PHYSIOLOGY

Reflection of Induced and Amplified Food Motivation in Impulse Activity of the Masticatory Muscles during Electrostimulation of the "Hunger Center" in the Lateral Hypothalamus in Rabbits

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We studied reflection of artificially induced and amplified food motivation in impulse activity of the masticatory muscles during electrostimulation of "hunger center" of the lateral hypothalamus in the absence and presence of food. The threshold stimulation of the lateral hypothalamus in hungry and satiated animals in the absence of food induced incessant food-procuring behavior paralleled by regular generation of spike bursts in masticatory muscles with biomodal distributions of intervals between pulses. This reaction of masticatory muscles during stimulation of the lateral hypothalamus in the absence of food was an example of the anticipatory reaction reflecting characteristics of the action result acceptor. Higher level of hunger motivation during threshold stimulation of the lateral hypothalamus in hungry and satiated rabbits in the course of effective food-procuring behavior increased the incidence of spike burst generation during the food capture phase, but did not modify this parameter during the chewing phase. Impulse activity of the masticatory muscles reflected convergent interactions of food motivation and support excitation on neurons of the central generator of chewing pattern.

Key Words: *lateral hypothalamus "hunger center"; electrostimulation; masticatory muscles; impulse activity*

According to the pacemaker theory of motivations, "hunger center" of the lateral hypothalamus (LH), as the initiative motivatiogenic center, produces ascending activation of the limbic structures and brain cortex and thus forms the exploratory and food-procuring behavior [3]. LH "hunger center" can also realize descending stimulation of neurons of chewing pattern generator in the medulla oblongata by modulating the standard central chewing program [5,6]. It is known that excitation of the motivatiogenic hypothalamic centers is reflected in myoelectric activity of masticatory muscle [4,7].

Stimulation of the LH "hunger center" in satiated animals shows the patterns of impulse activity of masticatory muscles characteristic of artificially induced food motivation, while electric stimulation of this center in rabbits subjected to food deprivation makes it possible to study reflection of enhanced food motivation in the temporal structure of impulse activity of masticatory muscles. Study of reflection of

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artificially induced and amplified food motivation in the patterns of impulse activity of masticatory muscles is therefore an important problem.

We compared the patterns of masticatory muscles impulse activities during LH electric stimulation in fasting and satiated rabbits in the absence and presence of food.

MATERIALS AND METHODS

Impulse activities of the *m. masseter propria* (MMP) and *m. mylohyoideus* (MM) were recorded via chronically implanted electrodes [1,2] during electric stimulation of the "hunger center" in the absence and presence of food in the experimental box in Chinchilla rabbits under conditions of free behavior after 24-food deprivation or fed before the experiment. In parallel, behavioral activity of animals was recorded using a webcamera. LH was stimulated with an STM 100C stimulator through pre-implanted bipolar nichrome electrodes. The stimulation parameters were as follows: 20-30 Hz frequency, 0.2 msec pulse duration, and 2.5-3.5 V voltage. The temporal parameters of impulse activities of the masticatory muscles (in msec) were analyzed in an automated mode using AcqKnowledge software [1,2]. The temporal parameters of impulse activity of motor units (MU) of MMP and MM were processed using Statistica 6.0 software. The significance of differences between the samples was evaluated by the Mann–Whitney U test at $p<0.5$.

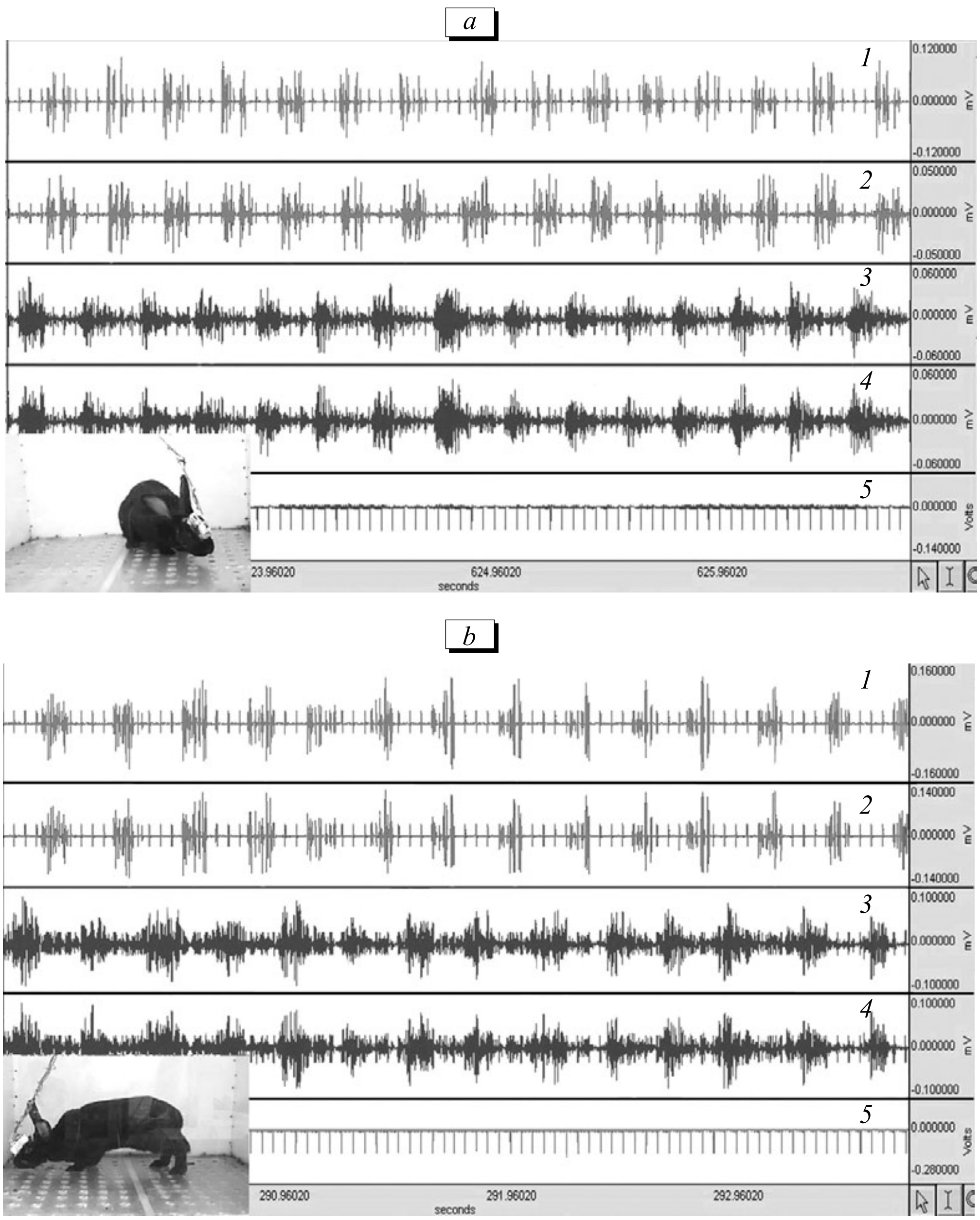

Fig. 1. Impulse activity of MMP (*1*: right; *2*: left) and MM (*3*: right; *4*: left) in a fasting rabbit (24-h food deprivation; *a*) and rabbit fed before experiment (*b*) during threshold stimulation of LH in the absence of food. Here and in Fig. 3: electronograms *1-4* show low-amplitude artifacts of LH stimulation, emerging in accordance with the frequency of rectangular stimulating electric pulses (*5*). Lower part: time — 1000 msec; right: calibration signals: *1-4* (mV), *5* (V); lower part, left: animal behavior.

RESULTS

Stimulation (in the absence of food) of LH "hunger center" in fasting rabbits and rabbits fed before experiment induced incessant food-procuring behavior paralleled by regular generation of action potential (AP) bursts by MMP and MM in the chewing rhythm (Fig. 1), which was uniformly reflected by the structure of time organization of the masticatory muscle impulse activity: bimodal distribution of intervals between pulses with peaks at 5-35 and 170-250 msec (MMP) and 5-30 and 155-235 msec (MM) in fasting rabbits and at 5-45 and 160-240 msec (MMP), and 5-35 and 145-225 msec (MM) in satiated rabbits. Testing of the successive intervals between pulses for distribution normality by Shapiro−Wilk's W test showed that the data did not correspond to normal distribution (W=632,939; $p<0.001$). The frequency of AP burst generation was characterized by slight variability, which was seen from unimodal distributions of the AP burst-like rhythm periods (Fig. 2). The frequency of AP burst generation by the masticatory muscles was 3.64 Hz or 218.67 cycles per minute (MMP) and 3.62 Hz or 217.41 cycles per minute (MM) in hunger and 3.62 Hz or 217.17 cycles per minute (MMP) and 3.63 Hz or 217.77 cycles per minute (MM) in satiation (Table 1), that is, there were no significant differences ($p>0.05$). The frequency of the MMP and MM AP burst-like rhythms during LH stimulation in the absence of food was lower than under conditions of food-procuring behavior forming on the basis of need in nutrients (Table 1, Table 2; $p<0.05$). The regulatory generation of AP bursts by the masticatory muscles during LH stimulation in the absence of food was an example of the anticipatory reaction, as it was not characteristic of food-procuring behavior formed on the basis of the need in nutrients [1,2]. The generation of AP bursts in MM under conditions of LH electrostimulation in hungry and satiated animals in the absence of food anticipated by 118.07±1.51 msec the emergence of AP bursts in MMP, this indicating the reciprocal relationships between the masticatory center motoneurons innervating MM and MMP. We had previously found a similar regularity, then analyzing MM and MMP impulse activities during natural food-procuring behavior [1,2].

Hungry and satiated animals with free access to food developed under conditions of threshold stimulation of LH effective food-procuring behavior including the food capture and chewing phases paralleled

TABLE 1. Statistical Parameters Impulse activity (msec) in MMP and MM in Rabbits Subjected to 24-h Food Deprivation and Fed before Experiment under Conditions of LH Threshold Stimulation in the Absence of Food

Parameters		MMP				MM			
		interval between pulses in AP burst	duration of AP burst	interval between bursts	period of AP burst-like rhythm	interval between pulses in AP burst	duration of AP burst	interval between bursts	period of AP burst-like rhythm
Hunger	*n*	3944	1000	1000	1000	5208	1000	1000	1000
	M	18.99	68.60	205.78	274.38	16.26	75.88	200.09	275.97
	σ	11.01	19.70	26.60	32.56	9.18	16.67	28.25	32.94
	m	0.18	0.62	0.84	1.03	0.13	0.53	0.89	1.04
	Me	16.50	69.00	204.50	272.50	14.00	73.50	195.50	270.50
	25%	10.00	54.00	188.50	253.50	9.00	654.75	181.00	253.00
	75%	25.00	82.50	219.00	292.50	20.50	85.50	217.25	296.50
Satiation	*n*	3369	1000	1000	1000	5490	1000	1000	1000
	M	24.03	80.50	195.78	276.28	16.86	90.16	185.36	275.52
	σ	13.56	16.77	26.60	26.78	9.00	16.49	24.28	29.28
	m	0.23	0.53	0.84	0.84	0.12	0.52	0.77	0.93
	Me	21.00	83.00	194.50	275.50	14.50	88.50	185.50	274.25
	25%	13.00	65.75	178.50	259.00	10.00	78.25	170.00	257.50
	75%	32.50	92.50	209.00	291.50	21.00	101.50	199.25	291.50

Note. Here and in Table 2: *n*: sample volume; *M*: arithmetic mean; *Me*: median; σ: standard deviation; *m*: error of the mean, 25% and 75% quartiles.

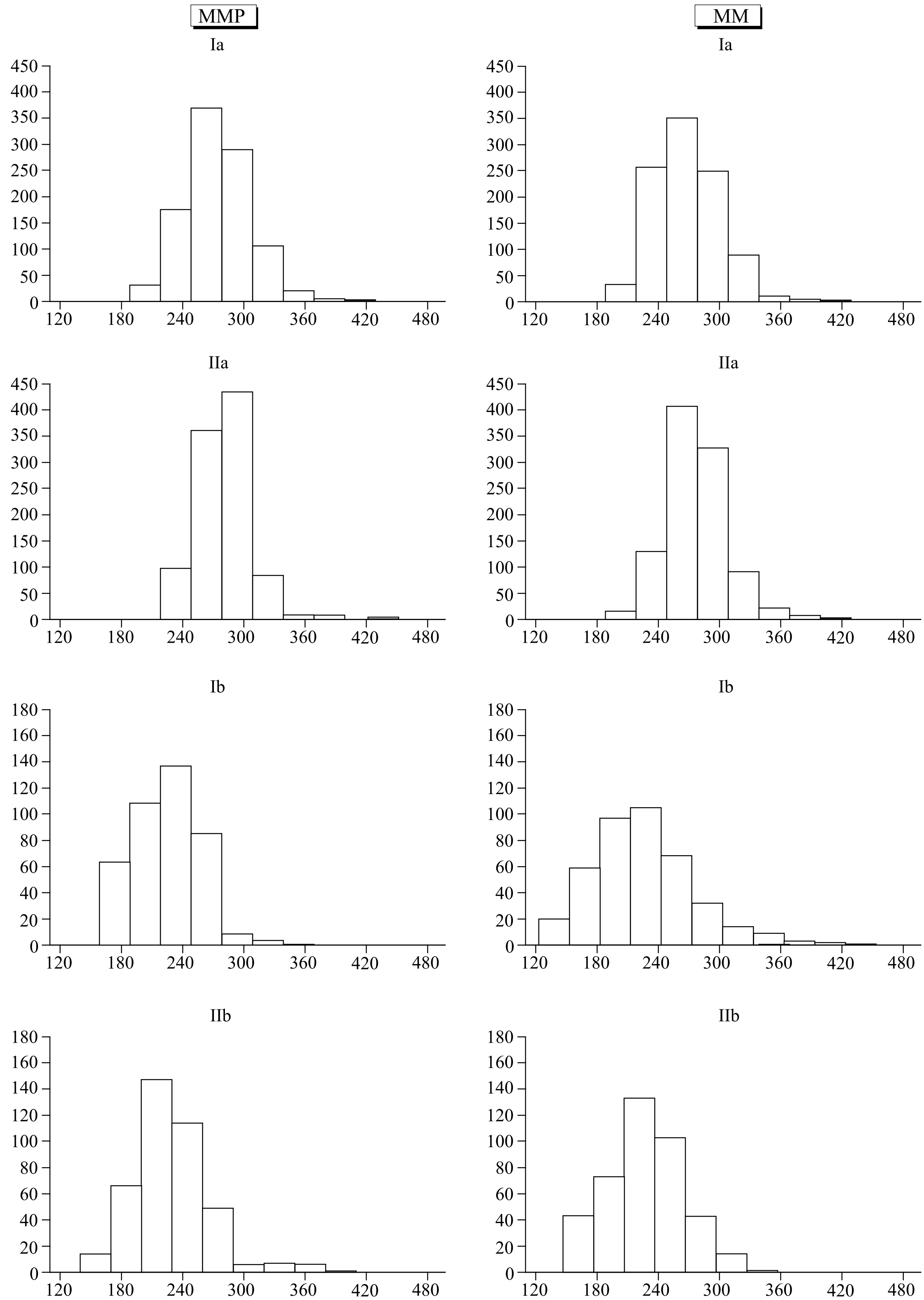

Fig. 2. Histograms of MMP and MM AP burst-like rhythm period distribution in rabbits subjected to 24-h food deprivation (I) and fed before experiment (II) during electric stimulation of LH in the absence and presence of food and the effective food-procuring behavior developing during stimulation (food capture phase). Abscissa: periods of AP burst-like rhythms, msec; ordinate: absolute frequency of AP burst-like rhythm periods. For Ia and IIa: n=1000; for Ib and IIb: n=410.

TABLE 2. Statistical Parameters of Masticatory Muscles (MMP and MM) Impulse activity (msec) in Rabbits Subjected to 24-h Food Deprivation and Fed before Experiment during Effective Food-procuring Behavior under Conditions of LH Threshold Stimulation and Natural Food-procuring Behavior

Parameters		Food capture phase				Food chewing phase			
		interval between pulses in AP burst	duration of AP burst	interval between bursts	period of AP burst-like rhythm	interval between pulses in AP burst	duration of AP burst	interval between bursts	period of AP burst-like rhythm
Food-procuring behavior during LH stimulation (hunger)	*n*	1849 / 1536	410 / 410	410 / 410	410 / 410	23 185 / 27 946	6800 / 6800	6800 / 6800	6800 / 6800
	M	10.02 / 15.62	45.19 / 58.50	180.85 / 166.96	226.04 / 225.46	11.69 / 13.55	39.89 / 55.75	222.05 / 205.23	261.93 / 260.98
	σ	5.10 / 9.83	18.79 / 28.57	32.06 / 41.29	32.21 / 49.95	5.28 / 7.69	17.45 / 21.61	37.48 / 33.71	37.56 / 35.83
	m	0.12 / 0.25	0.93 / 1.41	1.58 / 2.04	1.59 / 2.47	0.03 / 0.05	0.21 / 0.26	0.45 / 0.41	0.46 / 0.43
	Me	8.00 / 12.00	45.00 / 53.75	179.50 / 163.25	225.00 / 221.25	10.50 / 11.00	38.00 / 54.00	217.50 / 200.00	257.50 / 257.50
	25%	7.00 / 8.50	28.50 / 36.00	157.00 / 139.50	203.50 / 190.50	8.00 / 9.00	26.50 / 41.00	197.50 / 183.50	237.00 / 237.50
	75%	11.00 / 20.00	57.00 / 75.50	204.50 / 188.00	248.00 / 251.00	14.50 / 15.50	50.00 / 67.50	241.00 / 222.25	280.50 / 280.50
Food-procuring behavior during LH stimulation (satiation)	*n*	1857 / 2470	410 / 410	410 / 410	410 / 410	37 378 / 31096	6800 / 6800	6800 / 6800	6800 / 6800
	M	15.23 / 12.69	69.00 / 76.48	159.55 / 151.11	228.54 / 227.59	11.72 / 15.16	64.42 / 69.31	196.34 / 191.53	260.77 / 260.84
	σ	8.22 / 6.19	25.43 / 27.99	34.93 / 31.01	38.44 / 37.24	5.09 / 10.17	22.86 / 23.56	35.84 / 40.48	38.19 / 43.56
	m	0.19 / 0.12	1.26 / 1.38	1.73 / 1.53	1.90 / 1.84	0.03 / 0.06	0.28 / 0.29	0.43 / 0.49	0.46 / 0.53
	Me	13.00 / 10.50	68.50 / 73.00	154.50 / 149.50	224.00 / 224.50	10.50 / 11.00	62.50 / 69.00	191.00 / 187.50	256.00 / 257.00
	25%	9.50 / 8.50	53.00 / 56.50	133.50 / 128.50	203.50 / 204.00	8.50 / 8.50	48.00 / 55.00	173.00 / 168.00	236.00 / 234.00
	75%	17.50 / 15.00	85.50 / 97.50	178.50 / 172.50	249.00 / 252.00	13.50 / 18.50	78.50 / 82.50	212.50 / 210.50	280.50 / 283.50
Natural food-procuring behavior without LH stimulation	*n*	2363 / 2922	410 / 410	410 / 410	410 / 410	21 607 / 30 864	6800 / 6800	6800 / 6800	6800 / 6800
	M	13.10 / 11.67	75.48 / 83.20	160.19 / 152.32	235.67 / 235.52	13.46 / 12.94	42.78 / 58.75	216.52 / 200.91	259.29 / 259.65
	σ	7.76 / 6.62	29.74 / 25.24	36.33 / 27.49	48.81 / 34.71	7.00 / 9.43	20.56 / 25.38	32.24 / 40.87	33.72 / 40.04
	m	0.16 / 0.12	1.47 / 1.25	1.79 / 1.36	2.41 / 1.71	0.05 / 0.05	0.25 / 0.31	0.39 / 0.50	0.41 / 0.49
	Me	10.50 / 9.50	78.50 / 85.75	155.00 / 152.00	231.00 / 234.75	10.50 / 9.50	39.00 / 57.50	212.00 / 196.00	256.00 / 254.00
	25%	8.50 / 7.50	54.00 / 64.00	131.50 / 128.00	200.00 / 213.00	9.00 / 7.50	27.00 / 38.50	195.00 / 170.00	236.00 / 234.00
	75%	14.50 / 12.50	97.00 / 102.00	181.00 / 173.50	260.50 / 258.50	16.50 / 13.50	53.50 / 76.00	234.00 / 226.50	277.00 / 280.00

Note. Numerator: MMP parameters; denominator: MM parameters.

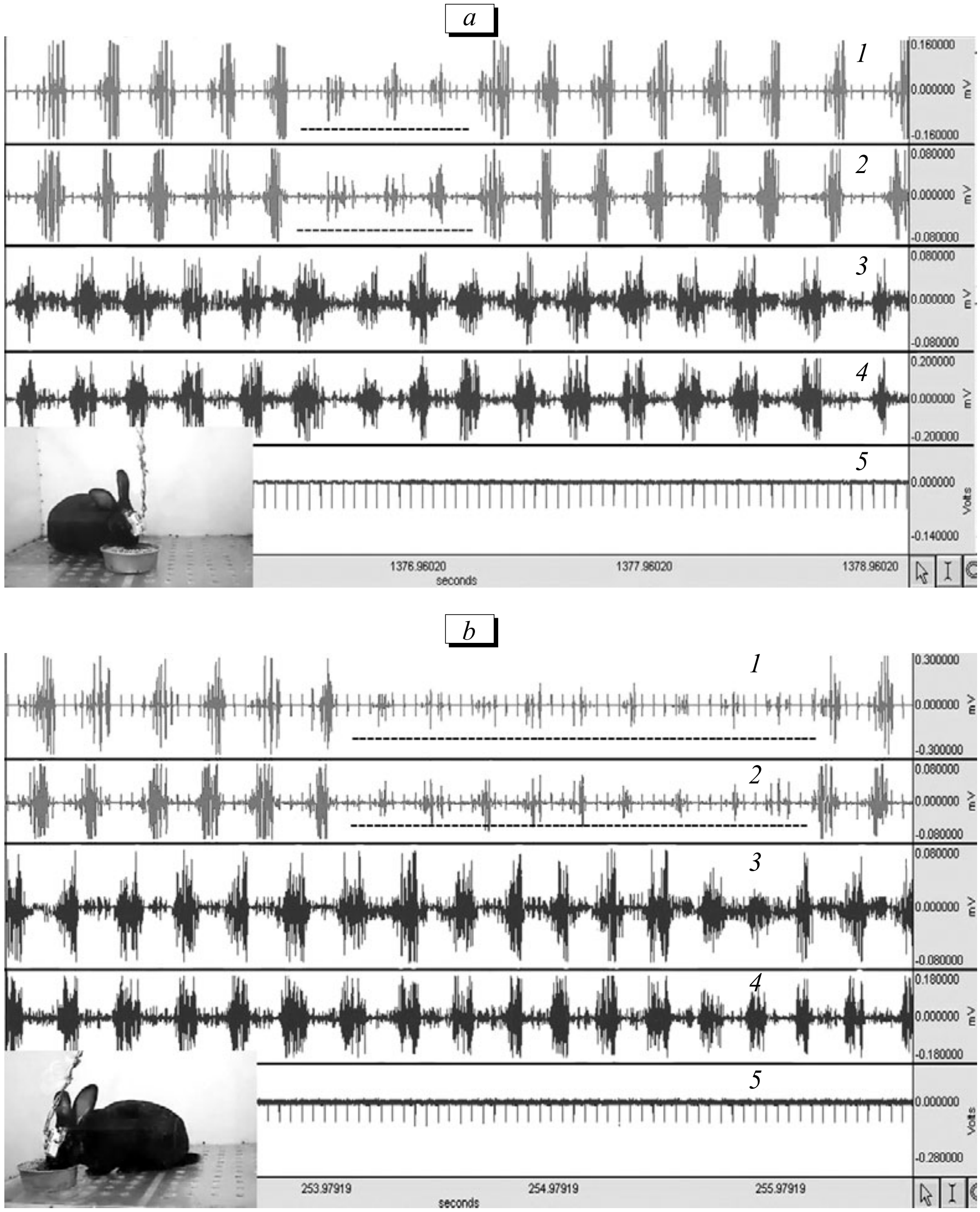

Fig. 3. Impulse activity of MMP (*1*: right, *2*: left) and MM (*3*: right, *4*: left) in a rabbit subjected to 24-h food deprivation (*a*) and fed before experiment (*b*) during threshold electric stimulation of LH and the effective food-procuring behavior emerging in parallel with it (intermittent line corresponds to food capture phase).

by regular generation of MMP and MM AP bursts in the chewing rhythm (Fig. 3). The frequency of the masticatory muscle AP burst-like rhythms during the food capture phase under conditions of LH threshold stimulation was 265.44 cycles per minute (MMP) and 266.12 cycles per minute (MM) in hunger and 262.54 cycles per minute (MMP) and 263.63 cycles per minute (MM) in satiation, that is, was virtually the same ($p>0.05$). However, the frequency of AP burst generation was significantly higher than during the capture phase of food-procuring behavior forming on the basis of need in nutrients (254.59 cycles per minute for MMP and 254.76 cycles per minute for MM; Table 2; $p<0.05$). The frequency of AP burst generation during the food chewing phase under conditions of LH "hunger center" stimulation in hungry and satiated rabbits virtually did not differ from the parameter under conditions of natural food-procuring behavior (Table 2; $p>0.05$). Hence, the increase of hunger motivation induced by electric stimulation of LH caused an increase in the frequency MU AP burst generation by the masticatory muscles during the capture phase but was inessential for it during the food chewing phase. Our data were in line with concepts of other authors [5,6] on the modulatory effects of LH "hunger center" on the standard program of chewing pattern generator, which could be activated by different modes: by afferent pulsation and by cerebrocortical descending effects [8].

The results indicate that the LH "hunger center" is involved in the formation of exploratory and food-procuring behavior of animals due to ascending stimulatory effects on the cerebral cortex [3] and descending stimulatory effects on the neuron activity in the chewing pattern central generator, manifesting by impulse activity of the masticatory muscles (regular generation of AP bursts in the chewing rhythm). The development of regular generation of AP bursts by the masticatory muscles during LH stimulation in the absence of food was an example of the anticipatory reaction, reflecting the action result acceptor characteristics. Increase of hunger motivation level developing during electrical stimulation of LH, did not disorder the coordination of the masticatory muscles lowering and elevating the mandible. Impulse activity of the masticatory muscles reflects the convergent interactions of alimentary motivational and supporting stimulation on the neurons of the chewing pattern central generator. This possibility was proven for many cerebral neurons [3].

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