Effects of Electrical Stimulation of the Hunger Center in the Lateral Hypothalamus and Food Reinforcement on Impulse Activity of the Proper Masticatory Muscle in Rabbits under Conditions of Hunger and Satiation

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Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 149, No. 6, pp. 608-613, June, 2010
Original article submitted June 10, 2009

Threshold stimulation of the lateral hypothalamus in starving and preliminary fed (satiated) rabbits in the absence of feed induces searching behavior associated with burst-like impulse activity of proper masticatory muscle with a bimodal distribution of interpulse intervals, what represents an anticipatory type of reaction. The increase in the level of food motivation during threshold stimulation of the lateral hypothalamus in starving and satiated rabbits with the food offered led to successful food-procuring behavior, during which the frequency and amplitude of spike bursts in the proper masticatory muscle become comparable with those under conditions of natural foraging behavior stimulated by the need in nutrients. Motivational excitation and backward afferentation from food reward are addressed to the same neurons of the masticatory center in the medulla oblongata.

Key Words: *lateral hypothalamus; electrical stimulation; proper masticatory muscle, impulse activity, hunger*

According to pacemaker theory of motivation [6], structures forming the hunger center in the lateral hypothalamus (LH) play an initiative role in the organization of a complex of cortical and subcortical elements selectively activated by nutrient requirements. The food motivation center in LH exerts ascendant activating influences on the limbic structures and cerebral cortex, thus forming foraging behavior in animals.

Along with ascending activating influences, hunger center in the LH exerts descending stimulating influences on neurons of the masticatory center in the medulla oblongata [8,10].

Taking into account possible modulating influences of LH hunger center on neurons of the central generator of mastication pattern [7-10] and taking into account its leading role in the organization of the system of hunger brain excitement [6], it was interesting to investigate the effects of stimulation of LH hunger center on impulse activity of masticatory muscles under conditions of hunger and satiation.

Here we compare the patterns of impulse activity of proper masticatory muscle (PMM) electrical stimulation of LH in starving and satiated rabbits in the presence and absence of food.

MATERIALS AND METHODS

Impulse activity of PMM and MM in Chinchilla rabbits preliminary subjected to 24-h food deprivation or fed before the experiment was recorded via chronically implanted electrodes [2-5]. Effects of LH electrical stimulation on PMM impulse activity in the presence and the absence of the food in the experimental chamber were investigated under conditions of free

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0007-4888/10/1496-0671

behavior. In parallel, behavioral activity of animals was recorded with a web-camera.

Electrical stimulation of LH was performed using bipolar nickel-chromium electrodes implanted according to the approach of "travelling electrode". The following parameters of electrical stimulation were used: frequency 20-30 Hz, pulse duration 0.2 msec, voltage 2.5-3 V or 5-6 V, which corresponded to the threshold or submaximal strength of the stimulus.

Automatic analysis of temporal parameters of PMM pulse activity (in msec) was performed using MP-100 microprocessor and AcqKnowledge software. Temporal parameters of impulse activity of PMM motor units (MU) were statistically processed [1]. Significance of differences was assessed using Mann–Whitney *U* test, $p<0.05$.

RESULTS

Threshold stimulation of the hunger center in LH of satiated and food-deprived rabbits in the absence of food led to the appearance of exploratory and orientation and exploratory activity associated with uniform reorganization of PMM pulse activity manifesting in a shift of regular low-amplitude MU firing activity to high-amplitude burst-like activity (Fig. 1). We previously showed that such reorganization of PMM pulse activity appears during natural successful foraging and that it is not characteristic for exploratory behavior formed on the basis of organism requirements in nutrients [1]. Therefore, regular generation of spike bursts in PMM during threshold stimulation of LH in the absence of the food can be regarded according to functional system theory as an advanced-type reaction [6].

Activating influences of threshold stimulation of LH hunger center on motor neurons of the masticatory center in the medulla oblongata in starving and satiated in the absence of food were uniformly reflected in the structure of temporal organization of PMM pulse activity in the form of bimodal distribution of interpulse intervals with peaks at 5-40 and 140-260 msec (starving) and 5-45 and 140-240 msec (satiation), respectively. Testing the values of successive interpulse intervals for normal distribution using Shapiro–Wilk *W* test showed deviation of the experimental data from normal distribution model ($W=0.659121$, $W=0.632415$, $p<0.001$). The same was shown using parameters of descriptive statistics (Table 1). Duration of burst-like activity periods was characterized by low variability, which was demonstrated by unimodal distribution of the time intervals (Fig. 2). The periods of burst-like activity generated by PMM in starving and satiated animals lasted for about 274.99 msec with standard deviation 34.47 msec, which corresponded to the fre-

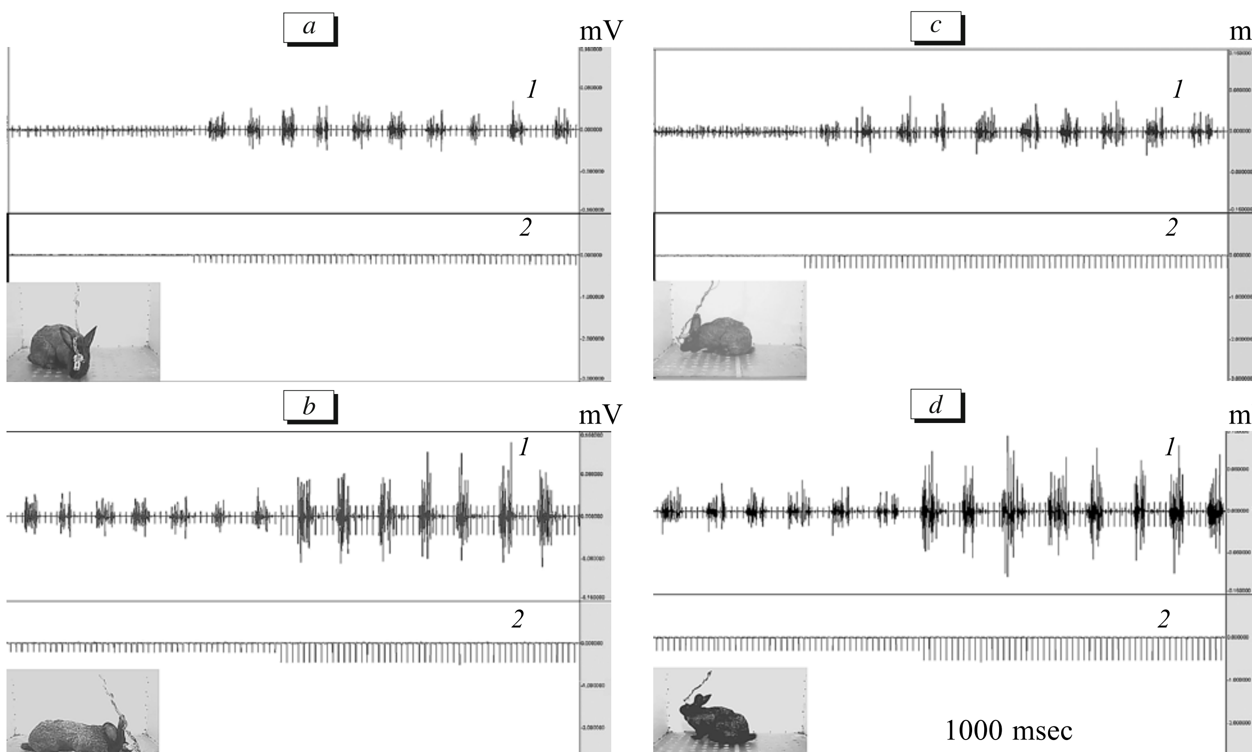

Fig. 1. PMM impulse activity (*1*) in a rabbit exposed to 24-h food deprivation (*a*, *b*) and in a satiated rabbit (*c*, *d*) during threshold (*a*, *c*) and submaximal (*b*, *d*) LH electrical stimulation in the absence of the food. Low-amplitude artifacts from LH stimulation can be seen on electrogram *1*. They correspond to frequency of stimulating square electric pulses (*2*).

TABLE 1. Temporal Parameters of PMM Impulse Activity (msec) in Rabbits Exposed to 24-h Food Deprivation and Satiated Rabbits during Threshold and Submaximal LH Stimulation

Parameter	Starving rabbits (24-h food deprivation)			Satiated rabbits		
	n	*M*±*m*	As	*n*	*M*±*m*	As
Threshold stimulation						
Interpulse intervals	1506	54.78±1.85	1.62	1742	47.52±1.55	1.81
Interpulse intervals in spike bursts	1206	20.36±0.34	0.69	1442	19.13±0.31	0.86
Burst duration	300	81.85±1.66	-0.04	300	91.93±1.55	-0.43
Interburst intervals	300	193.13±2.08	0.56	300	183.99±1.90	0.38
Periods of burst-like activity	300	274.99±1.99	0.58	300	275.92±1.99	-0.23
Submaximal stimulation						
Interpulse intervals	1421	58.60±2.11	1.48	1303	64.11±2.27	1.40
Interpulse intervals in spike bursts	1121	18.45±0.34	1.13	1003	20.85±0.39	0.84
Burst duration	300	68.94±1.45	0.51	300	69.70±1.64	0.31
Interburst intervals	300	208.63±1.83	0.0005	300	208.75±2.18	0.46
Periods of burst-like activity	300	277.58±1.68	-0.01	300	278.45±2.25	0.36

Note. Here and in Table 2: As: asymmetry coefficient.

TABLE 2. Temporal Parameters of PMM Impulse Activity (msec) in Rabbits Exposed to 24-h Food Deprivation and Satiated Rabbits during Successful Foraging Behavior Developing during Threshold LH Stimulation and during Natural Foraging Behavior (after 24 h Food Deprivation)

Parameter	Food capture phase			Food mastication phase		
	n	*M*±*m*	As	*n*	*M*±*m*	As
LH stimulation (state of hunger)						
Interpulse intervals	1146	49.78±1.72	1.25	14,255	60.69±0.68	1.17
Interpulse intervals in spike bursts	846	16.60±0.30	1.03	10,475	12.74±0.07	2.49
Burst duration	300	46.81±1.12	0.69	3780	35.30±0.26	1.57
Interburst intervals	300	143.34±1.63	0.64	3780	193.58±0.43	2.97
Periods of burst-like activity	300	190.15±1.69	0.39	3780	228.88±0.46	2.56
LH stimulation (satiation state)						
Interpulse intervals	1214	46.94±1.55	1.38	19,958	43.49±0.49	1.74
Interpulse intervals in spike bursts	914	17.71±0.36	0.84	16,178	10.75±0.04	3.38
Burst duration	300	53.96±1.24	0.53	3780	46.02±0.30	1.21
Interburst intervals	300	136.00±1.80	0.84	3780	183.59±0.48	2.99
Periods of burst-like activity	300	189.96±1.74	0.44	3780	229.61±0.49	2.48
Without LH stimulation						
Interpulse intervals	1581	41.97±1.36	1.76	16,973	51.59±0.59	1.42
Interpulse intervals in spike bursts	1281	16.94±0.26	1.11	13,193	11.00±0.05	2.46
Burst duration	300	72.35±2.17	0.45	3780	38.39±0.23	1.15
Interburst intervals	300	148.85±1.79	0.93	3780	193.25±0.39	2.73
Periods of burst-like activity	300	221.20±2.41	0.69	3780	231.64±0.41	2.35

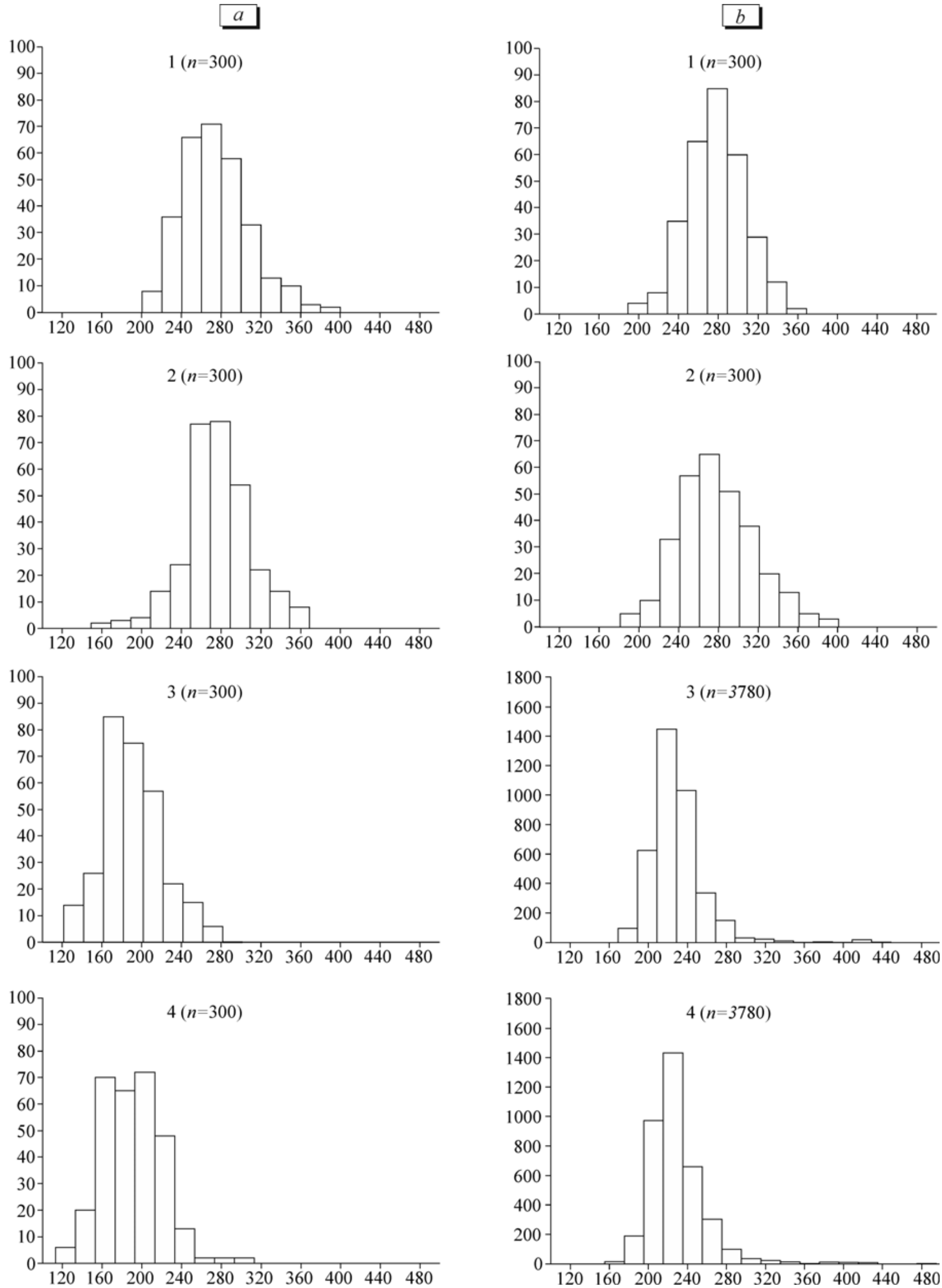

Fig. 2. Distribution histograms of PMM burst-like activity periods in rabbits exposed to 24-h food deprivation (*1*) and in satiated rabbits (*2*) during threshold (*a*) and submaximal (*b*) LH electrical stimulation in the absence of the food; in rabbits exposed to 24-h food deprivation (*3*) and in satiated rabbits (*4*) during threshold LH electrical stimulation in the presence of the food and during associated successful foraging behavior: phases of food taking (*a*) and mastication (*b*). Abscissa: values of burst-like activity periods, msec; ordinate: absolute frequency of time intervals.

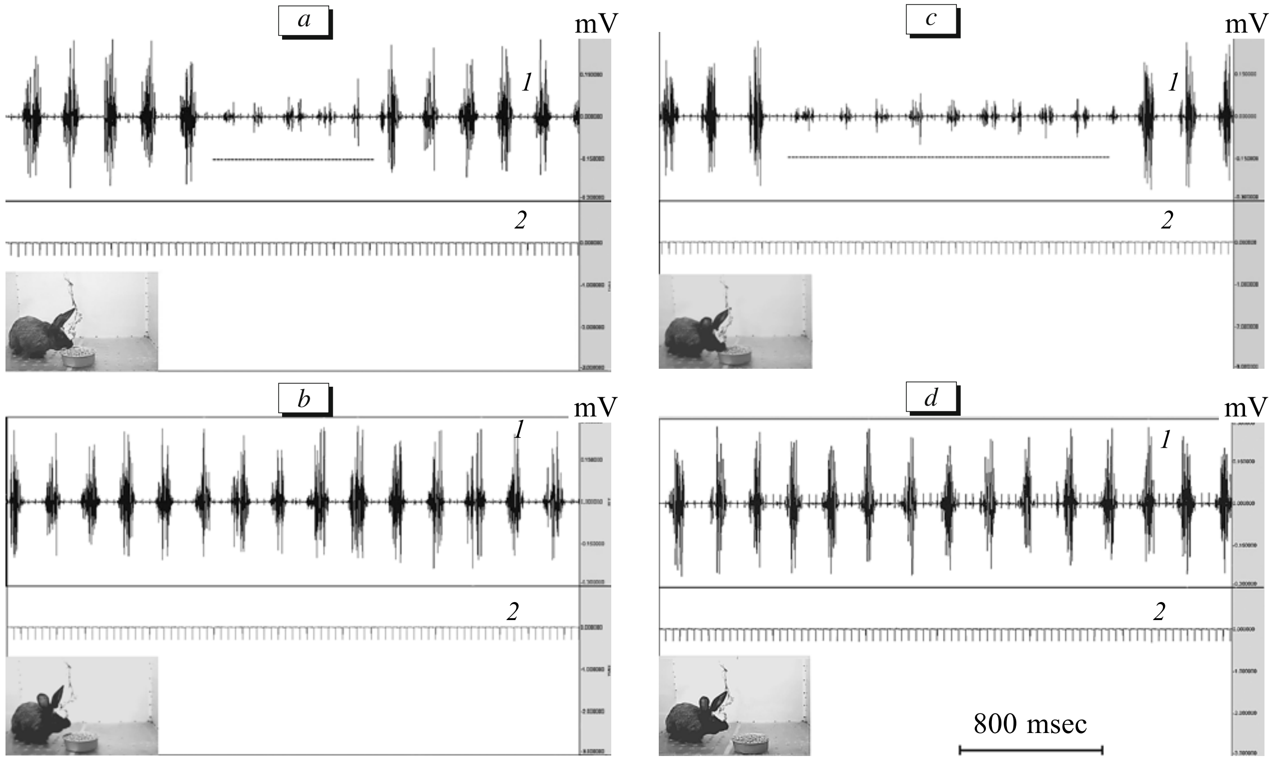

Fig. 3. PMM impulse activity (*1*) in rabbit exposed to 24-h food deprivation (*a*, *b*) and in satiated rabbit (*c*, *d*) during threshold electrical stimulation of LH and associated successful foraging behavior: *a*, *c*: food taking phase (dotted line); *b*, *d*: food mastication phase.

quency of 218.19 cycles per min, and 275.92 msec with standard deviation 34.39 msec or 217.45 cycles per min, respectively, *i.e.* there were no statistically significant differences. Differences were observed only in the ratio of burst duration to inter-burst intervals (Table 1) constituting periods of burst-like activity and contractive activity of PMM [2]. Our results showed that efferent influences induced by threshold stimulation of LH hunger center in rabbits in the absence of food enhance neuron excitability of the central generator of mastication pattern in the medulla oblongata, tune them on reinforcement, and activate central mastication program. Hence, our data confirms modern conceptions of organization of the mastication center [7,9].

Submaximal stimulation of LH in starving and satiated rabbits in the absence of the food was associated with increased spike amplitude in bursts (Fig. 1), but did not affect frequency of burst generation in PMM (Table 1). It indicates that the artificial increase of food motivation is associated with mobilization of high-threshold PMM MU and their amplitude becomes comparable to the amplitude of spikes generated during natural foraging behavior formed in response to organism requirements in nutrients.

Threshold stimulation of LH in hungry and satiated animals with free access to food was associated with successful foraging behavior including taking and mastication of food (Fig. 3). Frequency of high-amplitude bursts in PMM during threshold LH stimulation and associated foraging behavior was significantly higher (Fig. 2, 3; Table 2) than in the absence of food stimulus ($p<0.05$) and corresponded to 262.15 cycles per 1min in the food mastication phase in hungry rabbits, and 261.31 cycles per 1 min in satiated rabbits, and also had no significant differences with the values during natural foraging behavior (Table 2). Maximum frequency of spike bursts in PMM was observed during threshold LH stimulation in starving rabbits during food taking (Fig. 3), these values significantly ($p<0.05$) exceeded those in satiated animals and during natural foraging behavior (Table 2).

Thus, motivation food excitement and back afferentation from food reinforcement are addressed to the same neurons of the masticatory center in the medulla oblongata. Such possibility was demonstrated for various neurons in the brain [6].

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