Studying the Modulation of Brain Rhythms by Dynamic Cues

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ABSTRACT

It is well known that the theta band (4-12 Hz) is a brain rhythm associated to the self-movement of the animal [1] as well as to several cognitive functions [2]. The aim of this study has been to determine the possible modulation of this rhythm in relation to dynamic cues. With that purpose we employed an e-puck robot as a dynamic cue in contrast to the few precedent studies where dynamic stimuli were presented in a screen [4]. To take advantage of this technique we created behavioural protocols to assure the capacity of the rats to track the movement of the robot. During the protocols the behavior of the animal was characterized by recording the electroencephalogram (EEG). The EEG signal was filtered and the relation between the theta band and the robot's movement was then analyzed. This combination of tools, as the behavioural tasks including mobile robots as the EEG recording, result in a powerful technique to reveal the brain mechanisms involved in the tracking of dynamic cues.

Author Keywords

Dynamic cues, robot, theta band, hippocampus, movement and electrophysiology.

INTRODUCTION

Despite the fact that the tracking of moving objects has been profusely studied in various animal species, little attention has been paid to it in rodents and the first experiments began in the last decade [6]. Most of the studies used images presented in a screen as the stimuli [4] and the aim was to understand how the visual system tracked moving cues. Only few recent works have used real objects in the behavioural protocols. When the "object" was another rat the experimenters found some issues because the tendency of the animals was to do social contacts [7]. These factors lead us to the substitution of the rat by a robot and to design an original configuration to separate the space where the object is moving from the place in which the subject performs the discrimination task by a see-through cylinder (Figure 1A). There are different possible zones of the brain where the information of the dynamic cues could be processed. We are particularly interested on the spatial

A

B

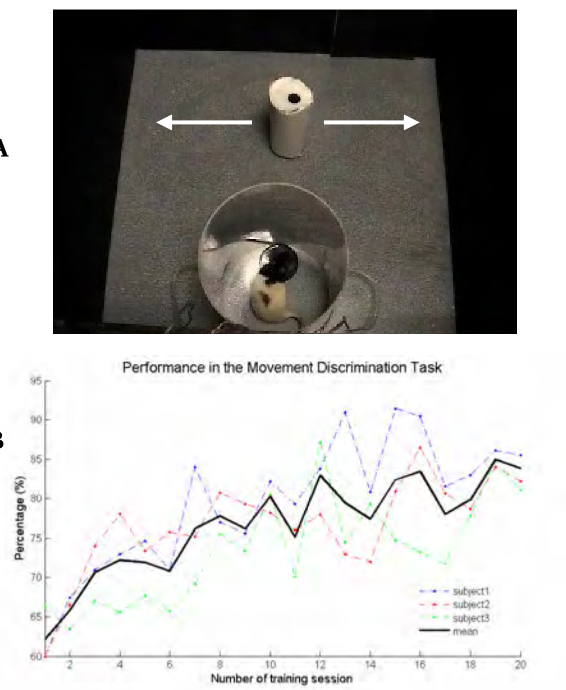

Figure 1. (A) Configuration of the behavioural protocol. The robot is covered by a white cylinder to increase its size and visibility. The rat should position its head above the operant platform to allow the beginning of the task (see black circle under the animal's head). (B) Learning curve showing the percentage of correct choices for three different subjects in colors and the averaged curve in black.

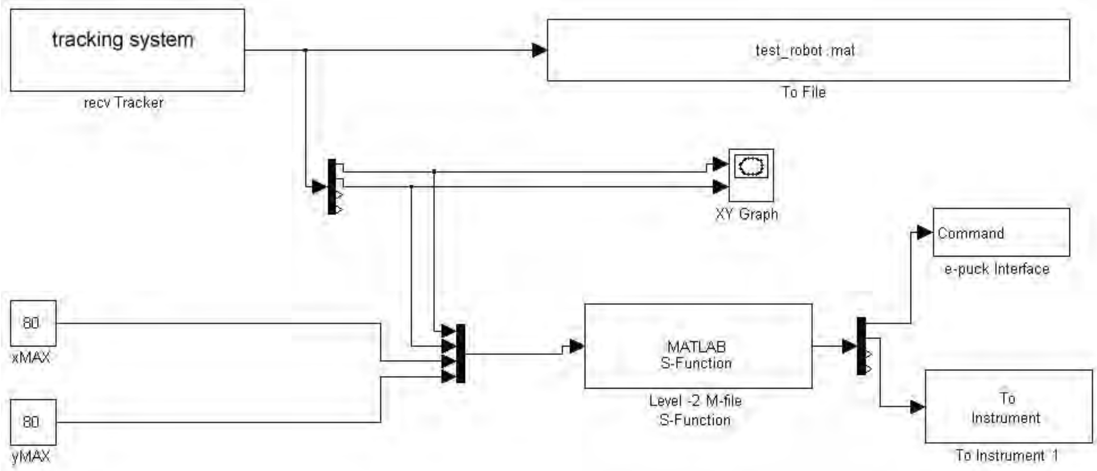

Figure 2. Control model of the protocols. In the upper left corner the block of the tracking system sent the data to the customed algorithm (MATLAB S-Function) that control the robot in the middle right (Command). Also a trigger is sent to the Labview software in the lower right corner (To Instrument) that controls the behavioural devices, infrared sensors and water deliverers (from Guger Technologies, GTEC).

components of the object tracking on relation to the own animal's position. Large evidence has been accumulated that places spatial processing during navigation in the hippocampal and parahippocampal areas [5]. The visual information necessary for object tracking probably converges in the hippocampus. On one hand is important to know the position of these objects (the dorsal path) and on the other hand the identification of the object (the ventral path) [2]. For these reasons we choose the hippocampus as the place to look for the neuronal correlates of tracking moving objects.

BEHAVIOURAL TASK

We control the protocols by Labview and Matlab interfaces. The movement of the robot was remotely controlled by the task execution via Bluetooth. To know how the rat behaves we track its position. A diagram of the simulink model can be seen in the Figure 2 (GTEC, Graz, Austria). To start a trial the subject must remain in a platform placed in the frontal part of the cylinder, facing the robot. After one second in the platform the robot starts its movement randomly to the left or the right and the rat must go to obtain reward in the water dispenser of the same side (Figure 1A). We trained the animals for at least two weeks before they reached stable performances over 80% of correct choices, n=3 (Figure 1B). At this point the animals are chronically implanted as we describe in the next section.

ELECTROPHYSIOLOGICAL RECORDINGS

To record the EEG during the protocols we implanted the trained rats with microdrives (AXONA. Ltd, London, UK) carrying tetrodes under deep anesthesia (ketamine / xylazine). This commercial scaffold allows us to move the four mounted tetrodes of Platinum/Iridium (90%/10%, California Fine Wire) below the cranium searching the CA1 zone of the hippocampus. In this area theta is a dominant rhythm and there are neurons (place cells) that fire when the animal is located in specific locations of the environment (place fields) [5]. We acquired the EEG signal during the behavioural protocols with an amplifier at 1200 Hz of frequency. The recordings were synchronized with the behavioural protocols in order to relate the behaviour with brain activity.

In Figure 3A the onset of the robot's movement is highlighted with a white line. We can see the averaged

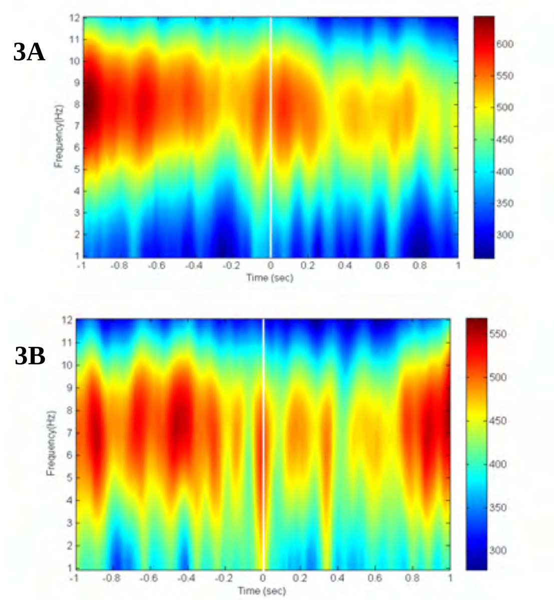

Figure 3. Averaged spectrogram for 100 trials. The spectrogram is done only with the trials where the rat's performance was correct. The color scale represents the band power and the units are μV^2. The white line corresponds to the onset of robot's movement in (A) and to the initiation of a sound in (B).

power of theta for correct trials where a period of two seconds is considered, one before the movement of the robot and one after it. By testing the spectrogram in the presence / absence of the robot we are currently determining the specific modulation of the rhythms exerted by the robot movement which is distinguishable from the rat's movement and attention.

RESULTS AND CONCLUSIONS

We have achieved to combine protocols of sensory discrimination by using robots as dynamic cues with electrophysiological recordings. Our early results show that there could be a modulation of the theta band secondary to the robot's movement. In Figure 3 we illustrate an example where the theta band has a different power distribution during the experimental and control protocols. While in the control without robot the power increases at least 700 ms after the sound presentation in the robot's protocol there is an immediate increase after the onset of the movement sustained for 200 ms. This response is homogenous for different animals (n=3) but is not yet significant. Future experiments will try to quantify the origin of the theta band modulation by a dynamic cue.

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