REFLEX REGULATION OF CAPACITY FOR WORK

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The possibility of raising the capacity of a muscle to perform work, by applying various external factors, has been demonstrated by V. O. Bugoslavskii [1], N. I. Konopasevich [5], and I. M. Sechenov [9], and has been confirmed by the work of numerous Russian and foreign authors. D. I. Shatenshtein and E. N. Iordanskaia [11] not only showed that the working capacity of the right arm could be raised by using the left arm, but also revealed that dependence of this effect on the strength of the additional stimulation and on the time intervals between stimulations. Soviet workers have also shown that it is possible to raise working capacity by means of conditioned reflex action, including the use of verbal signals [2, 3, 6, 7, 10]. Many aspects of reflex regulation of working capacity, of importance to the physiology of work and sport, are still insufficiently elucidated.

The present paper is devoted to the study of the effects of autitory stimuli and of skin temperature and motor analysors on the working capacity of the fatigued person.

EXPERIMENTAL METHODS AND RESULTS

The experimental subjects were put to work on an ergograph; by flexing the right arm at the elbow they raised a lever with a load of 10-14 kg 30 times a minute. The weight of the load raised by the right arm was determined for each individual after a prolonged period of training. Further observations were carried out with a load such that marked lowering of working capacity took place within 8-10 minutes of work. Supplementary stimulation of analysors was applied with a $1\frac{1}{2}$ -2-fold reduction of the height to which the load was raised. Only one supplementary stimulus was applied during an experiment. The auditory analysor was stimulated by means of a bell, loudness 50 decibels, and the skin temperature analysor by application of hot (40-44°) or cold (0, −1, −4, −7°) bodies to the skin over the biceps muscle of the arm which was not working.

Supplementary stimulation of the motor analysor was achieved by starting work with the left, previously inactive, arm. The movements of the left arm took place at the same rate as the right, but against a much smaller load (1-2 kg), or without a load.

Our observations showed that sounding the auditory stimulus caused a marked rise in working capacity. Daily repetition of the experiments showed that this effect was very transient (Fig. 1); for most subjects (7 out of 8) it disappeared after 2-4 repetitions.

Heat stimulation of the skin temperature analysor raised the amount of work performed by all the subjects, while cold stimulation produced this effect in two of three subjects. Repetition of the experiment, with both cold and heat stimulation, also led to a rapid extinction of the effect (after 2-3 repetitions)(Fig. 2). Only in one of the subjects (G.) did we find a relatively slow disappearance of the effect, both for auditory and temperature stimulation.

It is of interest that the amount of work performed was raised by the action of the verbal stimuli: "Cold" or "Heat."

Supplementary stimulation of the motor analysor, by starting work with the left arm when the right was showing signs of fatigue, raised the amount of work performed by the right arm (Fig. 3, A, B). During the first

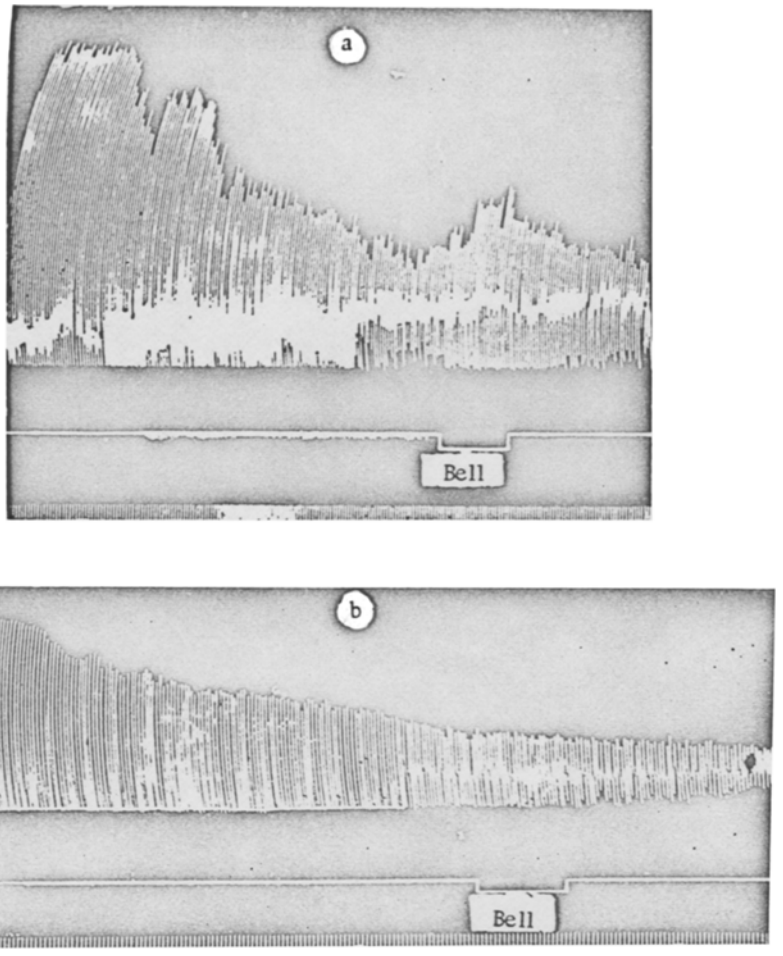

Fig. 1. Changes in working capacity due to stimulation of the auditory analysor. Explanation of tracings (from above down): ergogram, stimulation signal, time marker (1 second), a,b) data from different experiments.

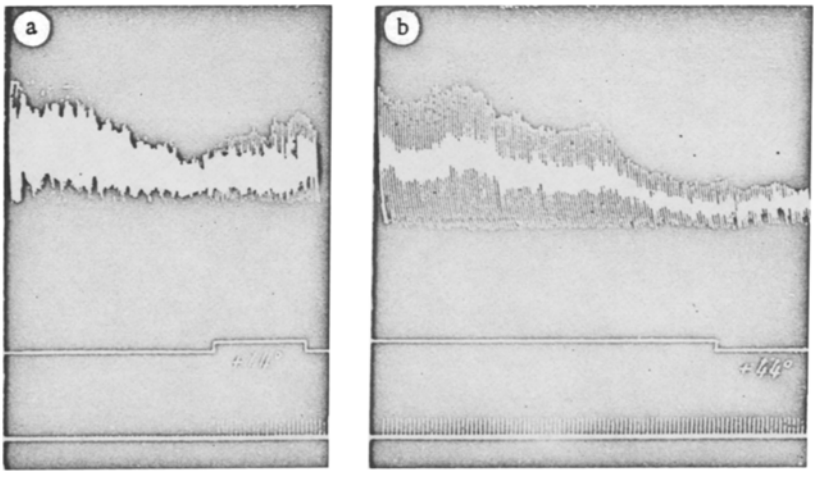

Fig. 2. Changes in the working capacity of the arm in response to stimulation of the temperature analysor.
Explanation of curves (from above down): ergogram, stimulation signal, time marker (1 second); a and b) data from different experiments.

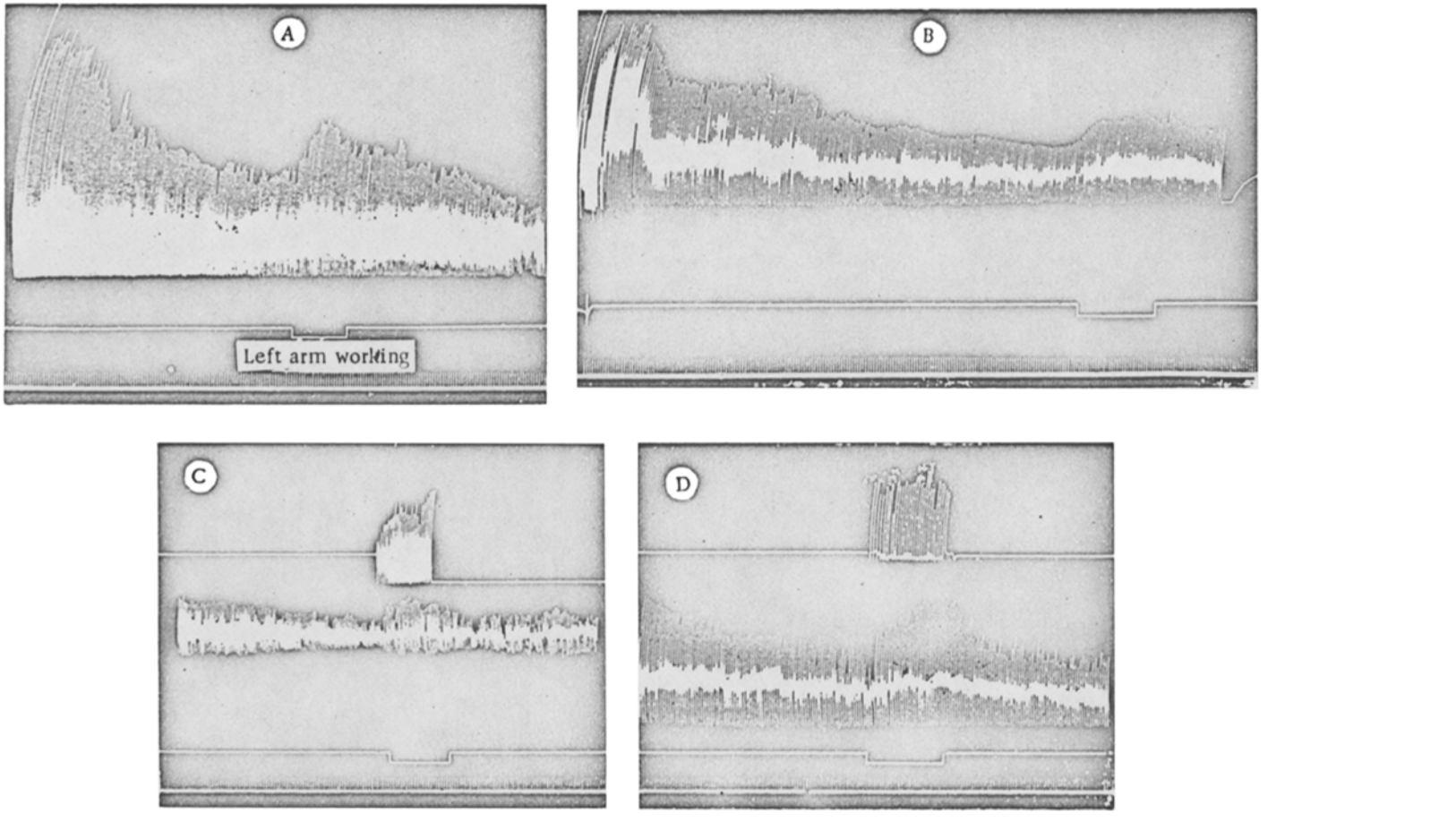

Fig. 3. Changes in working capacity due to the effect of supplementary stimulation of the motor analysor.
A and B with active, and C and D with passive movements of the left arm.
Explanation of tracings (from above down): for A and B, ergogram for the right arm, signal showing when the left arm began work, time marker (1 second); for C and D, recording of passive movements of the left arm, ergogram for the right arm, signal showing stimulation (passive movements of the left arm), time marker (1 second).

experiments this effect did not differ from that observed with stimulation of the auditory analysor, but a significant difference appeared as the experiments were continued: numerous repetitions (up to 30) did not reveal any tendency toward weakening of the effect.

In our next experiments we set in motion a device which caused passive movements of the left arm, at a time when the right arm began to show signs of fatigue. We found that passive movements of the left arm also raised the work performance of the right arm. The magnitude of this effect did not diminish with repetition of the experiment (Fig. 3, C, D).

In our further experiments we attempted to elucidate the effect of supplementary stimuli on the reactions which ensure the achievement of muscular work.

We performed experiments in which we studied the effects on gaseous metabolism and pulmonary ventilation of stimulation of the auditory analysor, and of the motor analysor by means of passive movements.

TABLE 1

Changes in Pulmonary Ventilation Associated with an Auditory Stimulus (a bell)

Day of observation				
1st	2nd	3rd	4th	5th
		(Pulmonary ventilation, in liters)		
1.0	0.2	0.4	0.7	1.6

As appears from Table 1, auditory stimulation (a bell) at first augments pulmonary ventilation, but this is followed by its diminution to values below those found initially, before stimulation was instituted.

Passive movements of the left arm also caused augmentation of pulmonary ventilation and of oxygen uptake, but this increase varied within certain limits, without manifesting a tendency towards diminution (Table 2).

It thus appears that the actions of the above-mentioned stimuli, applied both to rested and to fatigued individuals, manifest definite differences with respect to their effect on working capacity and on the effecting of reactions which enable muscular work to be done.

TABLE 2

Changes in Pulmonary Ventilation and Oxygen Uptake, With Passive Movements of the Left Arm

Index measured	Day of observation						
	1st	2nd	3rd	4th	5th	6th	7th
Pulmonary ventilation (in liters)	0.7	0.8	0.3	0.5	0.6	1.6	1.3
Oxygen uptake (in ml)	33	34	57	48	56	43	30

Each of the stimuli was a novel factor in the given situation when first applied, and could, according to the concepts of I. P. Pavlov, evoke an orientating reaction: "What is it?" The stimulator of the auditory analysor applied by us initially evoked a generalized state of alertness, as probably would any other fresh stimulus. This brought about an increase in pulmonary ventilation and in the amount of work performed. When the stimulation experiments were repeated, the effects were evidently concentrated in the analysor to which they were directed. The subject continued to hear the bell, but this no longer caused any change in work capacity, nor did it augment pulmonary ventilation.

Pulmonary ventilation rose the first few times the bell was sounded, but after a few repetitions the effect was inverted. In other words, the factor which initially had a stimulating effect became, after a few repetitions, an inhibitory one. This effect may be due to inductive inhibition, arising as a consequence of concentration of excitation. As has been shown by N. A. Popov [8], this type of reaction is characteristic of the orientating reflex.

With stimulation of the motor analysor, effected by movements of the arm, the stimulus passes directly to this analysor, increased excitation of which leads to increased work performance. It follows that, even after concentration of the initially generalized state of excitation, supplementary stimulation of the same motor analysor will take place, and this can apparently be maintained by irradiation from other centers in which excitation may arise as a result of stimuli from proprioceptors. The existence of excitation of this sort has been confirmed by the changes in pulmonary ventilation and gaseous metabolism observed when proprioceptors are stimulated. Working with cats, D. G. Kvasov and I. I. Naumenkov [4] have shown that direct stimulation of motor nerves supplying muscles leads to increase in pulmonary ventilation and blood pressure, even in the absence of muscular contraction.

The ability of proprioceptors to respond for a long time to stimulation by impulses of constant strength may be an additional factor favoring stabilization of the given reaction.

SUMMARY

The stability of changes of the muscular working capacity under the effect of various analysors was investigated in this work. This study was conducted on the background of decreased working ability of the right arm.

The results of these observations showed that increase of working capacity caused by stimulation of the cutaneous temperature and olfactory analysors disappears following repetition of these experiments 2 or 3 times. They are components of reaction of orientation. Increase of the working capacity under the effect of additional stimulation of the motor analysor is very stable under conditions of these experiments. Evidently, excitation of certain centers plays an important part in creation of stability of this effect. This excitation appears as an unconditioned reflex as a result of stimulation of the proprioceptors.

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