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# Studies on a Sense of Rhythm

## I. On the Fluctuation of the Interval of the Repetitive Action

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The conception that the *sense of rhythm* or *rhythmic perseption* exists subconsciously in human being prevails widely and it is also generally accepted that man has conception of inherent physiological time as distinct from usual time. But the conception is vague and has not been investigated scientifically.

Watanabe[6], one of the authors, once analysed the rhythm psychologically and Miss Tokita also analysed the fluctuation of the walking rhythm statistically in authors' laboratory.

The authors made an attempt to throw the light on the sense of rhythm and first the time perception (the time was divided in regular interval and uniform succession having no accent) was picked up for the fundamental process, i.e. the repetitive action, which was carried out by the standing gait for strong and big muscles and tapping of the thumb for the muscles of delicate movement, was analysed statistically from the standpoint of the interval fluctuation.

### Method

*Apparatus*—The action of the standing gait of the both feet and of the tapping of the right thumb were led through the electrical contact into Braun tube oscilloscope. Conditioning phone was applied with thyrathron oscillator and both were recorded with continuous recording camera. A part of the record is shown for an example in Fig. 1.

*Procedure*—The rhythmic action was performed at the frequency of 60, 80, 100, 120, 150, and 180 cycles per minute respectively. At first the performance was carried out about eighty times keeping time with sound (named here the conditioning phones), and then the sound was put out without stopping the action. After about eighty execution, one minute pause was interpolated, the same action was continued again without the sounds.

The male and female students were drawn as the subject.

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## Result and Discussion

1) $\bar{\tau}-S^2$ *diagram:*—The intervals of the repetitive action were plotted against the numbers of the actions recorded, for an Example, as shown in Fig. 1. To observe how large the fluctuation of the rhythmic action is and whether its variance is the same order at different frequency of

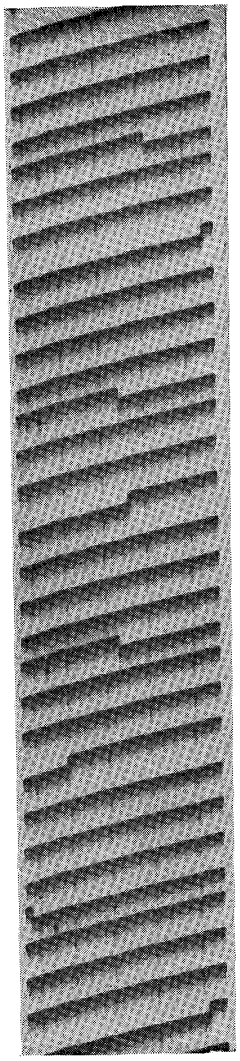

Fig. 1. An example of a record. Upward deflection was electrical contact marked. i.e. the thumb was bent. In case of walking it means the foot contacts to the ground.
Regular downward spike is time scale of 20 msec. and the conditioning phone (little longer spike) was recorded together in the vicinity of the upward deflection. Read right to left.

the rhythm, $\bar{\tau}-S^2$ diagram of Fig. 3 was drawn from the interval diagram of Fig. 2. This conception was the first time introduced by Hagiwara studying on the fluctuation of the interval of the rhythmic nerve impulses.[1),2)] $\bar{\tau}$ represents average of the intervals of repetitive action of appointed respective frequency and $S^2$ is square of its standard deviation. The square of the standard deviation was very large at the lower frequency and also a little larger at the higher frequency.

It is clear that the relative minimum variance situates where the line, starting from the origin, is tangent to the curve in the figure. This is in the range between $P'$ and $P''$ in the insertion of the Fig. 3.

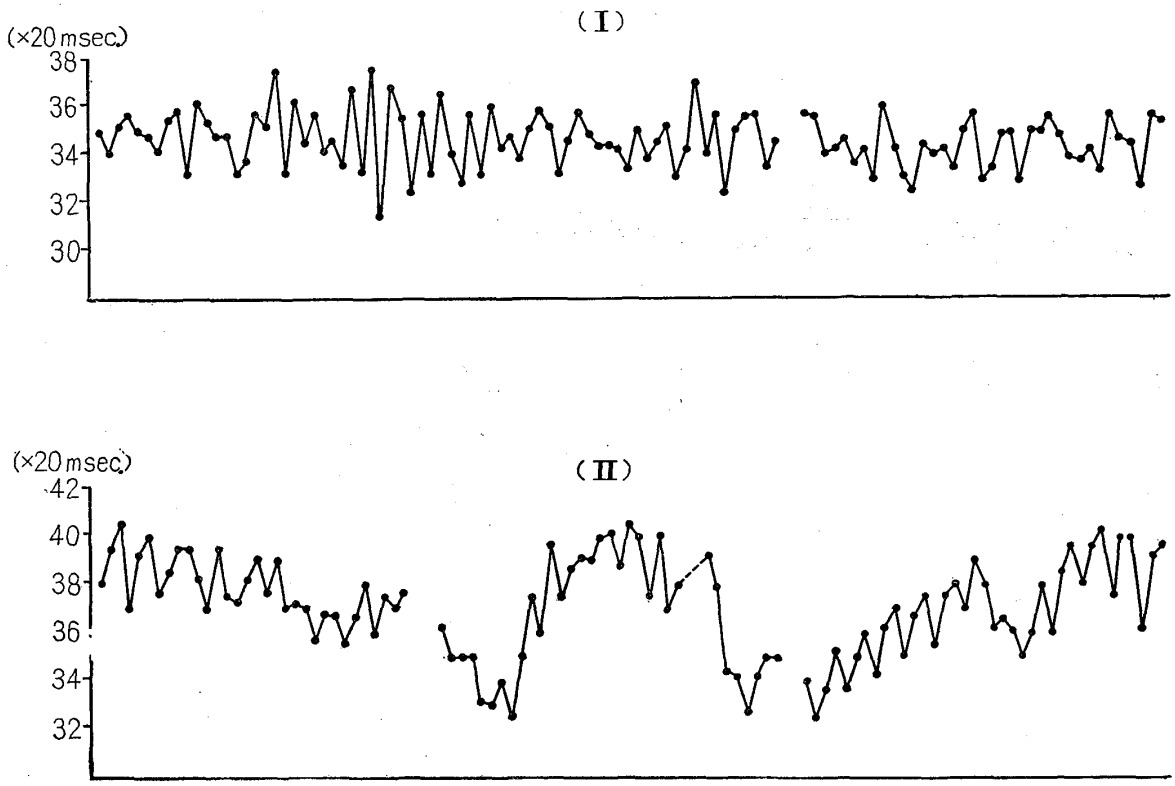


Fig. 2. (I) Interval of repetitive action of the standing gait, and (II) interval of R-spikes of the electrocardiogram was plotted against the numbers of the intervals.
Ordinate: length of interval of ×20 msec.

In case of standing gait, it was 480–630 msec. (95–125 c.p.m.), and 380–450 msec. (130–160 c-p.m.) in case of the tapping of the thumb.

In other wards, in the range of this frequency the fluctuation of the rhythmic action was carried out most accurately. When the frequency of the performance increased or decreased from this range, the variance of fluctuation became greater and accuracy of the performance became worse. This agreed fairly with the result in walking obtained with kymograph by Miss Tokita[7].

In case of the thumb the frequency which shows the minimum fluctuation shifted to the higher side of the frequency at the standing gait. Although in both cases the formation of the sense of rhythm in the brain is likely the same, the result strangely shows some discrepancy. The origin of this discrepancy is obscure but it seems that it probably depends upon the difference of the modulation of the nerve impulse pattern in the central nervous system or the inertia of each mass of muscles and body. And it is noteworthy that the frequency 95–125 c.p.m. obtained at standing gait coincided nearly with the frequency of the natural walking rhythm. (118.6 (93–138) in male, 122.9 (146–92) c.p.m. in female after Oinuma's table)[4].

According to Tokizane[5] the conception of spinalization and corticali-

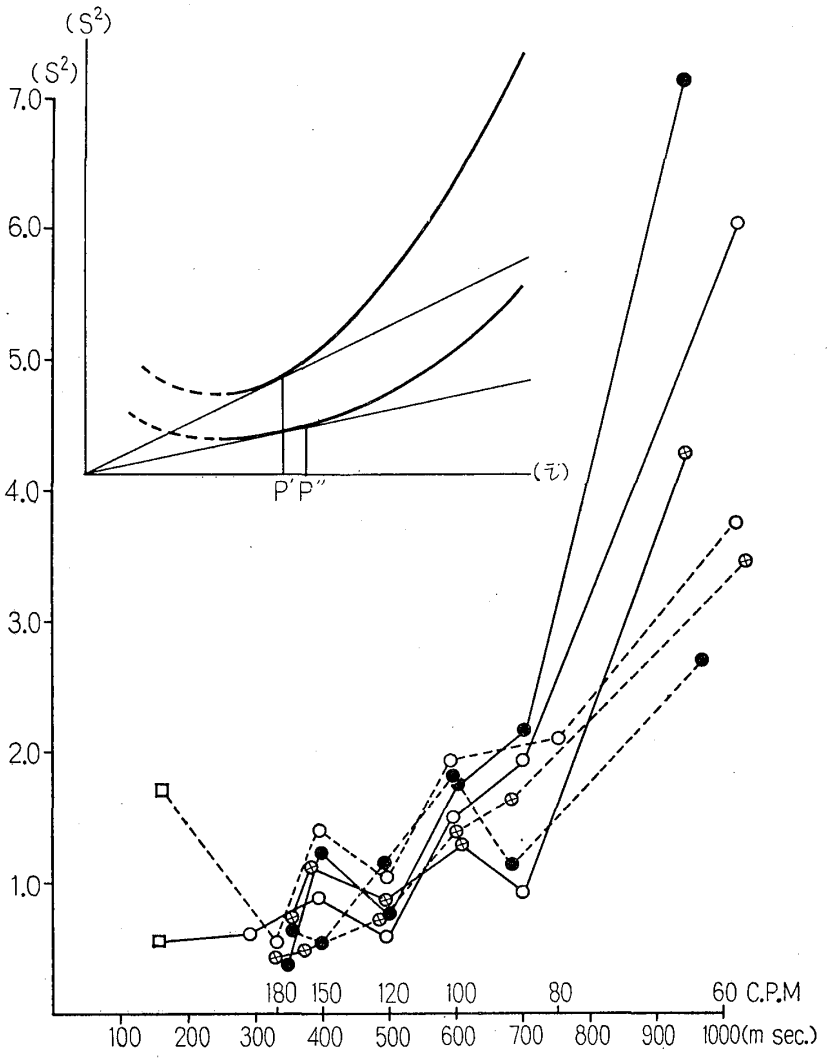


Fig. 3. $\bar{\tau}$-$s^2$ Curve obtained from the interval diagram. Dotted line shows the action of the right thumb. Solid line, standing gait.

●: taken from the action keeping time with conditioning phone.

○: in the case of the phone put out.

⊕: reproductive action which was executed after the one minute pause laid.

Abscissa: shows the average value of the time intervals of the repetitive action of the appointed frequency.

Ordinates: $S^2$ represents square of the standard deviation calculated in each frequencies.

□: Maximum frequency performed as fast as one could.

Inset is shematic representation of $\bar{\tau}$-$S^2$ curve being plotted all the data together and all the marks take between the two assumptive curves.

Range of P′–P″ is the frequency of the relatively minimum frequency.

zation was introduced on the study of the electromyograph and this is also realized in the authors' results. In the range of frequency 95–125

c.p.m. on the feet, 130–160 c.p.m. by the hand, the performance was executed as though it were reflexive, and beyond this range it was performed as if it were cortically innervated. However, it does not mean that the condition of innervation is literally reflexive or cortical under the present results as appointed out by Tokizane.

2) *Interval between the action and the conditioning phone*:—In general there is a certain reaction time between the stimuli and reaction even though in quick action. But in case of the experiment in which the action was performed to keep time with sound (in another ward, it equals to the consecutive reaction time), the record mostly obtained was that the performance preceded the stimulating phone and even when the conditioning phone preceded the performance, its latency was not so long as in the case of usual reaction time. The result was shown in Fig. 1 and Fig. 4.

When the sound intervals were varied smoothly from long to shorter interval, at the first experiment, the latency between the conditioning phone and performance was relatively large, and in the third repeated experiment, its coincidence was fairly good than before: it may attributed

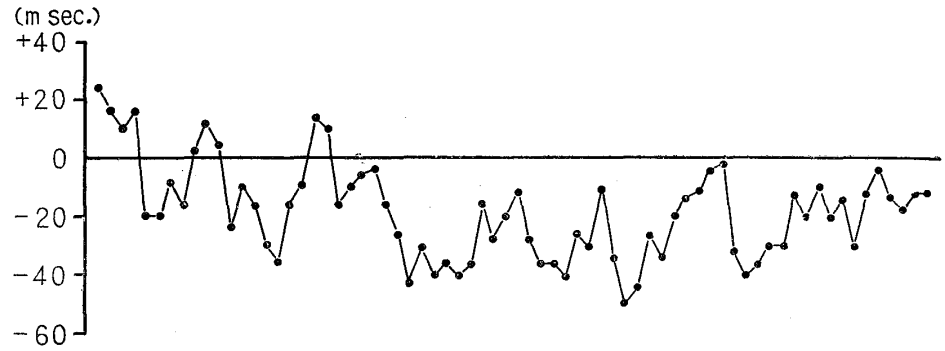


Fig. 4. Interval diagram of time latency between conditioning phone and action. In case of walking.
Ordinate: time latency between conditioning phone and action. (−) represents, the action preceded the conditioning sound, (+), vice versa.
Abscissa: numbers of the action.

to the *systimatization* of the conditional reflex. And when sound intervals were varied periodically, the curve of the performance interval diagram was almost the same form of the sound curve, but the former was delayed. The process of this time series formation is represented in Fig. 5 a and b.

The results obtained above mean that a certain rhythm would be organized in the central nervous system from the conditioning sounds of the uniform and regular intervals, and under these condition a certain reflexes series was formed in connection with the appointed frequency of the performance.

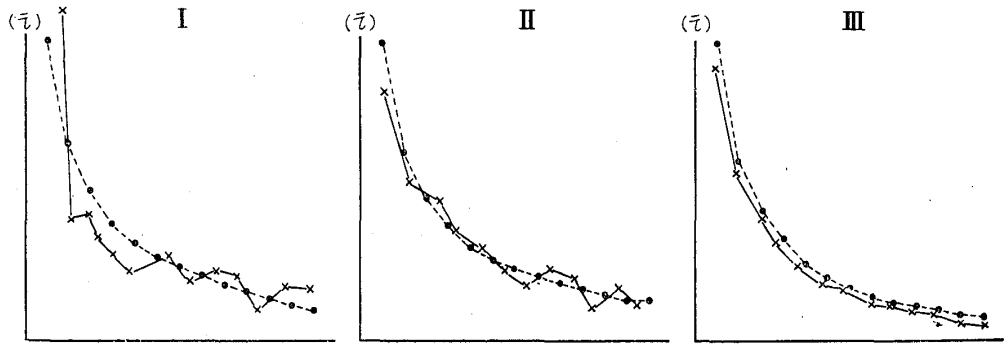


Fig. 5 a. Relation of interval diagram of conditioning phone and repetitive action when the sound frequency was varied smoothly in case of the thumb.
Solid line (×): action, broken line (●): conditioning phone.
Ordinate ($\bar{\tau}$): time interval of action and sound respectively.
Abscissa: I, II, and III, each represents series of the first, the second, and the third experiment.

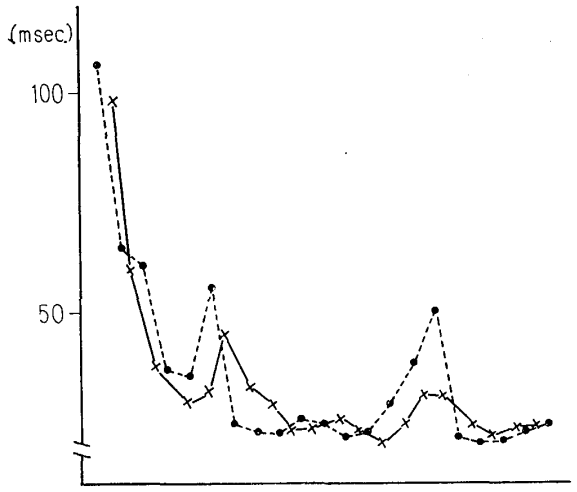


Fig. 5 b. The same as Fig. 5 a., Frequency of the conditioning phone was varied periodic. The form of the two curve is nearly the same but the curve of the action is delayed.

This could be regarded as a type of conditional reflex. And this fact may play a great part to minimize the fluctuation in case of the repetitive action and may make the action reflexive.

3) *Comparison of the frequency between the fluctuation of the electrocardiogram and the repetitive action*:—When these fluctuation was compared with that of the interval obtained from the *R*-spike of the electrocardiogram which is entirely autogenous origin, the fluctuation of the performance of the extremitates was small and about 1/2–1/4 of that of the heart rhythm. (See Fig. 2).

4) *Autocorrelation coefficient of the series of the repetitive action interval*:—Repetitive action described above showed fluctuation though little and this irregular fluctuation was statistically investigated. This was done as in the Ogawara's book[3]. First, the assumption was that the

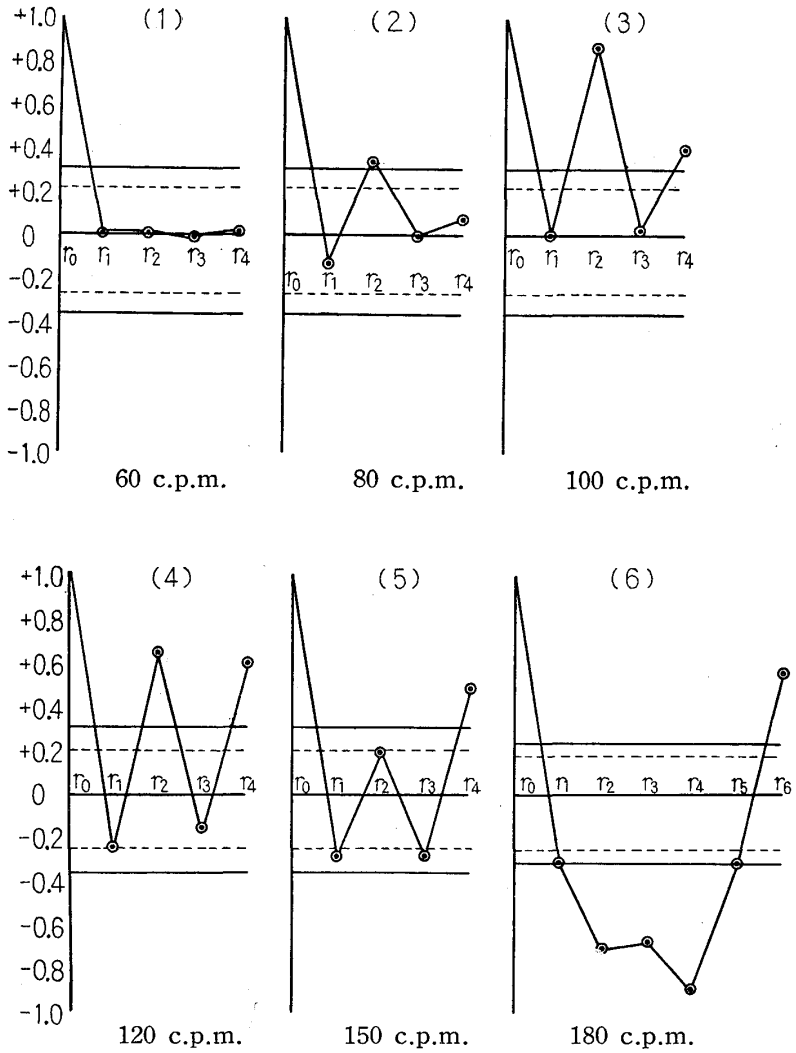


Fig. 6. Serial correlation coefficient calculated from the repetitive action by the thumb. Solid and Dotted lines show 5% and 1% of the significance level respectively. Refer to a textbook in details.

interval diagram shows stationary state within a certain period of the repetitive action and *autocorrelation coefficient* or *serial correlation coefficient* of the series of the action intervals were calculation. The interval had no correlation in the event of the action of 60 c.p.m. and of high frequency. On the contrary, in the other cases, another result was obtained, namely they had periodic correlation as was shown in Fig. 6.

Fig. 6 (1). shows that fluctuation of time interval is entirely at random and the other curves show that it has binary or quarternary time and at high frequency as shown in Fig. 6 (6)., the correlation curve became also the same form above or showed cyclic undulation. This would be equivalent to what is said in psychology: even if the sound was given at uniform succession and at regular time interval, man will receive it subjectively as if it were given in a group, and will form

*subjective rhythm*, such as the tick of a clock. In case of 60 c.p.m. the absolute variance or square of the standard deviation was being large. It seems to be difficult that man bears subjective rhythm in the mind. At high or maximum frequency it also seems the same periodic undulation was formed subjectively.

## Summary

Fluctuation of the rhythm was investigated in case of the regular repetitive action of the standing gait and tapping of the thumb and the following results were obtained.

1) Fluctuation of the time interval is little at the rhythm of the higher frequency but in the higher frequency it grows large again and relative minimum fluctuation was obtained at the frequency range of 95–125 c.p.m. in case of the standing gait and 130–160 c.p.m. in case of the tapping of the thumb respectively. The former is very similar to the frequency of the natural walk.

2) The repetitive action is a sort of a consecutive reaction time and is regarded as a conditional reflex in mechanism on the ground of the experiment (2).

3) When the conditioning phone of physically regular and uniform interval was applied, time series formed in the brain or central nervous system was organized subjectively and the effect was expressed to the performance which showed periodic rhythm at higher frequency in the view of auto-correlogram.

4) Fluctuation of the performance rhythm is about 1/2–1/4 of that of heart rhythm.

## Literature

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