AES 2011 Abstract

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Title: Temporal theta oscillation enhancement predicts successful memory encoding

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Abstract

Rationale Theta oscillations (4-8 Hz) in the hippocampus and the neocortex have been suggested to play a role in the encoding of new memories and long-term plasticity. Intracranial electrode field potential recordings provide high temporal and spatial resolution for studying these oscillations in humans during cognitive tasks. In humans, theta oscillations have been observed in many structures, including the hippocampus, during memory encoding and recall [1] and virtual maze navigation [2]. The amplitude of these oscillations was correlated to successful memory retrieval in a verbal memory task [3]. Here we characterize the encoding of memory signals at multiple temporal scales and different locations in patients with epilepsy during two complex memory tasks involving retaining sequential episodic information. We show selective modulation of theta activity for successfully recalled memories. This effort lays the groundwork for diagnostic memory testing in epilepsy patients based on quantifying a physiologic brain rhythm.

Methods Epileptic patients implanted with subdural electrodes for seizure localization were tested on two tasks. The first one was a classic multi-item short-term memory task [4]. Subjects were presented with a series of four images on a computer screen and, after a short delay (1-2s), shown a test image. The subjects had to indicate using a key press whether the test image was part of the previous image series or not. In the second task, the subjects were shown a series of 4-6 images. After a short delay, the patients were instructed to arrange the previously presented objects in the order in which they appeared

using the buttons on a key-pad.

Results In both tests, an increase in the amplitude of theta power with respect to the pre-task baseline was observed during the stimulus presentation period in the medial temporal lobe electrodes (Figure 1A). In contrast, electrodes in the frontal and parietal regions showed a decrease in theta power during the task compared to theta levels pre-trial (Figure 1B). Furthermore, there was a significant increase in theta power in the medial temporal lobe during successful trials ($p<0.01$, Wilcoxon's rank sum test, with respect to pre-task baseline, e.g. Figure 1A, top), while in the unsuccessful trials theta power dropped to levels pre-trial (Figure 1A, bottom). This result was consistent across 3 patients tested on both the tasks (29/70 electrodes in the temporal lobe and 15/25 electrodes in the frontal and parietal lobes).

Conclusions These results suggest a role of temporal theta oscillations in the encoding of successfully recalled memories. This spatially and temporally selective increase of theta power in the temporal structures during successful encoding of new information may be related to hippocampal theta oscillations implicated in memory formation [5]. This physiologically based quantitative assay of memory function may prove valuable in predicting postoperative memory outcomes in patients undergoing seizure surgery.

References

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Figures

Figure 1: Theta power in temporal electrodes predicts successful memory encoding. (A) Data from an example electrode on the parahippocampal gyrus during the second task. Average theta power (4-8 Hz) was significantly higher ($p<0.01$, Wilcoxon's rank sum test) than pre-trial baseline (blue line, blue dashed line represents SEM) in successful trials (green trace, top, black dashed lines indicate SEM). In unsuccessful trials (red trace, bottom, black dashed lines indicate SEM) theta power was comparable to the pre-trial baseline ($p>0.01$, Wilcoxon's rank sum test). (B) Data from an example electrode on the postcentral gyrus during the second task. Average theta power in parietal electrodes remained unchanged for successful versus unsuccessful trials. In contrast to temporal electrodes (A), average theta power in parietal electrodes decreased during the trial compared to pre-trial baseline. During the task the patients were shown a series of four objects on a computer screen (black vertical lines). The patients had to indicate the order in which the objects were presented using a gamepad (first response indicated by magenta vertical line).