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The spontaneous theta rhythm recorded from the hypothalamus posterior in the cat *in vivo*

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Abstract. Rhythmical slow activity (theta) was mapped in the hypothalamic region in freely moving cats. We recorded well synchronized and high amplitude theta rhythm in the medial part of the hypothalamus posterior area. The EEG recordings made from lateral part of this hypothalamic region contained only irregular activity. These findings support earlier observations concerning the topography of hippocampal formation desynchrony and synchrony system. The observations of the present study also suggest that the hypothalamus posterior area is actively involved in the mechanisms responsible for generating theta oscillations in the cat.

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INTRODUCTION

Rhythmical slow-wave activity (theta, RSA) is a high voltage, well synchronized and almost sinusoidal waveform, generated in a few regions of the mammalian brain (Bland and Whishaw 1976, Bland 1986). The major generators of this activity are positioned in the hippocampal formation (regions CA1, CA3c and dentate gyrus area) (Bland 1986, Konopacki et al. 1988, Bland and Colom 1993). Behavioural and pharmacological studies have provided evidence for two types of the hippocampal theta rhythm in the rat and rabbit. The first, termed type 1 theta has a frequency range of 6-12 Hz, occurs during voluntary movements and is atropine resistant. Type 2 has a frequency range of 3-9 Hz, it occurs during immobility and is atropine sensitive (Bland 1986). It is necessary to point out that the existence of these two distinct types of theta activity in the hippocampal formation in the cat is controversial (Bland 1986). This species seems to generate both theta rhythms during immobility and voluntary motor behaviour. The intraperitoneally injections of atropine sulphate were reported to completely block the whole band of spontaneous theta rhythm in the cat (Gralewicz 1982, Sainsbury 1985). Moreover, it was documented that the cat spontaneous hippocampal theta activity is mediated mainly by the cholinergic M1 receptor subtype (Gołębiewski et al. 1993).

Several early studies demonstrated that theta oscillations recorded in the hippocampal formation area depend on the influences of the brain stem reticular formation (Vertes 1982, Vertes 1986). It is well established that activation of the brain stem reticular formation by high-frequency electrical stimulation elicited rhythmical slow-wave activity in the hippocampal formation area (Bland 1986, Vertes 1986). It has been suggested that the occurrence of hippocampal theta oscillations is controlled by medial septal/vertical limb diagonal band of Broca area (MS/vDBB). Lesions of the medial septal nucleus abolished rhythmical slow activity in the hippocampal formation (Green and Arduini 1954, Petsche et al. 1962). Furthermore, Petsche et al. (1962) recorded medial septal cells that fired in rhythmic bursts at the frequency of hippocampal theta. These observations led the authors to hypothetize that rhythmically bursting cells in the medial septal area acted as pacemaker for the generation of theta rhythm in the hippocampal formation (Petsche et al. 1962). The recent years have changed previous suggestion concerning the medial septal mediation of the hippocampal theta rhythm. It was reported that injections of procaine into the MS/vDBB region reduced the amplitude of reticularly elicited hippocampal theta activity, but had no effect on its frequency (Kirk and McNaughton 1993). It suggests medial septal region to be involved only in modulation of amplitude of the hippocampal theta activity.

The number of recent investigations showed that reticular influences are relayed *via* the posterior part of hypothalamus. The majority of studies concerning the hypothalamic mediation of the hippocampal formation theta rhythm analysed the effectiveness of electrical stimulation of the mesencephalic structure on theta production. Specifically, the electrical stimulation of the medial hypothalamus resulted in production of hippocampal theta and the stimulation of the lateral hypothalamic region was found to produce hippocampal desynchronization (Anchel and Lindsley 1972, Wilson et al. 1976). In addition, Bland and Vanderwolf (1972) demonstrated that the most effective synchronizing sites were localized in the dorsomedial and posterior part of the hypothalamus. Anchel and Lindsey (1972) also demonstrated that lesions of the medial hypothalamus blocked hippocampal formation theta and lesions of the lateral hypothalamic region abolished desynchronizing type of response. These data were interpreted as resulted from stimulation or lesion of two different neuronal systems passing through the lateral hypothalamus (LH) and medial hypothalamus (MH) from the brain stem reticular formation, which produce desynchroning and synchroning influences to the hippocampal formation (Anchel and Lindsley 1972, Wilson et al. 1976) . The findings mentioned above were obtained mostly on rats. The participation and role of the hypothalamic region in

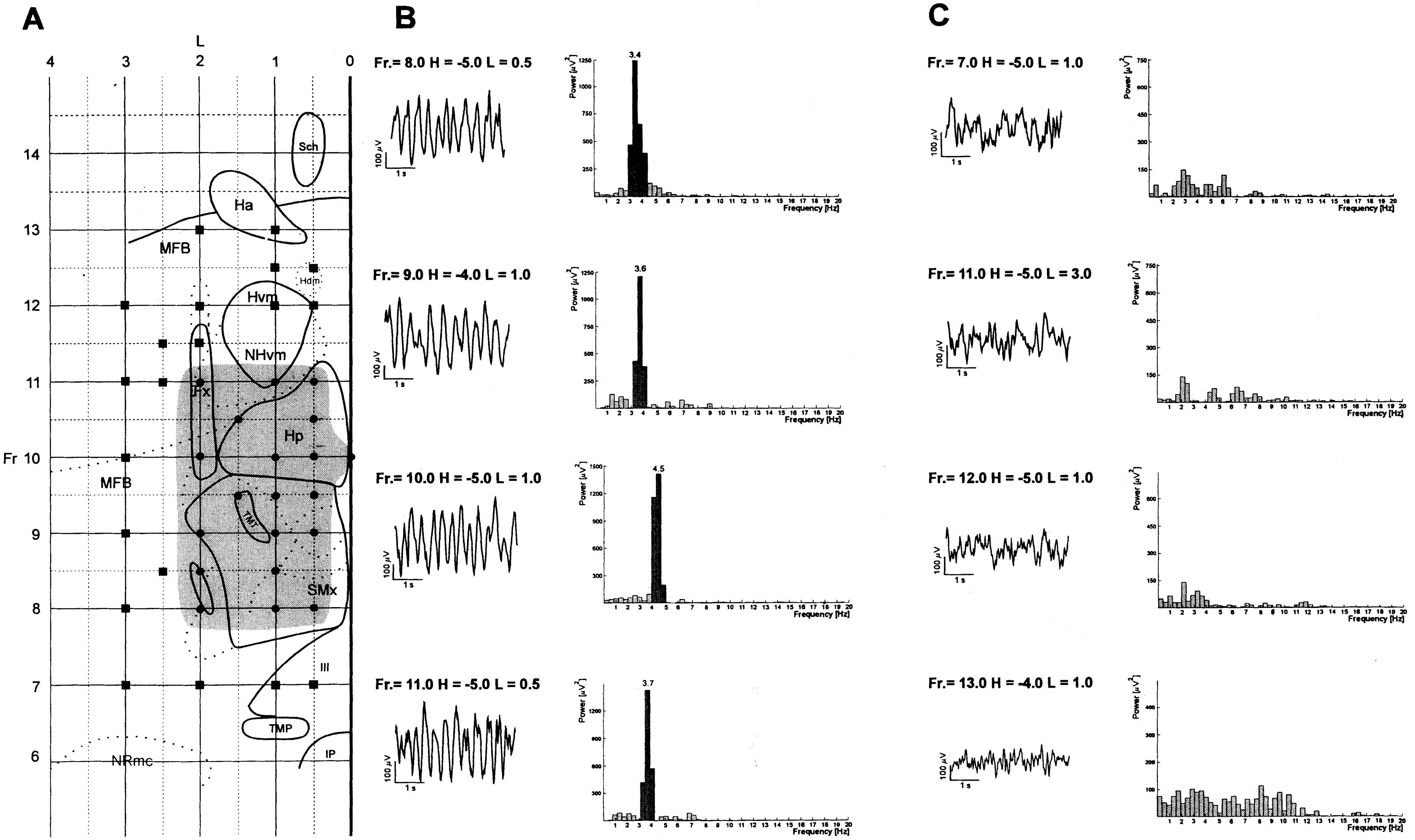

Fig. 1. The topography of the spontaneous theta rhythm in different areas of the hypothalamus in freely moving cats. A, the placement of the recording electrodes according to the frontal and lateral stereotaxic planes (● - theta present, ■ - theta not present); shadowed field shows the region of the hypothalamus theta rhythm can be recorded from; B, 5-s samples of the spontaneous theta rhythms recorded from different positions of the recording electrodes in the area of the posterior hypothalamus (left) and related power and frequency spectra (right); C, 5-s samples of irregular activity recorded from different positions of the recording electrodes in the hypothalamic region (left) and related power and frequency spectra (right).

producing theta oscillations in the cat has never been examined in details. In the present study we attempted to answer the question whether the hypothalamus is capable of generating theta rhythm in the cat.

METHODS

Ten adult cats of both sexes, weighting 2.0 to 3.0 kg were used in our experiments. The animals were anaesthetized with sodium hexobarbital (90 mg/kg, i.p.) and mounted in a stereotaxic apparatus for surgery. The cats were implanted with monopolar electrodes in the area of the hypothalamus posterior, according to the stereotaxic coordinates: from the frontal plane (Fr) 7.0 to 13.0, lateral (L) 0.0 to 3.0 and horizontal (H) -4.0 to -5.0. Additionally, an indifferent electrode was possitioned in the frontal cortex. The recording electrodes were made of stainless steel wires; 200 μm in diameter; coated with teflon except 0.5 mm for a tip. All electrodes were connected with a socket, which was secured to the skull with a methacrylate resin (Duracryl Special, Spofa, Prague). The details about the stereotaxic surgery have been described previously (Brudzyński and Eckersdorf 1988).

Ten days after the surgery EEG recordings were made from the freely moving animals using electroencephalograph (AM-1, Poland) with the time constant set 0.1 s and the high frequency filter set at 35 Hz, connected to the microcomputer (IBM-PC). The EEG signals were on-line displayed on the computer monitor. The hypothalamic activity was recorded in 5-min episodes, with 5-min breaks in between. All data were analysed off line with use of the computer software Spike-2 (Cambridge Electronic Design Ltd., England).

RESULTS

The examined hypothalamic region extends from the frontal plane (Fr) 7.0 to 13.0, lateral (L) 0.0 to 3.0 and horizontal (H) -4.0 to -5.0 (Fig. 1A.). The best synchronized and the highest amplitude theta rhythm was recorded from the posterior/medial part of the hypothalamus (Fr. 8.0 to 11.0, L 0.0 to 2.0 and H. -4.0 to -5.0) (Fig. 1B.). Hypothalamic theta oscillations occurred in a few-second episodes, separated by periods of irregular activity. Amplitude of this rhythmical activity ranged from 100 to 500 μV and frequency from 3.3 to 4.9 Hz. The EEG signals from the remaining part of the mapped region - the lateral part of the hypothalamus area - failed to produce traces of theta rhythm. Only irregular patterns of activity were observed (Fig. 1C).

DISCUSSION

The main finding of the present study was demonstration that the hypothalamic area is involved in production of theta rhythm in the cat. We recorded well synchronized and high amplitude spontaneous theta activity from the hypothalamus posterior area. These findings are consistent with the previous suggestion that this area contains cells firing rhythmically in the frequency of theta (Kirk and McNaughton 1991, 1993, Bland et al. 1995). Moreover, we demonstrated that only from the medial part of the hypothalamus posterior it is possible to record well synchronized theta activity. The recordings made from the lateral part of the Hpt include traces of irregular activity and theta rhythm has never been recorded from this region. These observations confirm earlier hypothesis concerning the topography of desynchronizing and synchronizing pathways passing through the LH and MH areas from the brain stem reticular formation (Anchel and Lindsey 1972, Bland and Vanderwolf 1972). Further experiments are essential to answer the question what the relationship between the posterior hypothalamic theta and theta activity typically observed in the limbic cortex exists.

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