



# Fluctuation of biological rhythm in finger tapping

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## Abstract

By analyzing biological rhythms obtained from finger tapping, we have investigated the differences of two biological rhythms between healthy and handicapped persons caused by Parkinson, brain infraction, car accident and so on. In this study, we have observed the motion of handedness of all subjects and obtained a slope  $a$  which characterizes a power-law relation between frequency and amplitude of finger-tapping rhythm. From our results, we have estimated that the slope  $a = 0.06$  is a rough criterion in order to distinguish healthy and handicapped persons. © 2000 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

There are various regular biological rhythms in our body, such as heartbeat [1], hormone secretion and up-down of blood pressure in a day, movement controlled by autonomic nerve system. However, the periods of these rhythms are really not constant but fluctuating. Peng et al. analyzed the fluctuation of interval of heartbeat by detrended fluctuating analysis (DFA) [1]. They define  $y(k) = \sum_{i=1}^k [B(i) - \langle B \rangle]$ , where  $B(i)$ ,  $\langle B \rangle$  and  $k$  are the  $i$ th interval, average of  $B(i)$  and number of data of heartbeat, respectively. Fluctuation  $F(n)$  is calculated as  $F(n) = \sqrt{(1/N) \sum_{k=1}^N [y(k) - y_n(k)]^2}$ , where  $n$ ,  $y_n(k)$  and  $N$  are, respectively, box size, least-squares estimation of  $y(k)$  by box size  $n$  and number of boxes. They found a relation of  $F(n) \sim n^{-\alpha}$ , and investigated a difference of  $\alpha$  between healthy and handicapped persons. They say that the case of  $\alpha=1$  corresponds to  $1/f$  noise. This relation is also found in various phenomena of natural world [2–4].

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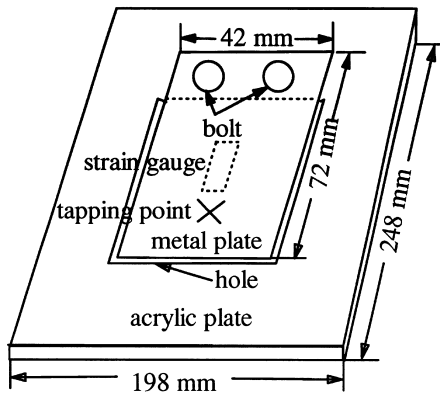


Fig. 1. Experimental apparatus.

The human hand behaviors are one of the most important conscious motions. The studies of its biological mechanism have been done in order to analyze a control system [5]. For e.g., Engbert et al. made a model for bimanual movement [6]. They observed and made a model for a motion of different periods differences between the left and right hands. They analyzed the data by transforming to simple code (0 or 1 defined on a relative deviation) and using the well-known Shannon entropy. Chen et al. found a long time correlation in the fluctuation of finger tapping rhythm by analyzing spectrum density [3]. They recorded an error of time from metronome which controls a finger tapping rhythm. They analyzed the data by using spectrum density, and found a relation of  $S(f) \sim f^{-\alpha}$ ,  $\alpha = 0.54$ , where  $S(f)$  and  $f$  are power and frequency.

If a person has a handicap, his/her movement may not be the same as that of healthy persons. In this study, we have performed a finger tapping experiment in order to find the difference of two biological rhythms between healthy and handicapped persons. In our experiment, we have measured the power of strain of metal plate tapped by finger and investigated a relation between the frequency and the amplitude of the biological rhythm in finger tapping by using the Fourier transformation. From our experimental results, we have estimated the slopes which characterize the biological properties between healthy and handicapped persons.

## 2. Experimental method and result

The length, width and thickness of the metal plate of our experiment in Fig. 1 are 72, 42 and 1 mm, respectively, and a strain gauge is set up on the back of the metal plate. The gauge measures the strain of a metal plate by finger tapping.

Our subjects who are healthy and handicapped persons tap on the metal plate by one finger of their handedness and the power of strain by his finger tapping is measured. The constant tapping rhythm and strength in the finger tapping are decided by each subject, i.e., the rhythm and strength are different from each other.

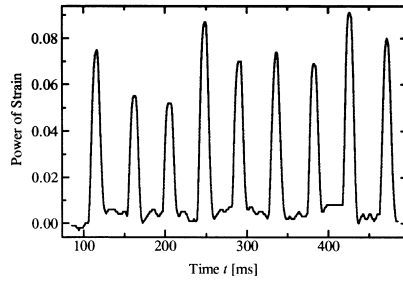


Fig. 2. Record of strain of metal plate. The power of strain is measured by tapping the metal plate with a strain gauge.

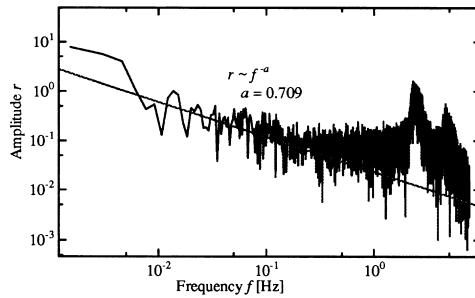


Fig. 3. Amplitude of the power spectrum of the finger tapping obtained from a healthy person.

In this experiment, the age of the healthy persons ranges from 22 to 79 and that of handicapped persons from is 57 to 81. The sampling frequency is 100 Hz and the record time is about 653 s. In the case of old or handicapped persons, when they cannot keep on tapping for 653 s, we excluded their data. In this paper, we have analyzed the experimental data of 40 healthy persons and 15 handicapped persons. One of our experimental results are shown in Fig. 2. The power of strain in Fig. 2 is measured by tapping the metal plate with strain gauge.

From Fig. 2, we have calculated the frequency  $f$  and the amplitude  $r$  of finger tapping rhythm by the fast Fourier transformation (FFT). The distribution of frequency obtained by experiment can be expressed as

$$r \sim f^{-a}, \quad (1)$$

for a long-term correlation  $f < 1$  Hz. The slope  $a$  may express differences of status of neuronal cell, locomotion system, muscle and so on and we have concentrated on investigation of a value of the slope  $a$ . If the finger tapping has a long time correlation, the slope  $a$  is close to 1 ( $1/f$  noise). If the main components of finger tapping are white noise, the slope  $a$  is close to 0.

We have analyzed all our experimental data by FFT and calculated the slope  $a$  according to Eq. (1). Figs. 3 and 4 are one of our experimental results of healthy and handicapped persons, respectively. A peak which is located in the high-frequency region

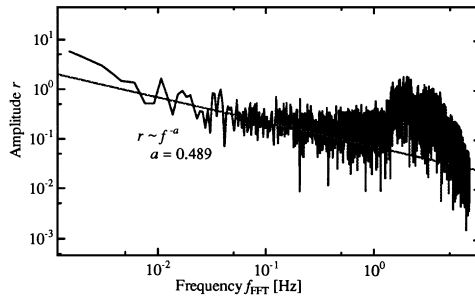


Fig. 4. Amplitude of the power spectrum of the finger tapping obtained from a handicapped person.

in Figs. 3 and 4 in both graphs indicates the short-time rhythm of the subject. When we evaluated the slope  $a$  in figures, we did not use  $f < 1.5 \times 10^{-3}$  Hz region, because the record time is 653 s. Therefore, we have concentrated on the middle frequency region between  $1 \times 10^{-2}$  Hz and  $5 \times 10^{-1}$  Hz in this experiment.

Furthermore, we have also investigated the change of the slope  $a$  on the learning effect of finger tapping. We have performed the same finger-tapping experiments by the same subject several times. However, we have found that the slopes  $a$  of healthy and handicapped persons with learning are almost the same as the experimental results without learning effect.

In Figs. 3 and 4, the slopes  $a$  are 0.709 and 0.489, respectively. Generally, the slopes  $a$  of the healthy and the handicapped persons are 0.6–1.0 and 0.3–0.6, respectively.

### 3. Conclusion

We have found that the slopes for healthy and handicapped persons are different. The probability  $p$  for the slope  $a$  is shown in Fig. 5. From Fig. 5, we note that the slope  $a = 0.60$  is a rough criterion in order to distinguish healthy and handicapped persons. If the slope  $a$  is equal to or near to 1, it shows the  $1/f$  noise with long-time correlation. If  $a$  is equal to or near to 0, it shows the white noise with no correlation. From our results (Fig. 5), we have found that most of the healthy persons have a long-time correlation, in contrast most of the handicapped persons have less correlation. Therefore, we estimate that the healthy persons easily make a regular finger tapping rhythm, but the handicapped persons may not make it.

We have to investigate more samples of various subjects. For example, we would like to do our experiment by using young people, because their biological systems are forming and more activities. Furthermore, we will investigate as to “Why are the slopes  $a$  of healthy and handicapped persons 0.7 and 0.4, respectively?” and “What are the main factors to change  $a$ ?”. In the near future, we need a model of this finger tapping.

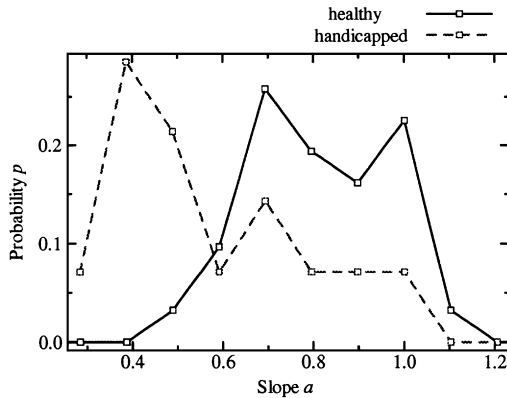


Fig. 5. Histogram of the slope  $a$  of finger tapping by using FFT. The  $p$  means the probability of the slope  $a$  which has been expressed by Eq. (1). Solid and broken line shown the results of healthy and handicapped persons, respectively.

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