

STRESS-INDUCED CHANGES IN BEHAVIOR AND FUNCTION OF THE NEUROHORMONAL SYSTEMS IN MONKEYS DIFFERING IN SOCIAL RANK

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Particular attention is currently being paid to the study of neurohormonal mechanisms of individual resistance to stress, and, in particular, the humoral-hormonal regulation of domination-subordination interactions, under conditions of emotional stress (ES), and correlation between rank and the typologic features of individual resistance to the action of psychogenic stimuli [6, 7, 9]. This aspect of the examination of the pathogenetic mechanisms of ES concentrates attention on the specificity of response of an individual, depending on his or her position in the hierarchy, and it is interesting in particular for the evaluation of the qualitative uniqueness of individual emotional-behavioral reactivity and processes involved in the breakdown of psychological adaptation.

The aim of this investigation was to study behavioral and neurohormonal components of ES in monkeys differing in their social status.

EXPERIMENTAL METHOD

Experiments were carried out on 20 sexually mature male sacred baboons weighing 28-33 kg, aged 8-12 years, kept in groups of five to a cage, and characterized by stable hierarchical relations within the herd. ES was induced by immobilization of the unanesthetized baboons for 2 h in the horizontal supine position, by means of a system of fixation that did not damage the skin. Individual and social behavior was studied by ethologic methods of our own design, enabling the frequency, duration, and order of appearance of 68 behavioral patterns to be recorded [4]. To study the hierarchy of dominant ranks and to detect social connections between individuals in the group, correlation matrices were used [5], defining the frequency and direction of interaction of the baboons simultaneously. The ethologic parameters were recorded periodically: before immobilization and 2, 4, 6, 24, 48, and 72 h after it began. The first collection of material (ethologic cut) at these time intervals amounted to 60 min of uninterrupted observation. The concentration of cortisol (C) was determined by competitive binding with protein [8], testosterone (T) by radioimmunoassay [1], and dopamine (DA) and serotonin (5-HT) spectrofluorometrically [2]. For this purpose, blood was taken from the cubital vein in a volume of 5-6 ml in accordance with the following schedule: before and 2, 6, 24, 48, and 72 h after the beginning of immobilization.

EXPERIMENTAL RESULTS

The study of individual differences in the neurohormonal balance of the male baboons revealed definite differences in initial blood levels of biogenic amines and steroid hormones, depending on the social rank they

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TABLE 1. Blood Levels of Biogenic Amines and Steroid Hormones in Male Sacred Baboons of Different Social Rank, during Emotional Stress

Compound tested	Time of blood sampling, h	Dominance (n=4)	Subdominance (n=4)	Low-ranking (n=4)
DA, ng/ml	0	264±46	187±13	201±37
	2	451±21 $p_1<0,01$ $p_1<0,001$	266±17 $p_1<0,01$	401±18 $p_1<0,01$ $p_2<0,002$
	6	351±52	194±39	341±48 $p_1<0,05$
	0	181±7	134±17	129±23
	2	304±22 $p_1<0,001$	234±21 $p_1<0,02$	311±37 $p_1<0,01$
	6	367±21 $p_1<0,001$ $p_2<0,01$	181±29	401±59 $p_1<0,01$ $p_2<0,02$
C, nmoles/liter	0	641±31	703±27	857±41
	2	1420±151 $p_1<0,01$	1004±36 $p_1<0,001$	1278±29 $p_1<0,001$ $p_2<0,002$
	6	1751±179 $p_1<0,0001$ $p_2<0,02$	1122±41 $p_1<0,001$	1516±67 $p_1<0,001$ $p_2<0,01$
	0	35,6±2,7	37,7±4,0	20,6±2,8
	2	19,9±3,6 $p_1<0,02$	22,0±1,9 $p_1<0,02$	10,4±1,3 $p_1<0,02$ $p_2<0,01$
	6	10,1±4,4 $p_1<0,01$	16,8±0,9 $p_1<0,01$	5,6±0,9 $p_1<0,01$ $p_2<0,001$

Legend: p_1) Significance of differences compared with background, p_2) significance of differences compared with subdominant, DA) dopamine, 5-HT) serotonin; C) cortisol; T) testosterone

occupied (Table 1). For instance, higher values of DA and 5-HT were found in dominant individuals, whereas the highest cortisol concentration and the lowest testosterone level were recorded in monkeys occupying the lowest social position. Meanwhile, in some subdominant individuals the blood testosterone level was higher than in dominant males (Table 1).

Despite significant differences in the initial level of hormones and mediators, during ES changes in the neurohormonal balance, similar in direction and intensity, were observed in dominant and low-ranking baboons under conditions of ES (Table 1). For instance, the highest cortisol level, recorded 2 h after the beginning of immobilization, in dominant and low-ranking baboons exceeded the level of this hormone in subdominant individuals by 117%, ($p < 0.02$) and 17% ($p < 0.01$) respectively. Under these conditions more marked suppression of the hormonal function of the gonads was observed in dominant and low-ranking males: the testosterone level 6 h after immobilization was 72% ($p < 0.01$) and 73% ($p < 0.01$) in these animals respectively, compared with 55% ($p < 0.01$) in the subdominants. The greatest increase in the blood DA level, observed 2 h after the beginning of exposure to stressor stimuli was 71% ($p < 0.01$) and 100% ($p < 0.05$) in high- and low-ranking baboons respectively, whereas in the subdominants this increase amounted to 42% ($p < 0.01$). During analysis of the time course of the blood 5-HT level in monkeys of different social status, a prolonged and marked response was observed with the maximal increase in the serotonin level in dominant and low-ranking males after 6 h, whereas in subdominants the greatest increase in the 5-HT concentration was observed 2 h after the beginning of immobilization (Table 1).

Very characteristically the individual features of the hormonal background for the stress reaction correlated clearly with behavioral manifestations which, in turn, were determined by the social rank of the animal in the group. In the period after exposure to ES the most marked and prolonged inhibition of psychoemotional and locomotor activity was recorded in the dominant and low-ranking baboons. In baboons occupying high- and low-ranking positions, 2 h after the beginning of immobilization suppression of comfort-seeking (by 78 and 60%, $p < 0.05$), investigative (by 69 and 57%, $p < 0.05$), and affiliative (by 17 and 23%, $p < 0.05$) behavior was observed, whereas in the subdominants there was a tendency for investigative activity to increase, and the probability of appearance of elements of affiliative distant behavior rose significantly (by 117%, $p < 0.01$). Normalization of investigative activity, a

tendency toward restoration of locomotor functions, and the appearance of elements of agonistic behavior were observed in the subdominant males 6 h after the beginning of exposure to stress. Dominant and low-ranking individuals continued to stay in a state of disturbed psychological adaptation. Restoration of motor activity and normalization of psychological processes with the appearance of elements of agonistic emotional reactions and forms of behavior took place during the next 24 h after immobilization in the subdominant baboons. During this period only a tendency toward normalization of locomotor, investigative, and comfort-seeking behavior was noted. In low-ranking individuals 24 h after the beginning of immobilization, against the background of restoration of psychological activity and locomotor functions, the manipulative activity and probability of appearance of elements of comfort remained significantly low.

Simultaneous analysis of the functional state of the neurohormonal systems and of behavioral manifestations of ES in baboons occupying different positions in the hierarchy thus indicate a connection between rank and the character of neurohormonal reactivity of the animals; the degree of disintegration of intraspecific behavior in response to immobilization for 2 h was most marked in individuals with a diametrically opposite hierarchical StatUS. Association of the action of aversive stress-inducing stimuli with chronic strain on particular specific functions of the CNS, maintaining behavior of the dominant and low-ranking males with the appropriate modality of motivation, can be regarded as one possible mechanism leading to the formulation of the disturbed psychological adaptation of these males, i.e., the possibility cannot be ruled out that realization of the psychogenic derangement of the program of intraspecific behavior takes place in accordance with the well-known principle of selective damage to activated systems in ES [3]. The marked heterogeneity of the behavioral activity of these monkeys in the period preceding ES clearly reflects their dominant and low-ranking status in the established system of hierarchy, and suggests that the highly motivated level of coexistence and of intraspecific interaction in the dominant males and the constant anxiety and fear in the lowest ranking baboons can be regarded as activated forms of species-specific behavior and, consequently, those most vulnerable to the action of psychogenic stimuli. The intensified activity of these individuals during ES may perhaps be realized to a certain degree also by a mechanism of emotional resonance, when signals of the behavioral reaction of the other members of the group, which at that moment are under the influence of similar aversive stimuli, potentiate the negative manifestations of ES in dominant and low-ranking baboons. Changes in the neurohormonal balance in these individuals are distinguished highly characteristically by a more protracted and inverted type of reaction, indicating lower stability of function of the neurohormonal stage of regulation as a whole in dominant and low-ranking males compared with subdominants.

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