

## EFFECTS OF EMOTIONAL FACTORS ON PHYSICAL PERFORMANCE OF DOGS ON THE TREADMILL

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*Abstract.* In dogs exercising on a treadmill, increase of physical performance was particularly pronounced when the animals were punished by an electric shock for slowing the speed of running and also upon hypothalamic stimulation producing flight response. This was accompanied by alterations of autonomic and metabolic functions. Food and stimulation of hypothalamic self-stimulation areas used as a reward for better performance was also effective, but only at the beginning of the work. On the other hand, hypothalamic and midbrain stimulation which produced a passive fear response decreased the intensity of work. Autonomic and metabolic functions were strongly affected. It appears that both the animal's motor activity and vegetative processes may be influenced by motivational factors in the course of physical performance.

### INTRODUCTION

Factors determining physical performance and development of fatigue are not fully understood. Particularly, little is known about the mechanisms through which the central nervous system regulates the ability to perform muscular work. The role of nervous factors in adaptation to physical exercise is not only limited to a direct action on muscular activity, but is also involved in mobilization of energy sources and in maintaining homeostatic processes on an adequate level to meet the organism's increased requirements. Especially during emotional excitement the function of many organs may be altered as to provide optimal conditions for the work performed (Blair et al. 1959, Wilmore 1968). Sheffield (1948) introduced avoidance procedure into his experiments with guinea pigs and found it efficient in increasing the running speed of these animals.

Although dogs are often used as subjects for studies in physiology of exercise, it is not easy to estimate the relationship between actual effort and maximal performance capacity. For this reason the present study was undertaken. Its aim was to investigate the physical performance of exercising dogs under the influence of motivational factors and in the course of brain stimulation producing emotional effects.

#### MATERIAL AND METHOD

The experiments were carried out on 18 male mongrel dogs weighing 15–20 kg which had easily learned to run on the treadmill. Under Evipan anesthesia concentric electrodes were chronically implanted into the hypothalamus and midbrain according to stereotaxic coordinates taken from the atlas of Lim et al. (1960). Their extracranial ends were soldered to connectors of a plexiglas plug screwed into the parietal bone. Experiments began not earlier than after three weeks following surgery.

Five series, each consisting of five experimental sessions were made in the morning hours preceding feeding of the animals.

In Series I the speed of the treadmill band was adjusted individually to the dog's optional activity. In each session the dog performed three 1 km runs at a 15° grade with 1–1.5 min intervals between. The running periods were accounted as controls.

In Series II the dogs were shown meat and received it after having performed each run. Thus the animal could attain the reward sooner by increasing the running speed.

In Series III a pair of uninsulated copper wires wound on a plastic plate was placed in the back of the treadmill. A voltage ranging from 0 to 500 v r.m.s. was applied to the coils using a 50 cycle/sec sine wave regulated by means of an autotransformer. When the dog slowed down, his hindleg pads touched the wires and the animal was exposed to an electric shock which could be avoided by increasing the running speed.

In Series IV the experiments were carried out as in controls. Their purpose was to check in what measure improvement of performance observed in the course of experiments depended on the effect of motivational factors and how far on training due to repeated exercises.

In Series V hypothalamic and midbrain structures were stimulated in exercising dogs. For this purpose the electrodes were connected to a stimulator through an isolation unit by means of long and flexible wires which did not impede the animal's performance. 1 msec square pulses of a frequency of 200 cycle/sec were used, their amplitude being set up so as to produce optimal effects.

At the beginning of each session and after each 1 km run, electro-

cardiogram was recorded to measure the heart rate. Rectal temperature was measured and blood was sampled from the saphenous vein to determine lactate (Ström 1949), pyruvate (Rindi and Ferrari 1956) and glucose (King 1957) levels. The "excess lactate" was calculated from lactate and pyruvate concentration in blood according to Huckabee's (1958) formula and was considered as an index reflecting the degree of anaerobic metabolism. Values of all above-mentioned parameters (except work intensities) are expressed as an increase above the control levels.

For histology the dogs brains were fixed in 10% formalin and embedded in celloidin. 50  $\mu$  sections were cut in the frontal plane and stained after Nissl and Weigert.

## RESULTS

### *Effects of food motivation and shock avoidance on running speed*

Results are shown in Table I. It appears that in shock avoidance conditions (Series III) the running speed of the dogs increased more than with food motivation (Series II). This was particularly evident in the third run. Correspondingly, heart rate, rectal temperature and blood lactate level were more elevated after work in "punishment" than in "re-

TABLE I

Work intensity, heart rate, rectal temperature, blood lactate and blood glucose concentration increase after exercise performed in experiments with fear and food motivated work. Experiments were successively performed in 18 dogs

	Fear motivation	Food motivation	<i>p</i>
Work intensity (kgm/min/kg)	51.1 $\pm$ 0.8	39.3 $\pm$ 0.7	<0.001
Heart rate (beats/min)	71.0 $\pm$ 3.1	53.0 $\pm$ 3.1	<0.001
Rectal temperature (°C)	2.0 $\pm$ 0.1	1.3 $\pm$ 0.1	<0.001
Blood lactate (mg/100 ml)	35.0 $\pm$ 2.9	15.0 $\pm$ 2.3	<0.001
Blood glucose (mg/100 ml)	5.9 $\pm$ 2.9	1.8 $\pm$ 1.0	not sign.

All the values are means  $\pm$  standard errors. *p*, statistical significance of differences between corresponding values.

ward" situation. The blood glucose level was not significantly altered in both kinds of experiments as compared to control values. When slowing of speed was not followed by an electric shock (Series IV, the intensity of work was close to control values (Table II).

TABLE II

Work intensity, heart rate, rectal temperature, blood lactate and blood glucose concentration increase after exercise performed in control experiments (Series I and Series IV). Experiments were successively performed in 18 dogs

	Control experiments (Series I)	Control experiments (Series IV)	<i>p</i>
Work intensity (kgm/min/kg)	36.6±0.5	38.2±0.9	not sign.
Heart rate (beats/min)	42.0±3.4	55.0±3.0	<0.01
Rectal temperature (°C)	1.4±0.1	1.4±0.1	not sign.
Blood lactate (mg/100 ml)	14.5±2.3	15.0±2.1	not sign.
Blood glucose (mg/100 ml)	3.0±1.1	1.9±0.9	not sign.

All the values are means  $\pm$  standard errors. *p*, statistical significance of differences between corresponding values.

#### *Effects of electrical stimulation of the brain upon performance*

Electrical stimulation of hypothalamic and midbrain areas in non-exercise conditions elicited three types of behavioral responses: flight, passive defence reaction and self-stimulation.

Flight was elicited in 7 dogs by stimulating the dorsolateral and ventral hypothalamus and preoptic area (Fig. 1). Every slowing of the run was punished with an electric stimulation to the brain structures. According to values shown in Table III the running speed on the treadmill during stimulation of these regions was of the same range as in concurrently performed experiments in shock avoidance conditions. However, heart rate, rectal temperature, blood glucose and "excess lactate" increased more in experiments with brain stimulation.

Passive defence reaction was produced in 6 dogs by stimulation of midbrain tegmentum and dorsolateral and medial hypothalamus (Fig. 2).

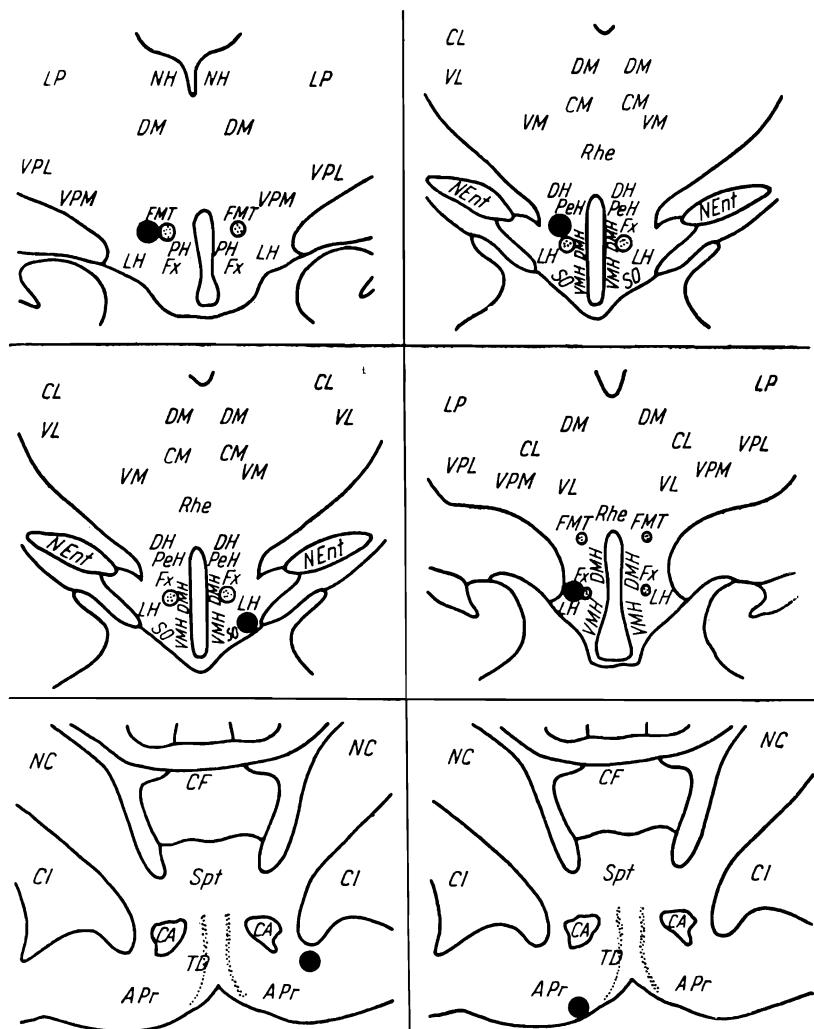


Fig. 1. Frontal sections through dog's brain. Black dots indicate points producing a flight response upon electric stimulation. Abbreviation: APr, preoptic area; CA, anterior commissure; CF, columna fornicis; CI, internal capsule; CL, centro-lateral nucleus; CM, centrum medianum; DH, dorsal hypothalamus; DM, dorsomedial thalamic nucleus; DMH, dorsomedial hypothalamic nucleus; FMT, fasciculus mammillothalamicus; Fx, fornix; LH, lateral hypothalamus; LP, nucleus lateralis posterior; NC, caudate nucleus; NEnt, nucleus entopeduncularis; NH, nucleus habenulae; PeH, periventricular nucleus; PH, posterior hypothalamus; Rhe, nucleus rheuniens; Spt, septum; SO, supraoptic nucleus; TD, taenia diagonalis; VM, ventromedial thalamic nucleus; VMH, ventromedial hypothalamic nucleus; VL, ventrolateral nucleus; VPL, nucleus ventralis posterolateralis; VPM, nucleus ventralis posteroventralis.

TABLE III

Work intensity and an increase in heart rate, rectal temperature, "excess lactate" and blood glucose concentration after exercise performed in experiments with brain stimulation and shock avoidance.

Experiments were successively performed in 7 dogs

	Experiments with brain stim- ulation	Experiments with shock avoidance	
Work intensity (kgm/min/kg)	56.2±2.7	51.1±0.8	not sign.
Heart rate (beats/min)	127.4±9.1	92.8±7.3	<0.01
Rectal temperature (°C)	2.9±0.1	2.0±0.1	<0.001
"Excess lactate" (mg/100 ml)	56.4±7.2	37.3±3.2	<0.01
Blood glucose (mg/100 ml)	51.8±9.1	8.2±3.6	<0.001

All the values are means  $\pm$  standard errors.  $p$ , statistical significance of differences between corresponding values.

The stimulation was maintained during the whole running period. It consisted of a marked inhibition of motor activity. Running speed during stimulation of these areas was lower than in controls and two animals ceased to perform the exercise. In spite of this, increase of heart rate, blood lactate and blood glucose was significantly higher. Rectal temperature markedly increased upon hypothalamic stimulation (Table IV).

In 5 dogs self-stimulation was produced by stimulating different loci within the preoptic area and hypothalamus including mammillary bodies (Fig. 3). These animals, in exercise conditions, were "rewarded" by brain stimulation for increasing the running speed. Parameters of the current were the same as those found optimal for self-stimulation. A greater amount of work was done only at the beginning of each exercise and later on, the speed was as in controls. Increase of heart rate, rectal temperature, blood lactate and blood glucose did not exceed control values (Table V).

#### DISCUSSION

The results presented here confirmed my earlier observations (Kruk 1968). Electric shock applied to the pads of the dog's hindlegs for slowing the speed of running appeared to be very effective. The animals exercised

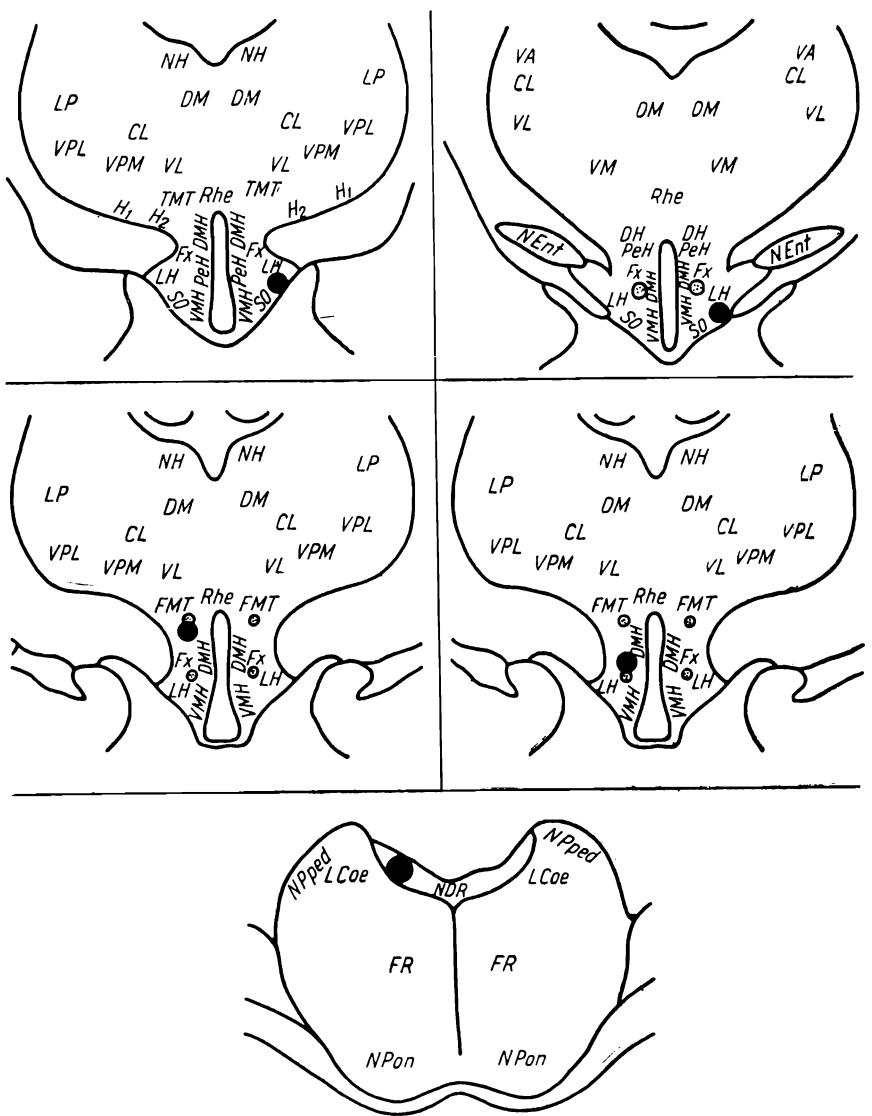


Fig. 2. Frontal sections through dog's brain. Black dots indicate points producing passive defence reactions. Abbreviations: FR, reticular formation;  $H_1$ ,  $H_2$ ,  $H$ , area  $H_1$ ,  $H_2$ ,  $H$ ; LCoE, locus coeruleus; NDR, nucleus dorsalis raphe; NPped, parapeduncular nucleus; NPon, nuclei pontis; TMT, tractus mammillothalamicus. Other denotations as in Fig. 1.

on the treadmill with great intensity in spite of evident symptoms of fatigue. A high rate of performance could be demonstrated by a significant rise of blood lactate considered as an index of hard (Paul and Issekutz

TABLE IV

Work intensity and an increase in heart rate, rectal temperature, "excess lactate" and blood glucose concentration after exercise performed in experiments with brain stimulation and shock avoidance.

Experiments were successively performed in 6 dogs

	Experiments with brain stimulation	Experiments with shock avoidance	<i>p</i>
Work intensity (kgm/min/kg)	31.0±2.8	52.5±2.9	<0.001
Heart rate (beats/min)	71.8±10.0	52.8±6.6	<0.01
Rectal temperature (°C)	3.2±0.1	2.0±0.1	<0.001
"Excess lactate" (mg/100 ml)	59.1±5.7	35.0±2.0	<0.001
Blood glucose (mg/100 ml)	45.5±7.6	6.8±0.5	<0.001

All the values are means  $\pm$  standard errors. *p*, statistical significance of differences between corresponding values.

1967) and very hard work (Wathen and Rostorfer 1962, Yoder 1964, Issekutz 1965, Brzezińska and Nazar 1969). Food motivation improved performance only at the beginning of each session. As fatigue developed the running speed gradually decreased although meat was offered to the animals. This fact may be due to an increase of body temperature which was revealed already after the first run. Such explanation is consistent with Brobeck's statement (1960) that hyperthermia reduces the excitability of the hunger center.

Stimulation of brain areas producing a flight response increased the dog's running speed on the treadmill and the intensity of work was equal to or exceeded that observed in shock avoidance situation. Also autonomic and metabolic effects accompanying work performed during brain stimulation were more pronounced. This was particularly evident with hyperglycemia produced by hypothalamic stimulation and blood glucose not exceeding control values as observed in shock avoidance conditions. The rise of blood lactate, with high "excess lactate" may speak for strong activation of the adrenergic system and release of catecholamines. Glagoliev and Tomilina (1966) observed hyperglycemic effects in cats by stimulating the same areas of the brain. After the stimulation of these areas Goldfien and Ganong (1962) found an increase of catecholamines in the blood of anesthetized dogs. Similar symptoms of adrenergic activa-

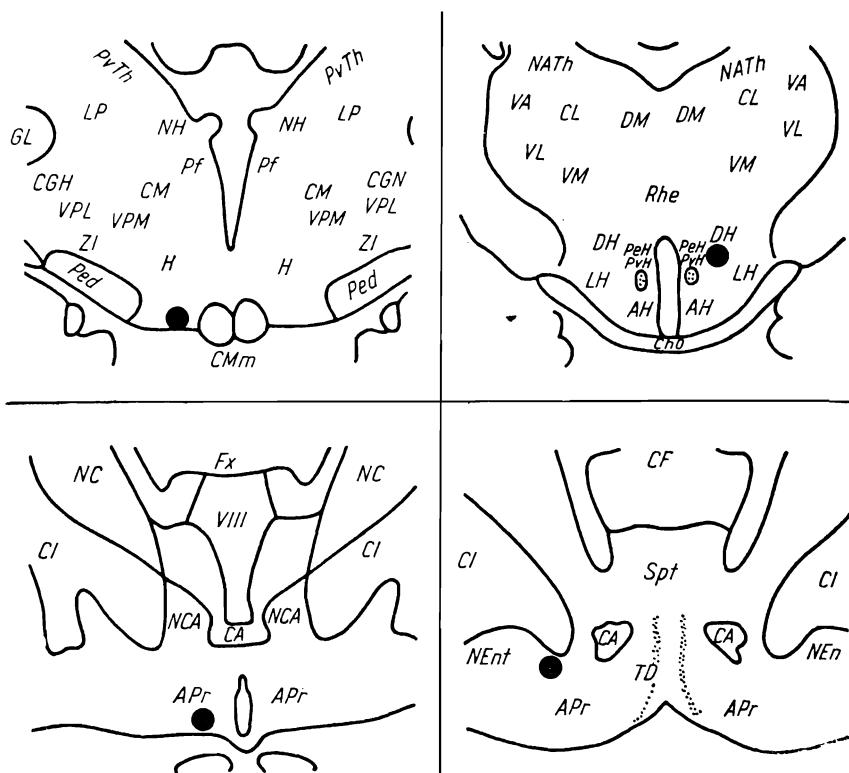


Fig. 3. Frontal sections through dog's brain. Black dots indicate self-stimulation points. Abbreviations: CF, crus fornicis; ChO, optic chiasma; CMm, mammillary body; NCA, nucleus commissurae anterioris; NCM, centromedial nucleus; Ped, peduncle; Pf, parafascicul nucleus; PvH, paraventricular nucleus; PvTh, pulvinar thalami; V III, third ventricle; ZI, zona incerta. Other denotations as in Fig. 1.

tion were found in dogs exhibiting a passive defence reaction upon stimulation of the midbrain and hypothalamic areas. This led to an increase of heart rate, hyperglycemia and rise of blood lactate not adequate to the intensity of work performed.

One should take into account that rapid development of fatigue and cessation of performance coincided with a marked increase of body temperature. This is consistent with the data of Young et al. (1959) who found hyperthermia to be main factor affecting physical performance of dogs. Also in man exercising under heat stress, performance capacity was greatly reduced when body temperature rose up to 39°C, whereas "excess lactate" was as in controls (Sołtysiak et al. 1969). The most rapid rise of body temperature was found upon stimulation of hypothalamic areas producing a passive defence reaction. In these dogs hyperthermia de-

TABLE V

Work intensity and an increase in heart rate, rectal temperature, blood lactate and glucose concentration after exercise performed in experiments with brain stimulation and in controls. Experiments were successively performed in 5 dogs

	Experiments with brain sti- mulation	Control experiments (Series IV)
Work intensity (kgm/min/kg)	36.2±1.4	33.7±0.9
Heart rate (beats/min)	38.0±10.0	48.0±3.0
Rectal temperature (°C)	1.5±0.1	1.4±0.1
Blood lactate (mg/100 ml)	2.2±1.2	3.6±1.9
Blood glucose (mg/100 ml)	3.5±0.3	1.7±0.3

All the values are means  $\pm$  standard errors. The differences between corresponding values are not significant.

veloped already after two runs and was considered as main factor deteriorating performance. On the other hand, passive defence response produced by midbrain stimulation had no hyperthermic effect.

Stimulation of hypothalamic areas from which self-rewarding phenomena were observed in non-exercise conditions (Sadowski and Kruk 1969) could also be used as a motivational factor increasing performance. Heart rate and metabolic changes were adequate to work intensity. Similarly as in experiments with food motivation this effect was mostly pronounced at the beginning of the exercise.

Fear can thus improve performance, only if a behavioral response to it is flight or avoidance of a painful stimulus. Muscular activity of the animal is then enhanced and autonomic functions are activated adequately to the intensity work. On the other hand, during a passive fear reaction there is a dissociation between a strong activation of the adrenergic system and a decreased motor activity. With positive reinforcement, such as food reward or stimulation of self-rewarding areas, improvement of performance is short-lasting and more susceptible to fatigue.

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