Closed-loop RSS to improve memory in humans: a pipeline to estimate individual theta frequency

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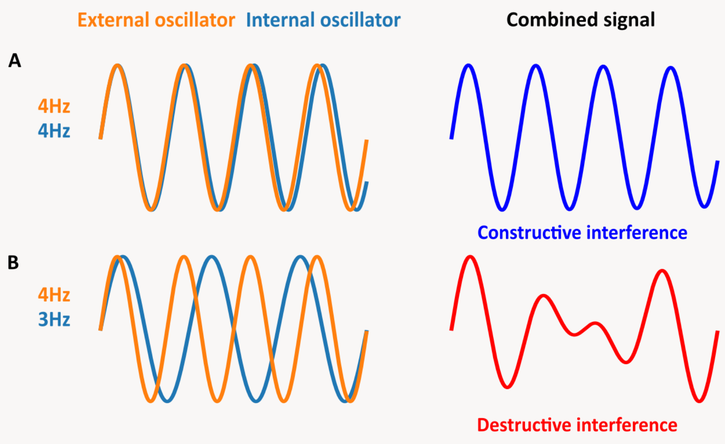
Introduction

- Theta oscillations (4-8Hz) have a crucial role in human episodic memory
- 4-Hz rhythmic sensory stimulation (RSS) has proven to be effective in increasing memory performance in healthy subjects[1,2]
- However, individual differences in oscillatory frequency are functionally relevant and influence the behavioural outcome[3,4]

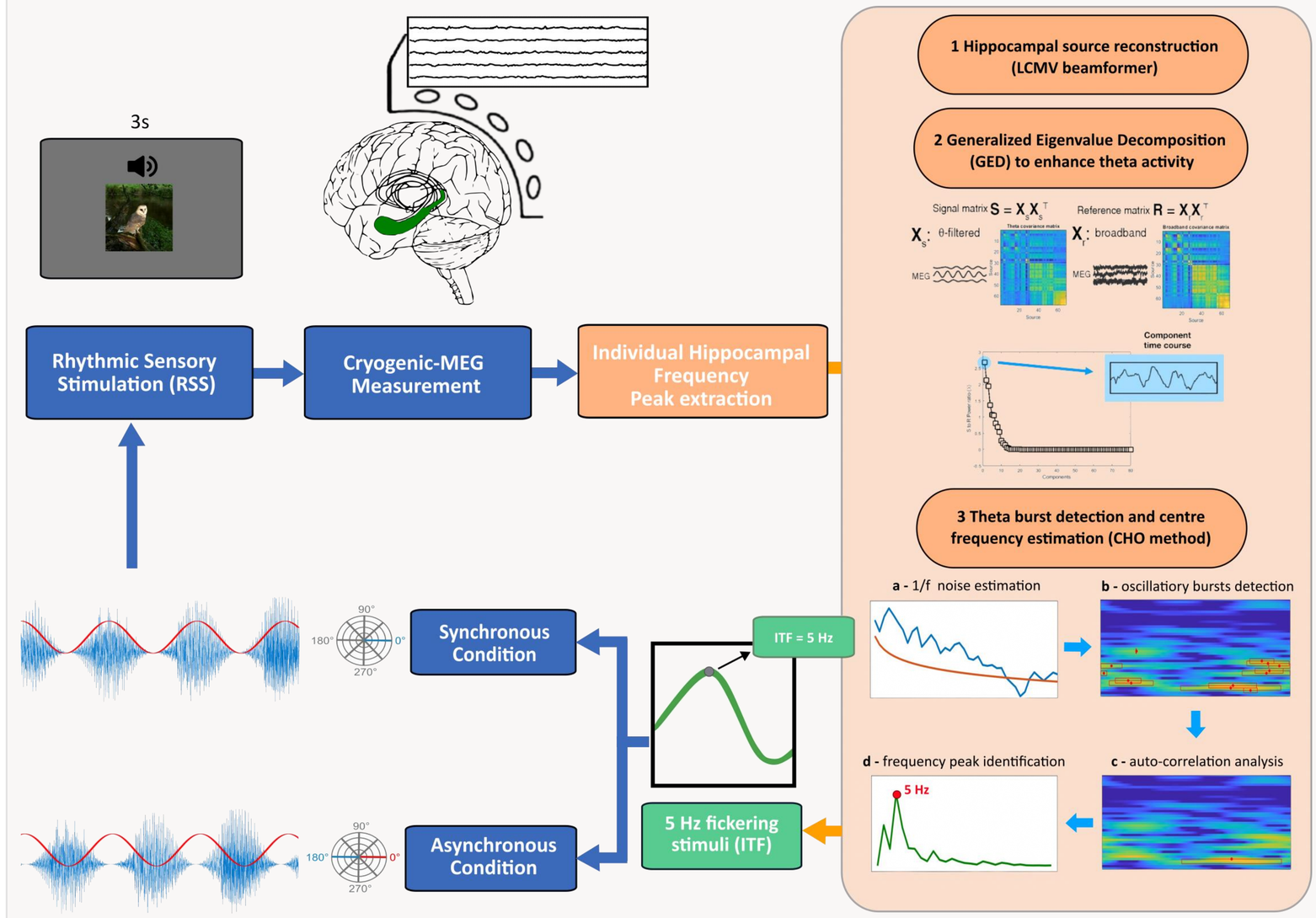
Objectives

- Developed a new pipeline designed to estimate the individual hippocampal theta frequency in real-time during a memory task and dynamically align the stimulation parameters to it

Rationale



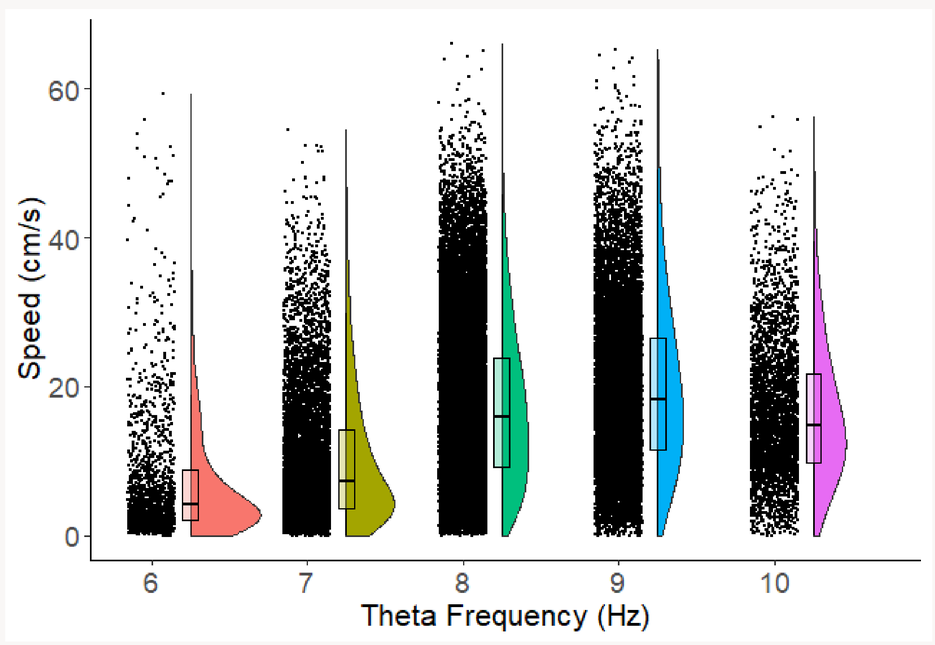
Pipeline



Closed-loop setup. Brain activity is recorded using cryogenic-MEG. Real-time extraction of hippocampal activity is achieved through LCMV beamforming. Generalized Eigenvalue Decomposition (GED)[5] is then used to extract the component maximising the contrast between theta and broadband activity. The resultant time course is then analysed to detect the presence of oscillatory bursts and their centre frequency using the Cyclic Homogenous Oscillation Detection method (CHO)[6]. The audio-visual stimuli are modulated to match the Individual Theta Frequency (ITF) and presented to the participant. In the synchronous condition, the sound (blue) and the video (red) are synchronised (0° phase offset); in the asynchronous condition, the phase of the sound is shifted by 180° from the video.

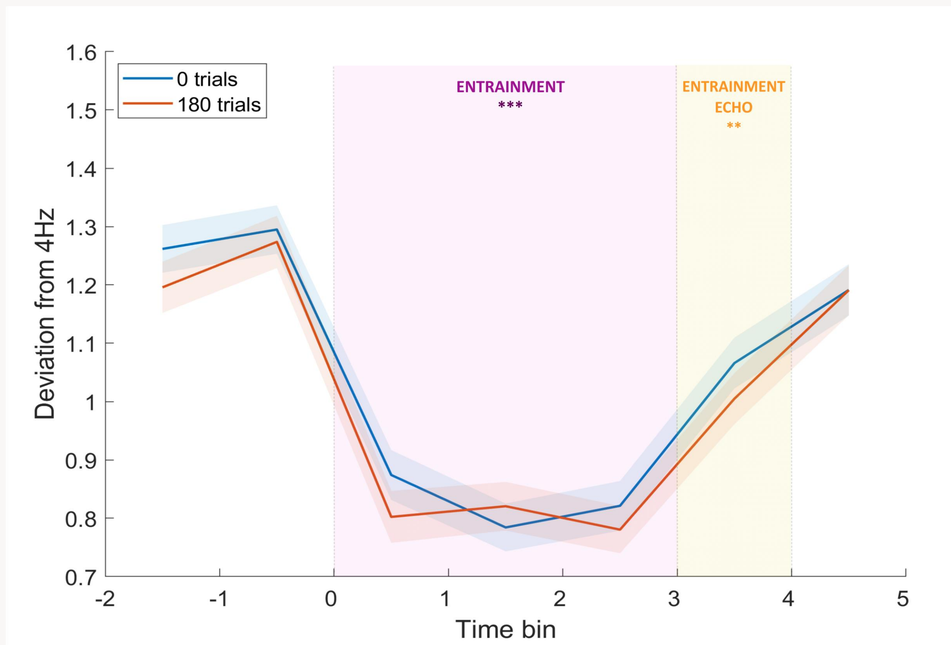
Validation

LFP rodent dataset



The combined use of GED and CHO applied to LFP data from rodents running in an open field was able to reproduce the **positive relationship** between rodent **running speed** and **hippocampal theta frequency.**

MEG 4-Hz RSS human dataset



The full pipeline applied to a MEG 4-Hz RSS memory paradigm was able to detect an **entrainment** effect at the hippocampal source level Interestingly, it also highlighted what seems to be compatible with **entrainment echo.**

References

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Future steps

- Validate the pipeline on a simultaneous MEG-iEEG dataset
- Test whether a multi-sensory closed-loop stimulation at a frequency that matches the momentaneous endogenous individual hippocampal theta rhythm boosts memory ability consistently within participants

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