waterfall, the yellow energy area of the spectrogram was widened, which means that the energy in the beta brain wave area increased, and the alpha brain wave increased slightly. [12] [14] [15]

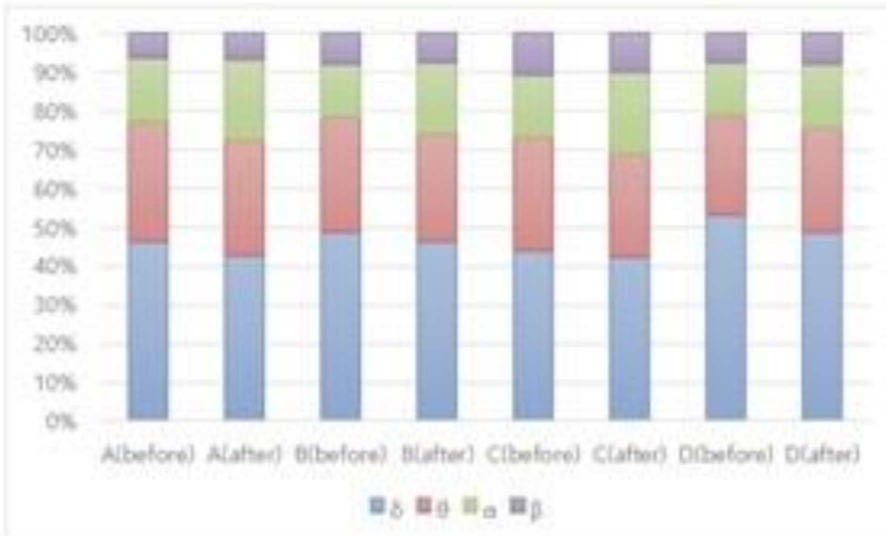

Figure 4. The Ratio of brain wave levels of the four subjects before and after hearing the Broken Falls sound.

5. CONCLUSION

In this paper, we analyze the sound composition of Broken Falls in terms of frequency based on the way humans perceive sound and explain its acoustic characteristics. In order to further study the response of the human brain to the Broken Falls sound stimulus, the EEG signal was analyzed with a frequency spectrum and the EEG component and the content of the EEG signal were obtained. And compare the results before and after hearing the sound of the waterfall.

As a result of audio frequency domain analysis, the full spectrum energy distribution characteristic is similar to pink noise. However, there are three distinct bimodal peaks located in the low, medium and high frequencies. This is the result of the resonance created by the sound of water flowing with the surrounding environment due to the special structure of Broken Falls. EEG analysis is performed using PSD based on linear prediction. In conclusion, listening to the sound of the waterfall shows that it can induce more β waves while suppressing the δ waves. In particular, the harmony of harmony created by flowing two magnificent waterfalls as if they cross each other is well reflected in the sound characteristics of the mystery. Therefore, the sound of Broken Falls is believed to improve people's health by relieving fatigue and stress and relaxing the body.

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