The present studies addressed the neurophysiological principles of the interaction of sensory and cognitive processes, particularly the formation of cognitive structures, in conditioned reflex training of monkeys to visual recognition. The acquisition of a conditioned operant reflex requiring the discrimination (differentiation) of stimuli differs fundamentally from many other types of conditioned reflex. We note that the interaction of the body with the environment, according to Pavlov, occurs on the basis of analysis of perceived information and the synthetic activity of the nervous system, resulting in an organism’s adaptive behavior: “All the data indicate that elementary analysis and elementary synthesis must be distinguished from higher analysis and synthesis. While the former (specific analysis) has its primary basis in the properties and activity of the peripheral components of the analyzers, higher synthesis and analysis occur mainly on the basis of the properties and activity of the central components of the analyzers” ([14], p. 159). We emphasize that the bases of the study of analyzers, i.e., complex systems which process sensory information for conditioned reflex behavior and responsible for the formation of cognitive structures in conditioned-reflex behavior in monkeys: relationship with type of visual information.

The characteristics of learning processes and long-term memory (LTM) were studied in rhesus macaques discriminating visual stimuli (geometrical figures of different shapes, sizes, and orientations, and with different spatial relationships between image components). Trained monkeys were tested for the ability to perform invariant recognition after stimulus transformation, i.e., changes in size, shape, number of objects, and spatial relationships. Analysis of behavioral characteristics (correct solutions, refusals to decide, motor response times) revealed differences associated with the type of visual information. When monkeys discriminated between black and white geometrical figures of different shapes and orientations, as well as black-and-white figures with different shapes or orientations, the learning time was short and transformation of the stimuli had no effect on correct solutions: there was complete transfer of learning. When monkeys discriminated figures of different sizes or complex images with different spatial relationships, the learning time was significantly greater. Changes in the size and shape of figures led to significant reductions in correct solutions and significant increases in refusals to solve the task and in motor reaction times. Invariance of discrimination in this case appeared after additional training. The results obtained here showed that in conditioned reflex learning, the sensory processing of stimuli has the result that discriminatory features are formed in LTM, i.e., cognitive structures (functional neurophysiological mechanisms), these supporting the classification of visual images. The temporal conditioned link of the executive reaction is established with these. Their formation is determined by the type of sensory information and the existence in LTM of separate subsystems for spatial and non-spatial information.

KEY WORDS: rhesus macaque, learning processes, long-term memory, visual discrimination, cognitive structures, types of sensory information.
Macaca mulatta

months after training, even though the bandpass width of persisted in long-term memory in rhesus macaques for 4–12 relation to a defined spatial frequency or light bar width discrimination of geometrical figures. Selectivity acquired in cognitive structures organizing feature spaces in which dis-

metrical figures of different shapes after transformation of contrast [3–6, 12, 13, 20]. Our previous studies in rhesus transformations such as rotation and changes in size and 20], and many animal species recognize stimuli after simple transformations such as rotation and changes in size and contrast [3–6, 12, 13, 20]. Our previous studies in rhesus macaques identified transfer of the discrimination of geometrical figures of different shapes after transformation of their contrast (negotiation-positive) and orientation, which are among the commonest transformations of visual objects [6–8]. These data indicated that the processes of learning and memory in monkeys could lead to the formation of cognitive structures organizing feature spaces in which discrimination boundaries identified in these spaces could, with certain image transformations, lead to invariant discrimination of geometrical figures. Selectivity acquired in relation to a defined spatial frequency or light bar width persisted in long-term memory in rhesus macaques for 4–12 months after training, even though the bandpass width of the acquired spatial frequency filter showed some increase [7, 8]. A more complex recognition structure based on a larger number of features, which could be formed on learn-
ing to discriminate geometrical figures of different shapes, persisted in long-term memory for 12 months without any change [7, 8].

We also note that results obtained from studies of the processes and mechanisms of invariance in animals are very contradictory [5, 11, 20]. Some data indicate transfer of learning after stimulus transformation, while others con-

trast this. Despite some reports addressing studies of the concrete neurophysiological mechanisms of invariance [7, 8, 17, 23], the principles of their formation in the long-term memory of animals on acquisition of a differential condi-
tioned reflex have yet to be identified. How, despite differ-
ences (often significant) in the versions of a given object subject to some transformation, can an animal assign the objects to a single class, i.e., recognize them? What part of the perceived visual sensory information is remembered and in what form is it stored? Do the processes of learning depend on the type of visual information? How are the pro-
ceses of comparing ongoing sensory information with functional cognitive structures formed and stored in long-
term memory organized? Unfortunately, these questions still lack definitive answers.

The aims of the present work were to seek new experi-

mental data in monkeys (rhesus macaques) to provide a fuller understanding of the mechanisms of invariant visual recognition, to clarify what part of the sensory information is stored in long-term memory on acquisition of a differential conditioned reflex, and to identify the form in which this information component is stored. The following task was addressed: experiments with acquisition of an operant reflex were performed in monkeys to study the characteris-
tics of the learning process linked with the classification of visual images and, using recognition after transformation of the conditioned stimuli with retention of only the initial classes, to identify the patterns of the formation of cognitive structures in long-term memory and their characteristics as determined by different types of visual information.

METHODS

Studies were performed on three adult rhesus macaques (Macaca mulatta) weighing 4–6 kg. During experiments, monkeys were seated in a primate chair. A test panel was placed in front of them; this had two screens serving simultaneously to present conditioned visual stim-

uli and as keys to report decision-taking. The automatic experiment control program [6] included the following sequence of signals: presentation of a tuning signal (a sound signal of duration 1 sec) and presentation of two condi-
tioned stimuli (exposure for 2 sec), which were projected onto the screen on the left and right sides simultaneously, in