RESEARCH NOTE

The Change in EEG When We Are Bored

Touma Katayama¹ and Kiyohisa Natsume¹,²

¹Graduate School of Life Science and Systems Engineering, ²BMIRC, Kyushu Institute of Technology
2–4 Hibikino, Wakamatsu-ku, Kitakyushu, Fukuoka 808-0196, Japan
E-mail: {katayama-touma@edu, natsume@}@brain.kyutech.ac.jp

Abstract English rhythm instruction materials (RIM) encourage users to learn English rhythms. However, when one repeats the same lesson many times, it is typical to become bored. What happens to brain waves in the event of boredom—do some brain waves change? To clarify this issue, we acquired electroencephalograms (EEG) of learners’ brain waves as they repeatedly completed the same RIM lesson. We also asked them to raise their hands when they felt bored. Time-frequency analysis using fast Fourier transforms of learners’ EEGs showed that the power of their α (8–12 Hz), β (8–30 Hz), and γ (30–50 Hz) waves first held constant, then decreased at many electrode regions over the course of the lesson. After the decreases in EEG power, the subjects raised their hands to indicate boredom. On the other hand, the power in the θ waves (4–8 Hz) did not change. These results suggest that the decrease in α, β, and γ power across wide regions of the skull can serve as signs of boredom among learners.

Keywords: EEG, boredom, α wave, β wave, γ wave

1. Introduction

There are some differences between Japanese and English speaking rhythms. Japanese people have to learn the English rhythm to communicate with others who speak English. English rhythm instruction materials (RIM) encourage Japanese students to learn the English rhythm [1]. There are seven lessons in the RIM. During each lesson, the learner has to speak aloud following a song sung by the English teacher while looking at the lyrics of the song in text format. RIM lessons are completed once per day for 5 days; the lessons lead the learner to read English sentences in an English rhythm, even if the learner uses a Japanese rhythm before the lesson. It is found that during the lessons, one type of brain waves (θ waves; 4–8 Hz) is induced in the frontal region [1].

However, when one completes the same lesson many times, one may feel bored. Feelings, or emotions, come from the brain, but the changes that occur in the brain when one feels bored have not yet been studied. During a previous study in which subjects had to push a button by their right or left hand for a long period of time, the electroencephalograms (EEG) power of the slow waves (θ and α) increased, but β waves (and then the intrahemispheric coherence of α waves) decrease [2]. We feel bored in various situations: for example, boredom can occur when one exercises for a lengthy stretch or when one eats the same foods at every meal. Thus, feelings of boredom accompany negative emotions. On the other hand, we can also consider the feeling of boredom as a behavioral turning point [3] or an indication of mental fatigue [4]. In experimental situations, many researchers conclude that a subject feels bored when his/her level of attention decreases [5] or when the task load is lower than his/her ability [6]. If we can scientifically verify the bored state of a learner during a learning period, it will become possible to develop a more-efficient educational system in which the learners can be informed about the optimal timing of rest or change in learning materials during the learning period. The relationship between feeling bored and change in heart rate (heart rate variability) has been studied [7]. The measurement of heart rate has poor time resolution. On the other hand, EEG reflects the state of the subjects, and measurement via EEG has sufficiently high time resolution to detect the boredom states of individual subjects. Therefore, we measured EEG when the subjects feel boredom.
2. Materials and Methods

2.1 Recording method for EEG

Four healthy male subjects (average age: 24 ± 2 years) participated in the present experiment. First, we recorded EEGs from each subject when he was in a calm state with his eyes open for 30 s (control). After that, the subjects completed one of the RIM lessons. During the lesson, the subjects had to follow the English teacher’s song, the lyrics of which were presented on the display, in a loud voice. The subjects had to repeat the same RIM lesson fifteen times. The total time taken to complete the experiment was about 18–19 min. The bored feeling (or boredom) is defined as the emotion experienced when an individual feels bored. They were asked to raise their hands when they felt bored. Eight EEG electrodes (Fz, F3, F4, Cz, Pz, Oz, T3, and T4) were placed on the subjects’ heads following the international 10/20 system. The EEG signals were amplified by an amplifier (X10000; BA1008; DIGITEX LAB Co., Ltd., Japan), subjected to a 0.5–100 Hz band-pass filter, and recorded into a personal computer using a LabDAQ2000 (Matsuyama Advance Co., Ltd., Japan) with a sampling frequency of 1 kHz.

2.2 Analysis method

For time-frequency analysis, the powers of the spectra were calculated by fast Fourier transformation (FFT) of the EEG signals using MATLAB software (Mathworks, Inc., USA). The time window of the FFT was set at 512 ms, and the overlap time was established as 256 ms. The respective control spectra were subtracted from each spectrum acquired during the experimental conditions. There were large fluctuations in EEG power over the time course of the experiment. Thus, EEG power levels through the time course of the experiment were averaged per 70-s time period. They were divided into four frequency domains: θ waves (the average value in the range of 4–8 Hz), α waves (8–14 Hz), β waves (14–30 Hz), and γ waves (30–50 Hz). The analytical protocol is shown in Figure 1.

![Diagram](https://example.com/diagram.png)

Fig. 1 The analytical method for EEG with eight electrodes: The time-averaged powers measured in the control condition were subtracted from the power at each frequency during exposure to RIMs. The subtracted powers were averaged across the frequency range of each wave type.

3. Results

The power in the α, β, and γ bands remained constant near the start of the lesson, but it decreased beginning around 200 s after the start at several electrode positions (Figure 2). After this decrease, the power values held constant. On the other hand, the power of θ wave remained constant not only just after the start of the lesson, but also after >200 s. The subjects reported feeling bored after the α, β, and γ power decreased (Figure 3). Similar results were obtained across the eight electrode positions.

The decrease in power of the different types of waves was estimated using the linear regression method; the slopes of the resulting regression lines are shown in Figure 4. The slopes were significantly different from each other, and the slope of the θ wave power was significantly smaller than those of the other wave types. The average correlation coefficients between power and time among the four subjects for the 200 s after the first peak are -0.57, -0.84, -0.92, and -0.88 for θ, α, β, and γ waves, respectively. The values of the coefficients of α, β, and γ waves are smaller than that of θ waves; all of the correlations were negative.

4. Discussion

In previous studies, researchers assumed that vigilance
eight positions, collected from subject A: This figure represents each wave power decreased in all electrodes. Fz, F3 and F4 are on the frontal, Pz and Cz are on the parietal, and T3 and T4 are on the temporal, and Oz is on the occipital region. The origin of the horizontal axis is the lesson start time.

Fig. 3 The temporal change in power around the peak of α power from 150 s before to 200 s after the onset of power decrease in the T3 region for all subjects: The labels “Raised” represent the times when the subjects raised their hands to represent boredom.

Fig. 4 The regression coefficient between power and time for 200 s after the power began to decrease at each frequency band: This figure represents α, β and γ waves significantly decreased. It represents the slope of the change of each power with time. The coefficient of the θ wave is significantly smaller than those of the other waves (p < 0.01; one-way repeated-measures ANOVA).

decrement is identical to boredom [5]. The vigilance decrement has been described as a slowing of reaction times or an increase in error rates as an effect of

Fig. 2 Temporal changes in the power of brain waves at all
time-on-task during tedious monitoring tasks. In those experiments, whether or not the subjects actually felt bored was not clarified. On the other hand, this study elucidated the changes in EEG that occur when subjects become bored. Therefore, boredom was defined as the feeling the subjects had when they repeated the same task several times.

In the present study, after the power of \( \alpha, \beta, \) and \( \gamma \) waves decreased widely across the skull, all subjects raised their hands. In contrast, the change in \( \theta \)-wave magnitude was smaller than that of the \( \alpha, \beta, \) and \( \gamma \) waves. These results suggest that wide decreases in \( \alpha, \beta, \) and \( \gamma \) power across the head can cause the subjects’ bored feelings. Because there are some delays between the start of the wave-power decrease and the time when the subjects raise their hands, it seems that it may take time for us to become consciously aware of the bored feelings, which result from unconscious neural activity.

In addition, one excluded subject failed to become bored when he repeated the same lesson numerous times. To confirm the results, we will compare the present EEG results with his results. The power of his \( \alpha, \beta, \) and \( \gamma \) waves decreased only in the right frontal region, and the change was not very large, as shown in Figure 2. These results support the conclusion that decreased \( \alpha, \beta, \) and \( \gamma \) power dispersed widely across the head indicates boredom.

In previous studies, decreased attention is thought to correspond with boredom [5]. Parieto-occipital \( \alpha \) waves can contribute to attention [8]. In the present study, not only parietal \( \alpha \) waves but also \( \beta \) and \( \gamma \) waves in other regions change with boredom. Boredom is accompanied by other processes than decreases in attention [7]; the change in brain waves across a wide area of the head—beyond parietal \( \alpha \) waves—may reflect these processes. Further studies are necessary to confirm this possibility.

Other psychophysiological parameters than brain waves, heart rate, blood pressure, etc. [6, 9] have been studied on the relationships with bored feelings. Compared with the measurement of heart rate or blood pressure, EEG measurement has a high time resolution. It is possible to detect learners’ bored feelings using EEG as soon as they feel bored. We are now trying to develop an adaptive e-learning system for English rhythm; it would be very useful for the system to respond immediately when the learners feel bored.

5. Conclusions

1) The power of \( \alpha, \beta, \) and \( \gamma \) waves first kept constant and began to decrease as each subject repeated a RIM lesson.
2) All subjects raised their hands to indicate bored feelings after the power of their \( \alpha, \beta, \) and \( \gamma \) waves began to decrease.
3) The change in \( \theta \) wave power was smaller compared with the changes in power of the \( \alpha, \beta, \) and \( \gamma \) wave types.

Acknowledgment

This work was supported by a KAKENHI Grant-in-Aid for Challenging Exploratory Research (Number: 22650205; 2010-2011).

References

Touma Katayama received his B.Sc. degree in the Department of Bioscience and Bioinformatics from Kyusyu Institute of Technology, Japan in 2011. Now he studies at the Master’s Course in the Graduate School of Life Science and Systems Engineering in the same Institute. He is interested in the relationship between boredom and electroencephalogram (EEG).

Kiyohisa Natsume received his Ph.D. from Tokyo University in 1993. From 1990, He started to study the relationship between brain rhythms and memory process in Fuzuka KIT. From 2001, He moved to Wakamatsu KIT and has continued the project. Recently he has started human EEG study to apply the obtained results to Brain Computer Interface. He is a neuroscientist and also tries to become a BCI system researcher and engineer.

(Received May 14, 2012; revised August 25, 2012)