VISUAL PATTERN DISCRIMINATION AT THE NEURONAL AND BEHAVIORAL LEVEL: AN ELECTROPHYSIOLOGICAL STUDY ON THE DORSAL LATERAL GENICULATE BODY IN FREELY MOVING CAT

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Key words: cat, pattern discrimination, dLGB, unit activity, visual stimuli

Abstract. Cats were trained in a go-no go visual pattern discrimination task with parallel recordings of single unit activity from the dorsal lateral geniculate body (dLGB). The poststimulus time histograms (PSTHs) evoked by the two different visual patterns were compared for each unit. The go-stimulus, which was rewarded by food, evoked a longer lasting tonic like neuronal response in comparison to the responses evoked by the no go-stimulus which was not rewarded. No differences could be observed regarding the latencies of the first excitatory peak of the PSTHs. The results indicate a modulatory influence upon dLGB unit activity depending on the biological relevance of the stimulus.

INTRODUCTION

Extraretinal influences of vigilance, biological motivation, eye and body movements or of nonvisual external stimuli are known to modulate the visual signal transmission at the dorsal lateral geniculate body (dLGB) level (2, 5, 11, 13). In thirst motivated rats it could be shown that the latencies of the flash evoked dLGB neuronal responses became shorter when the light was changed into a conditioned stimulus (3). Electrical stimulation of ascending midbrain reticular formation modulated the thalamic transmission by disinhibition of geniculate cell activity in
cats (14). Such electrophysiological findings were supported by results of morphological studies including tracer methods. Connections from hypothalamus, locus coeruleus, midbrain reticular formation, thalamic reticular nucleus and other brain regions to the dLGB were demonstrated in cats and other species (1,9). Behavioral experiments showing the ability of animals to discriminate visual patterns (16) have led to the assumption that neuronal processes of discrimination already occur at the dLGB level (7, 10).

In the present experiments we compared the responses of single dLGB neurons which were evoked by two visual patterns of different behavioral relevance; thus going far beyond the unspecific tonic influences.

METHODS

Experiments were performed on four adult female domestic cats. An approximately constant motivation for food was established by a 23 h food deprivation schedule. In order to minimize circadian influences on the animals' activity state all experiments were performed in the forenoon, at a fixed time for each cat. A visual pattern discrimination behavior was trained using a go-no go task. The animals were required to sit motionless but attentively on a starting place (40 X 40 cm) of the experimental chamber (2.5 X 3.0 m).

They were trained to fix the gaze on the middle of a screen where a small light emitting diode (LED) was situated serving as fixation point. The screen size was 50 X 50 cm, the distance between the animals' head and the screen was about 1.5 m.

Conditioned visual pattern stimuli which consisted of either a set of 5 vertical black and white stripes or 8 white filled circles on a black background, both patterns being of equal total luminance, were projected on the screen in random sequence during each session. The total visual angle was 25°, equal for both patterns.

In two cats the rewarded go-reaction to the feeder, was elaborated using the stripes pattern as the "positive" conditioned stimulus. In these animals the projection of circle pattern was not rewarded by food. The cats had to remain on the starting place (no go-pattern). In the experiments with the two other animals the stimulus relevance as to the reward/non-reward pattern was reversed. The cats were trained with stimulus presentations for 0.5 and 3.0 s, depending on the performance of the cat. After reaching a criterion of 80% correct behavioral reactions the stimulus duration was standardized to 1 ms in order to achieve re-
liable spike train data for subsequent compilation of poststimulus time histograms (PSTH). Because of the shorter stimulus duration the number of correct behavioral reactions decreased, but always exceeded the chance level.

The behavior of the animals was observed continuously using a TV-camera. Head and locomotor movements were recorded by means of an optoelectronic technique (12). Conditioned pattern stimuli were only given when the cat was sitting attentively at the starting place, fixating the LED. The reaction time, i.e. the time between stimulus onset and departure from the starting place, was determined through an infrared light-beam bordering the frontal edge of the starting place. For extracellular recording of the single unit activity (minimal signal to noise ratio 2:1) a tungsten microelectrode (impedance of 1-2 MΩ, at 800 Hz a.c.) was lowered into the brain according to stereotaxic coordinates corresponding to the location of the dLGB. For this purpose a micromanipulator was fastened to the skull. After preamplification the frequency modulated signal was transmitted radiotelemetrically to the receiver, and recorded on tape. Using the analyzer NTA 1024, the PSTHs were compiled separately for the go- and no-go-trials of the experimental session.

For histology a marking point was set electrolytically at the site of the electrode tip after the last recording session under deep anaesthesia. After dissection the locations of all electrode tips were reconstructed according to the micromanipulator scale readings.

RESULTS

The results were obtained from recordings of 26 histologically verified dLGB neurons. The recording periods amounted to a total of 30-40 min. The following parameters of unit activity were evaluated quantitatively: mean spike discharge rate during spontaneous neuronal activity, latency period of the neurons' responses to the positive (go) and the negative (no go) visual stimulus pattern, magnitude of the primary excitatory response, duration and configuration of the PSTHs, including the response phase after the first peak.

The mean spontaneous discharge rate was 57.0 imp./s, SD 26.0 i.e. the neuronal activity recorded in the cats attentive state when sitting motionless on the starting place. No attempt was made to classify the neurons according to degree and duration of their responses to the visual stimuli. In 20 out of 26 neurons the light stimulus induced a significant change of the discharge rate in comparison with the spontaneous activity ($\chi^2$-test, $P \leq 0.05$). In all cases the neuronal response to the stimulus consisted in initial increase of the discharge rate.
The peak latency of the primary excitatory response to the visual pattern (flash) was read from the PSTH. The peak latency of the responses to go-pattern presentations (53.5 ms, SD 31.7 ms) did not differ significantly from the latencies of the response to the no go-pattern (47.6 ms, SD 23.9 ms). This is shown in the latency histogram of Fig. 1. Note the similar course of the histograms for both the go and no go-pattern. In half of the total number of responsive neurons (n = 10) response latencies between 30 and 40 ms were observed. The latency of three neurons exceeded 100 ms. In control experiments involving 5 cats (78 neurons) a patternless diffuse flash stimulus of the same duration and luminance was given. A comparison with the pattern stimuli revealed a similar distribution of the response latencies. The magnitude of the first peak (taken from the PSTHs; bin by bin comparison) did not differ significantly between the go and no go neuronal response pattern, but the duration and shape of PSTHs differed systematically depending on the behavioral significance of the stimulus pattern. In 17 out of 20 responsive neurons the excitatory phase was prolonged tonic like up to 200 ms in comparison with the spontaneous discharge rate. It was never followed by an inhibitory phase.

The no go stimulus pattern evoked a shorter phasic-like response with
a duration up to 50 ms. This response was followed by a more or less strong inhibitory phase in half of the neurons.

Parallel to the neuronal activity the animal's reaction time to the go stimulus pattern was recorded. The mean reaction time of 520 ms, SD 170 ms was obtained from a total of 408 trials in four cats. In Fig. 2 the mean reaction time of the cat's go-reactions during this session is marked by a point below the PSTH.

![PSTH's of 2 single units](image)

**Fig. 2.** PSTHs of 2 representative single dLGB units with tonic like go-response and phasic like no go-response. Bin width: 2 ms. The mean behavioral reaction time of the cat in this session is marked by a point.

**DISCUSSION**

When comparing post-stimulus neuronal discharge patterns in a visual discrimination task, similarities and differences have been observed. Similarities refer to intensity and peak latency of the primary excitatory response. In the later response periods however, differences in the
shape of the PSTH could be established depending on the cats' behavioral go/no-go reaction following the visual stimulus. Flash latencies are short (30-40 ms for the majority of neurons) and may reflect the physical parameters of the light stimulus such as intensity and duration which are similar for both visual patterns. This assumption is supported by our earlier results (2), referring to response latencies of dLGB units to a patternless visual stimulus of the same duration and intensity as in the present experiments. The latency histograms showed a similar distribution. Decision making, as required in the present behavioral go/no-go-task, is generally regarded as a complex time dependent process, not being reflected in the very early period of the PSTH. Masland et al. (10) found only very little evidence for task-related changes in LGB neuronal discharge pattern. Statistical tests did not confirm the authors feeling about behavioral-dependent modifications of dLGB unit responses because of the great variability of the averaged PSTHs. Differences in LGB evoked responses in a visual pattern discrimination task were obtained by John et al. (7, 8). Visual evoked potential studies in cats by these authors showed that wave shapes became markedly different in a range of 30-50 ms after stimulus onset depending on the visual patterns. We found longer lasting differences (up to 200 ms) comparing the shapes of the PSTHs of the go and no go stimulus, possibly due to differences in stimulus application. In contrast to our experiments they used flicker trains of different frequencies for behavioral discrimination.

Longer lasting tonic like responses to the go stimulus were observed in 85% of the neurons (regardless whether circles or stripes were used as the positive stimulus).

This may be due to a reflection of a higher activation state in parts of the brain for triggering the behavioral trained motor program in the case of the go-stimulus presentation. Since it is known from studies in humans that late components of evoked EEG potentials are concomitant with stimulus evaluation processing (P 300) one could expect that the tonic excitatory response phase as revealed in the PSTHs of the go situation is also concomitant with the stimulus evaluation.

Taking into consideration the hippocampal (6) or more likely the thalamic (15) origin of P 300, one may assume that in the go situation the cortico-thalamic (-lateral geniculate) circuitry is activated to a greater extent than in the no go situation.

REFERENCES


Accepted 20 May 1988