THE ROLE OF DISTANT MEANINGFUL STIMULI IN THE REGULATION OF CARBOHYDRATE METABOLISM IN MONKEYS

I. S. Kanfor

Laboratory of the Physiology of Gas Exchange and Heat Regulation
(Head – Prof. R. P. Ol'nyanskaya) of the Department of General Physiology
(Head – Akad. K. M. Bykov) of the Institute of Experimental Medicine
(Dir. – Corresponding Member of the Akad. Med. Nauk SSSR Prof. D. A. Biryukov)
of the Akad. Med. Nauk SSSR, Leningrad
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Projects in the laboratories of I. P. Pavlov have served to establish that distant meaningful stimuli are of major importance in the conditioned reflex regulation of the digestive apparatus' activity. The role of these distant stimuli in the regulation of the metabolism, particularly gas exchange, has been shown in the works of R. P. Ol'nyanskaya [3, 4], A. R. Makarova [2], and I. S. Breslav [1]. It seemed important to elucidate the significance of these distant stimuli in the regulation of carbohydrate metabolism. This question has not been adequately studied.

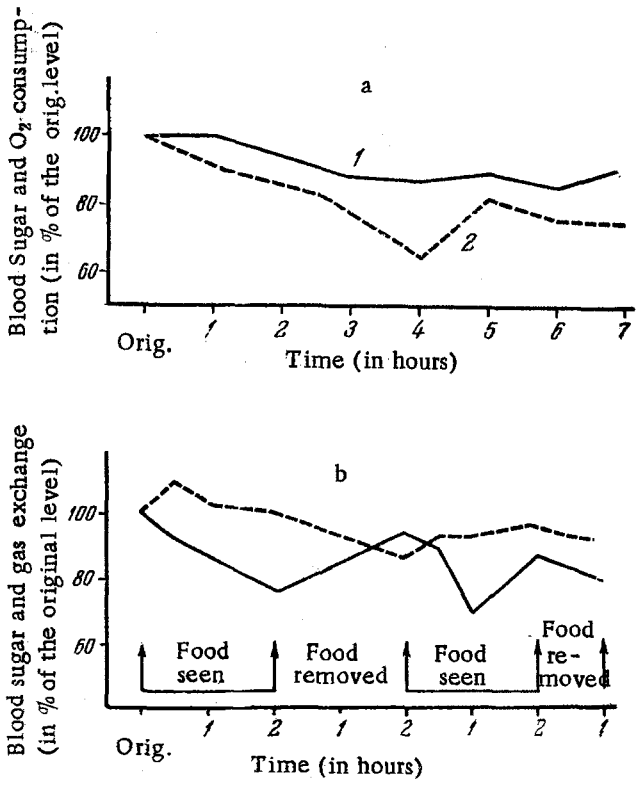

Fig. 1. Dynamics of the carbohydrate metabolism in the monkeys during the control experiments (a) and associated with the effects of observation of feeding (b). 1) Blood sugar concentration (in percents of the original level); 2) oxygen consumption (in percents of the original level, mean data).

Our investigations were carried out at the Sukhum Biological Station of the Akad. Med. Nauk SSSR, using 7 Macaca rhesus monkeys born in the nursery and well adapted to their living conditions.

TABLE 1. Blood Sugar Concentration in the Hungry Monkeys During Their Exposure to Monkeys Ingesting Food

Date of Experiment	Monkey's name	Original blood sugar concentration (in mg %)	Blood sugar concentration (in mg %)											
			during exp. period				food removed		during exp. period				food removed	
			½ hr	1 hr	1 ½ hr	2 hr	1 hr	2 hr	½ hr	1 hr	1 ½ hr	2 hr	1 hr	2 hr
1949														
19/VIII	Volna	99	99	99	54	43	72	72	43	43	54	48	27	—
22/VIII	Babochka	109	—	86	89	66	70	73	59	89	—	93	66	34
29/VIII	Vanessa	82	65	65	65	63	74	110	55	65	58	51	58	55
27/VIII	Zhuzhelitsa	83	81	72	99	83	83	77	68	66	65	65	83	70
1950														
20/IX	Saltan	100	72	77	—	63	69	84	—	—	—	—	—	—
25/IX	Tarantul	102	107	91	85	89	98	90	83	73	—	91	91	77
2/X	Rikk	87	88	82	—	65	72	95	83	55	—	79	58	—
	In percents of the original	100	92,5	86,4	82,5	71,3	81,7	90,3	69,6	69,6	67,5	77,3	69,9	62,8

TABLE 2. Gas Exchange in the Hungry Monkeys During Their Exposure to Monkeys Ingesting Food

Date of the experiment	Monkey's name	Original O_2 consumption (in ml/min)	Oxygen consumption (in ml/min) during the experiment										
			exposure period				food removed		exposure period			food removed	
			½ hr	1 hr	1 ½ hr	2 hr	1 hr	2 hr	½ hr	1 hr	2 hr	1 hr	2 hr
1950													
20/IX	Saltan	49,1	54,6	49,7	—	49,7	33,1	26,0	—	—	—	—	—
25/IX	Tarantul	45,4	49,0	47,0	47,7	41,1	45,2	43,2	47,5	47,5	47,5	49,9	45,2
2/X	Rikk	51,1	53,0	53,0	—	55,3	48,2	45,9	39,2	41,5	43,7	36,8	—
	In percents of the original	100	108	102,9	105	100,4	86,8	79	89,9	92,2	94,5	89,8	—

EXPERIMENTAL METHOD

In the morning, without being fed, the monkeys were periodically tested every hour for 7-8 hours. By means of an incision in the ear lobe the blood sugar concentration was determined, and the oxygen consumption was measured for intervals of 15, 30 and 60 minutes. During this procedure the animals were isolated from the other monkeys. After a day, we carried out a second experiment, in which we placed other monkeys, in the process of eating their food, in front of the monkey serving as the subject. A third experiment consisted of placing food products in front of the monkey, and, after a day, repeating this experiment after first feeding the monkey with these same products. A series of experiments was set up to study the effect of food odor on the metabolism; the food was placed in a chamber for the investigation of gas exchange, out of the animal's sight.

Taking into account the fact that monkeys eat at intervals the food offered them, under the conditions of our experiments we left the food in front of the animals for a period of only 2 hours, after which the remnants were removed and the cage cleaned. The interval between feeding was also 2 hours. Gas exchange was studied in a pneumatic chamber, following the method of Holden; the blood sugar concentration was determined by the Hagedorn-Jensen method.

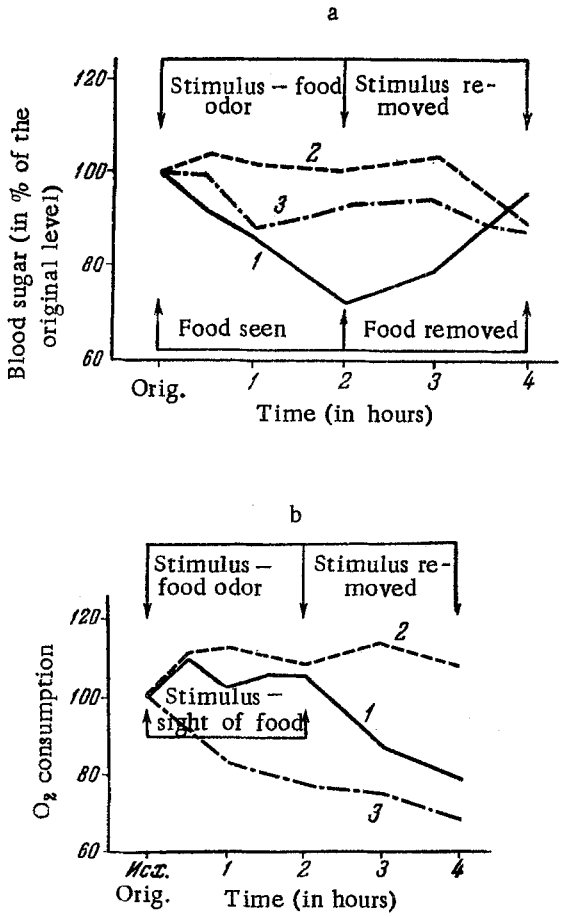

Fig. 2. The effect of stimulating visually (1) and with odor (2) (using food), and under control conditions (3), upon the dynamics of the carbohydrate metabolism in monkeys. a) Blood sugar concentration (in percents of the original level); b) oxygen consumption (in percents of the original level, mean data).

EXPERIMENTAL RESULTS

The results of the experiments showed that the blood sugar concentration and the oxygen consumption in unfed monkeys during the control period (Fig. 1a) gradually decreased from the beginning of the experiment to its end. In the periods of exposure to the monkeys eating their food, the experimental animals ("monkey observers") showed a decreased in their blood sugar concentration. After cessation of the feeding of the monkeys and the removal of the food remnants from the cages, the blood sugar level in the "monkey observers" increased. Repeat feeding of the other monkeys again caused a decrease in the blood sugar concentration of the "monkey observers."

Exposure to the monkeys eating their food caused an elevation in the oxygen consumption of the "monkey observers", reaching 125.7% of the original level. An increase in gas exchange was noted during the entire period of the secondary monkeys' feeding. Cessation of the feeding and removal of the food remnants from the field of vision of the "monkey observers" led to a decrease of the oxygen consumption of the latter during the entire two hour period. Repetition of these procedures caused an analogous effect a second time (Tables 1 and 2).

Similar date was also obtained with exposure of the "monkey observers" to food products.

Thus, in the "monkey observers" during the period of stimulation of the visual analyzers by food (or the ingestion of food by other monkeys) a decrease was noted in the blood sugar concentration, accompanied by an increase in oxygen consumption. After cessation of the feeding a gradual elevation of the blood sugar level was observed, along with a decrease in oxygen consumption (Fig. 1b). Hence, the sight of food products, as well as the sight of monkeys taking food, served as a complex "signal" stimulus for the "monkey observers," causing a metabolic acceleration in the organism of the experimental animal.

"monkey observers" either during their exposure to food products or after removal of the latter from their field of vision. Gas exchange data obtained under these conditions showed an increase in oxygen consumption during exposure of the fed animals to food. With removal of the stimulus the oxygen consumption decreased.

Thus, the dynamics of the carbohydrate metabolism during exposure of the fed monkeys to food differed substantially from its dynamics in the control experiments and in those experiments where the conditioned food stimuli acted on the visual analyzer of hungry monkeys.

Study of the effect of the food product odor on the olfactory analyzer of the monkeys showed a small increase in the blood sugar level, accompanied by an increase in oxygen consumption. These changes were not only observed during the exposure to the stimulus, but afterwards as well.

Comparison of the data on the changes in the blood sugar concentration and oxygen consumption, obtained during stimulation of the visual and olfactory analysers in the hungry animals (Fig. 2), illustrates certain characteristics in the carbohydrate metabolism alterations which are characteristic for each of the stimuli. It may be seen (Fig 2a) that with stimulation of the visual analyzer the blood sugar concentration decreases, while with stimulation of the olfactory analyzer it rises. The fall in the blood sugar level resulting from the effect on the visual analyzer is limited to the period of exposure to the stimulus, and reaches *
After removal of the stimulus from the animal's field of vision an elevation in the blood sugar concentration is observed, which returns to the original level after 2 hours. With stimulation of the olfactory analyser the increase in the blood sugar level continues to be observed for an hour after removal of the stimulus.

Oxygen consumption (Fig. 2b) was shown to be more intense (throughout all 4 hours of the experiment) in the case of stimulation of the olfactory analyzer. With stimulation of the visual analyzer the oxygen consumption decreased as soon as the stimulus was removed from the monkey's field of vision.

The material presented shows that the sight and odor of food causes conditioned reflex changes in the carbohydrate metabolism of apes. In this case the physiological state of the experimental animal is of essential importance : excitation of the alimentary center of an animal in the hungry state causes a more intense stimulation of the carbohydrate metabolism than that which is observed in fed animals.

The described changes in the carbohydrate metabolism are of a specific character. Stimulation by the sight of food causes a conditioned reflex acceleration in the carbohydrate dissimilation processes, while stimulation with food odor causes a conditioned reflex increase in the entrance of sugar into the blood, and subsequent accumulation of a surplus of sugar circulating in the blood. This specificity in the metabolic reactions indicates the specific effect of stimuli from various receptors on the conditioned reflex regulation of the carbohydrate metabolism, a regulation that is connected with the complex of conditions accompanying the intake of food by animals.

SUMMARY

Blood sugar content and the value of oxygen intake were studied in 7 hungry monkeys, "observers" of the eating monkeys or food. A marked reduction in the blood sugar level was noted with a rise of oxygen intake during the whole exposition period. In removing the food stimuli from the visual field of these monkeys the blood sugar level was seen to rise, whereas oxygen intake dropped. In monkeys fed prior to the experiment there were no such changes in the metabolism.

The smell of food caused a slight rise of the blood sugar content and a rise of oxygen intake.

Thus, specific changes in the carbohydrate metabolism occur during the action of distant food stimuli on the visual and olfactory analyzers.

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* Material omitted in the original Russian--Publisher's Note