Brain Research 1677 (2017) 101–117

Contents lists available at ScienceDirect

Brain Research

journal homepage: www.elsevier.com/locate/bres

Research report

Dynamics of spontaneous local field potentials in the anterior claustrum of freely moving rats

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ARTICLE INFO

Article history:
Received 10 June 2017
Received in revised form 18 September 2017
Accepted 19 September 2017
Available online 22 September 2017

Keywords:
Anterior claustrum
Local field potential
Rat

ABSTRACT

The functions of the claustrum are not well understood. Few studies explore its electrophysiological properties in awake animals. Here, we address this lacuna by recording spontaneous local field potential (LFP) activity in the anterior claustrum of rats freely exploring open field environments under differing conditions (light; dark; with, without an object present). We found three peaks in the LFP power spectral density (PSD) at 1–4 Hz, 4–7 Hz and 8–12 Hz. Two of those peaks, in the 1–4 Hz and 8–12 Hz bands, were present in almost all recordings and dominated the power spectrum. The power or frequency of detected peaks in some cases changed depending on the environmental context. The power of detected frequency bands of spontaneous LFPs showed varied patterns of distribution across the experimental arena. The 8–12 Hz band was predominantly found at running speeds of up to 6 cm/s. We suggest that spontaneous LFP activity in the anterior claustrum depends on the environmental context and running speed of the animal.

1. Introduction

The functions of the claustrum are not well-understood, as few studies have investigated its activity in unrestrained, behaving animals (Remedios et al., 2010, 2014; Renouard et al., 2015; Jankowski and O'Mara, 2015; Kitanishi and Matsuo, 2017). There are, however, several hypotheses regarding the functions of the claustrum (Smythies et al., 2012, 2014). Crick and Koch (2005) have suggested that the claustrum plays an important role in generating consciousness by integrating sensory information across different modalities (Crick and Koch, 2005). Others suggest that claustrum synchronizes activity of distant cortical fields to compute differing aspects of behaviorally-relevant information, and orchestrate its corticopetal flow (Rahman and Baizer, 2007; Smith and Alloway, 2010). The claustrum has also been suggested as having a key role facilitating the detection of naturalistic information to extract relevant sensory information, ignoring irrelevant background sensory noise and performing intended behaviors (Smythies et al., 2012; Remedios et al., 2014; Kim et al., 2016).

We have suggested that the anterior claustrum has a role in spatial information processing, because we have found spatially-tuned cells there (Jankowski and O'Mara, 2015; Kitanishi and Matsuo, 2017). Anterior claustrum possesses a small population of cells that in some aspects resemble hippocampal place cells. Object-responsive and boundary-responsive cells are also present in the anterior claustrum (Jankowski and O'Mara, 2015). We did not find head direction cells, however. During sessions in which we previously recorded place-like, boundary and object cells, we noticed that the local field potential (LFP) had epochs of rhythmic activity of different frequency and amplitude (Fig. 1; Solstad et al., 2008; Tsao et al., 2013). The rhythmic activity of LFPs in cortical areas has been linked to physiological processes such as perception, attention, movement, memory and learning (Banerjee et al., 2011; Ahveninen et al., 2012; Nácher et al., 2013, Haggerty and Ji, 2014; Hyafil et al., 2015). Here, we focus on the analysis of spontaneous LFP activity simultaneously recorded in the anterior claustrum of these rats freely exploring the same environment in different conditions (light; dark; object present/absent), to analyze the relationships between LFP activity and changes in the environmental context and running speed of the animal.

2. Results

2.1. General information

The LFPs subjected to analysis were simultaneously recorded on different sessions with 37 place cells, 21 boundary cells and 46

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https://doi.org/10.1016/j.brainres.2017.09.021
0006-8993/

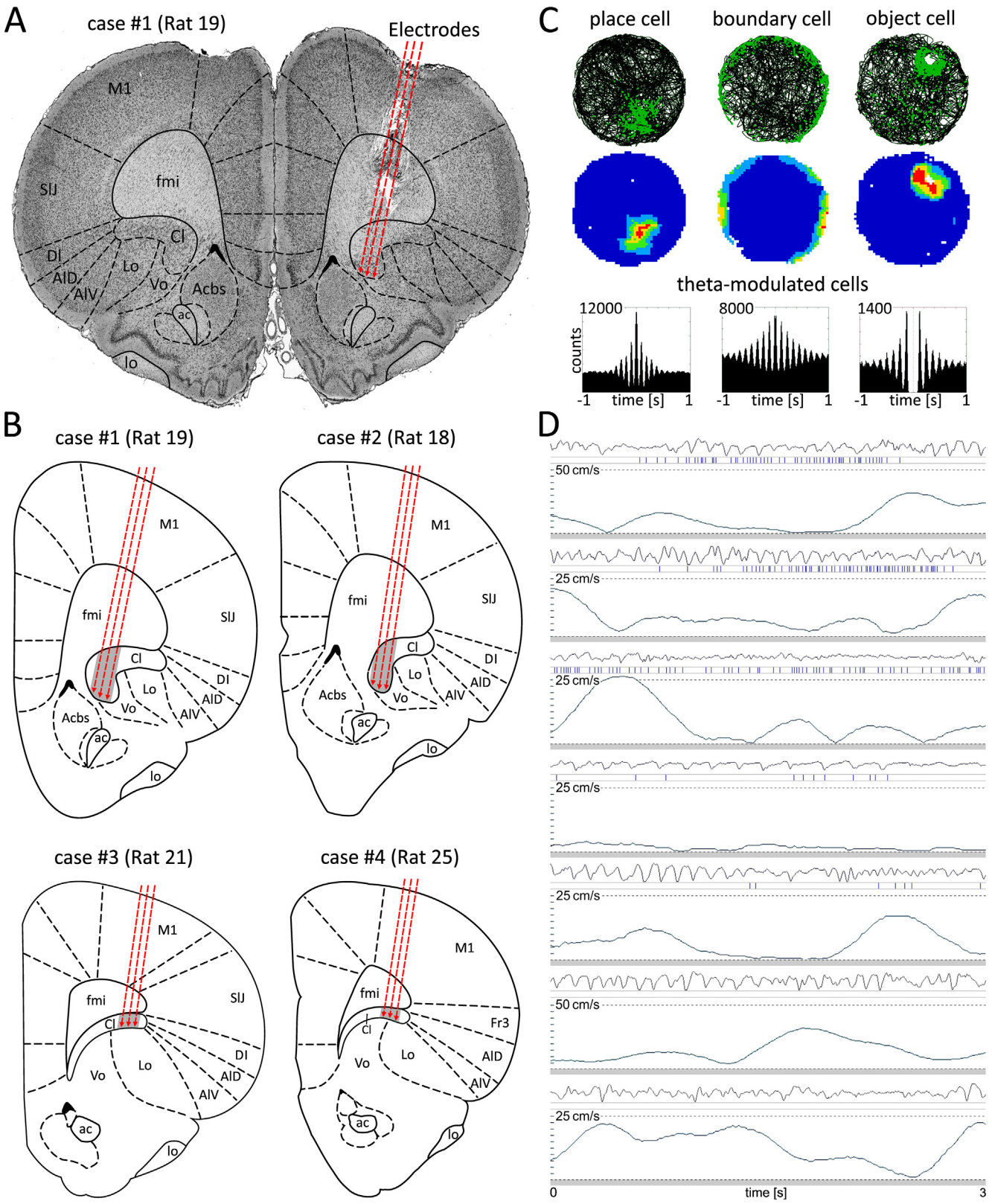

Fig. 1. Histological reconstructions, phenotypes of cells concurrently recorded with LFP in anterior claustrum and example of raw LFP traces from recording with an object cell. (A) Reconstruction of borderlines between the structures on chosen coronal section of rat brain. Borderlines were superimposed based on rat brain atlas (Paxinos and Watson, 1998, 2005, 2007) taking into account individual differences in the anatomy of tested rats. (B) The outlines of structures for all tested rats (cases 1–4; red dashed lines – trajectories of electrode array tracks; shaded areas – the estimated size of recorded area of anterior claustrum). The images do not show deformation of the tissue caused by the electrodes. (C) Types of cells recorded concurrently with the LFP. For place, boundary and object cells are presented examples of the animal's path with superimposed neuronal activity and derived from it firing intensity maps. For theta-modulated cells, representative autocorrelation histograms (±1 s) are presented. (D) 3 s long LFP traces, spiking activity of object cell and running speed are presented in the same time scales. Different types of rhythmic and non-rhythmic spontaneous LFP activity were observed while rat was freely exploring environment containing the object (circular arena with walls, ⌀96 cm). LFP signal was low-pass filtered with a cut off at 125 Hz and a 50/60 Hz notch filter.