

On Physical and Mental Fatigue*

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In this experiment the comparison was studied between the muscular and the nervous fatigue and the flicker phenomenal value of the optic nerve.

In order to measure the physical fatigue, various methods have been reported by many authors. In this experiment, a quantification of the fatigue was tried though the relation between the amount of mental activity and the FF (flicker frequency), which is useful in physical fatigue measurement with the change in respiration and pulse. In measuring the FF, respiration and pulse caused by physical work, it shows that the these three measured values are somewhat exponential, which might be called the exponential accumulation of fatigue. In mental activity slight relation was also found between fatigue and learning.

§ 1. Introduction

In recent industry, there have been appearing various fatigue with the increasement of work. Therefore, some considerations on such a complicated fatigue will not be useless.

The fatigue is caused and appeared in various ways, e.g., by purely mental activity, by purely physical work, and by various mixture of these.

In this experiment we used the self-made bicycle ergometer to measure the physical fatigue. The FF, the amount of CO₂ in expiratory air, and the pulse were measured three times, namely, just before working, during working and just after working. The change in these measures shows the amount of physical load by the simple physical work of revolving the bicycle. In this case, the work was regarded as a purely physical work, that is, the work was free from mental activity.

In order to examine the mental fatigue, we used the tracking work by an analog computer was adopted. The fatigue was measured indirectly by observing the change of the amount of work and the FF. Tracking work was consisted of visual activity and response action through mental feed back.

§ 2. Experimental Procedure

1. Subjects

In the experiment of the physical fatigue, 6 males and 1 female of from 19 to 25 years were subjected. Every one of these 7 persons

had a good physical constitution and was in good health.

For the mental fatigue experiment, a 21 years old male was chosen in a random way. This male also had a good physical constitution and was in good health, but he always wore glasses.

2. Methods

The physical load was given by revolving the self-made bicycle ergometer. Each person revolved this bicycle for 30 minutes at a time with the average speed of 15 revolution per minute and with the average load of 5–7 kg on the brawny brake.

The measurement of the following three items were carried out just before the activity and at every third minutes during the work.

- (1) Flicker test—A FF counting machine was used.
- (2) Amount of respiration—The expiratory air was taken from each person into a test tube and the amount of CO₂ contained in it was quantified by analyzing it by means of a gas analyzer.
- (3) Pulse—The number of pulse was counted on the radial artery during the period of 30 seconds.

For the mental fatigue experiment, an analog computer and Braun tube oscilloscope were used as shown in Fig. 1, and complex input signal was given and the pursuit operation was made to reduce the deflection from the cardinal line of the oscilloscope to the least in the tracking activity to the input signal. The flicker test was made every 30 minutes during the work. As in

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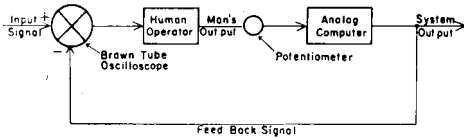


Fig. 1 Schematic diagram of experiment.

shown in Fig. 2, where there are the input signal, the manipulated variable, and the amount of error in the foregoing two. The results were evaluated through the error area between the input and the amount of work.

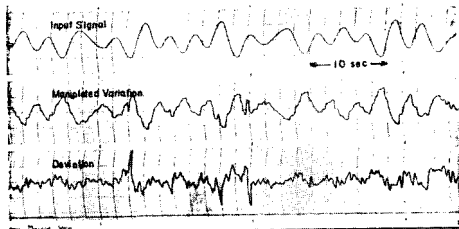


Fig. 2 Sampled presentation of data.

§ 3. Results

Fig. 3 & 4 and Tab. 1 show the average variation before and after the loading of physical work among the 7 persons tested.

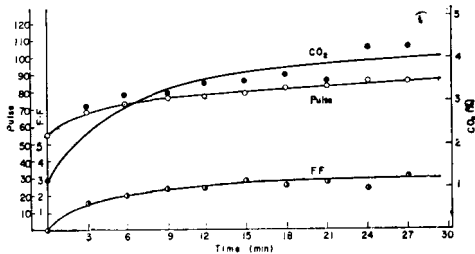


Fig. 3 FF, CO₂, pulse diagram of physical fatigue.

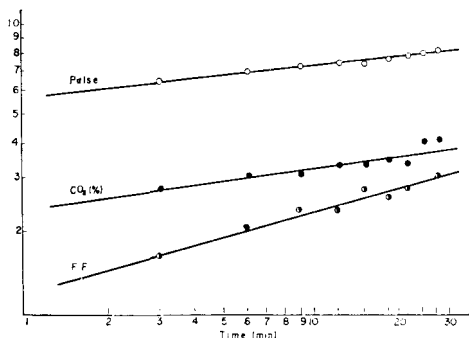


Fig. 4 Logarithmic presentation of physical fatigue.

Table 1
Average variation of physical work
(7 Subjects)

Time (min)	FF decreasing ratio (%)	Pulse increasing ratio (%)	CO ₂ (%)
Before	—	—	1.18
3	5.1	2.5	2.90
6	6.4	3.4	3.16
9	7.4	3.7	3.17
12	7.3	4.0	3.41
15	9.0	4.3	3.88
18	8.3	4.9	3.60
21	8.7	5.1	3.43
24	7.6	5.7	4.26
27	9.6	5.8	4.28

The FF in this case was intensity of decrease, that is, its average was 30.7 (c/s) before the loading and reduced by 8.8% after 30 minutes' work.

The number of pulse also decreased, but the results showed less dispersion than the other two.

Fig. 5 and Tab. 2 show the variation in the FF before and after the mental activity. Fig. 6

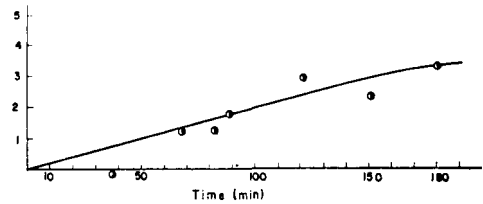


Fig. 5 FF diagram of mental fatigue.

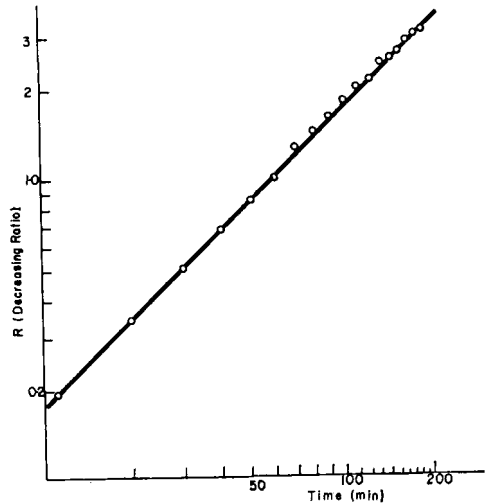


Fig. 6 Logarithmic presentation of mental fatigue.

shows a remarkable decrease of the FF logarithmically. There is some relation between the FF and the manipulated variable is expressed by dimension in Fig. 7.

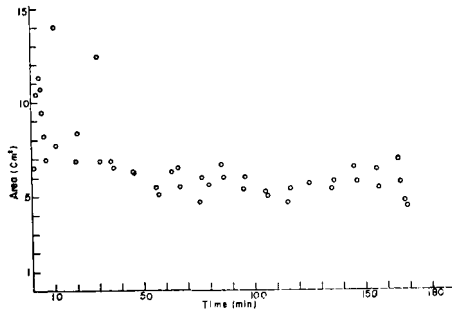


Fig. 7 Presentation of transformation of manipulated area with time.

Table 2
Variation of mental activity

Time (min)	FF decreasing ratio (%)	Error area (cm ² /min)
1	—	6.5
10		14.0
20		6.8
30		12.4
40	-0.1	6.5
50		5.9
60		5.9
70	4.6	5.4
80	4.6	6.0
90	6.8	5.8
100		5.4
110		4.8
120	11.0	5.3
130		5.5
140		6.0
150	8.7	6.2
160	12.2	5.4
170		

§ 4. Discussion

The statistical results of physical work (Fig. 3), it was found that the decreasing ratio of the FF are functionally nondecreasing with the load, as an example the decreasing ratio of the FF was 10% after 30 minutes' work. As might be known from the both logarithmic graph in Fig. 4, this ratio may be expressed by the exponential function $y = ax^b$.

Then, the curve obtained by way of try-and-error method may be expressed as,

$$y = 1.3 t^{0.1533}$$

t; time

These equations show that the decreasing ratio during the first 10 minutes after the loading is great and then becomes gradually saturated. The number of pulse counted during the same period as the FF showed the similar decrease tendency. However, after 30 minutes' work the pulse number increased by 6%. The variation between before the loading (73/min) and at the fourth minutes after the loading (91/min) was the greatest, then gradually increase, and showed no remarkable increase. The results could be expressed approximately in a curve, which shows that there were no individual difference in each pulse counts because the tested persons were of about same age and young people.

But, the variation in the amount of CO₂ in the expiratory air showed a different tendency from above two. The amount of CO₂ gradually increased with the continuation of work, but its increase ratio was inconsistent and irregular.

Fig. 5 shows the FF variation of mental activity. The decreasing ratio of the FF was about 5% after 60 minutes' working and 12% after 170 minutes' loading of work. This is represented by the both logarithmic graph in Fig. 6, and may be regarded as exponential. The following equation will express the curve,

$$y = 0.18 t^{1.018}$$

Compared with the physical FF, this curve shows a less increasing at an early stage, but with course of time, the exponential gradient shows that the mental FF becomes increasing more than in physical work.

Fig. 7 is the plotted results of the error area in the tracking acts. The fatigue shows that one is apt to learn the given work during the first 60 minutes, then go into a weary condition during the second 30 minutes, decrease one's working speed during the next 30 minutes, and then during the fourth 30 minutes gradually increase it, attaining to its peak after 160 minutes' working, and again decrease one's working speed gradually.

Both mental and physical works are done very effectively at first and then in a weary condition or in the fatigue with a repeated periodicity about 60 minutes, and during these repeated rhythms the fatigue will be accumulated.

In this experiment different measuring me-

thods were used in order to know the fatigue in different forms of work and activity. It was granted that the flicker test is effective for evaluating both physical and mental fatigue, and the FF was practically measured in both cases. However, each fatigue will be after all different, even though several persons were tested.

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