Gamma bursts length in the DLPFC predicts memory scan time in Sternberg task

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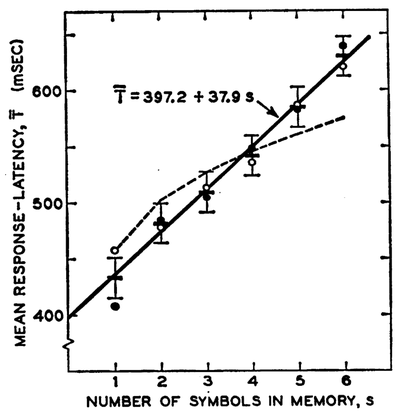
Introduction

Comparing incoming stimulus to the content of the memory is a fundamental function of a cognitive system. In 1966 Sternberg proposed that scanning short-term memory for a target has a form of an exhaustive serial search (Sternberg, 1966) and increases by 38 ms for each additional element in the memory. Based on this discovery theoretical works suggested gamma oscillations as a neural mechanism for the „memory scanning" process. Here we wanted to test gamma oscillations involvement in the memory scanning during Sternberg task.



Sternberg, 1966

Method

SUBJECTS AND TASK

We performed intracranial recordings in 13 neurosurgical, epileptic patients (14 sessions). We recorded local field potential (LFP) signals from depth electrodes implanted in DLPFC during a modified Sternberg task (Fig. 1) with three levels of memory load and pictures as a study material (Kaminski et al, 2017, Brzezicka et al., 2019).

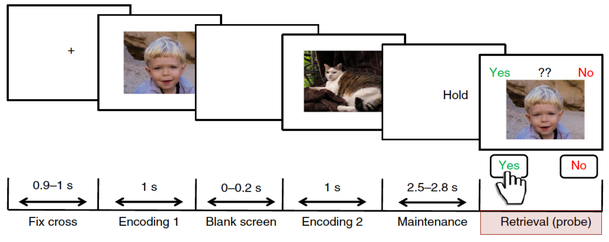


Fig. 1. Overview of the Sternberg task. Signal from retrieval period (shaded red) was used for analysis presented here.

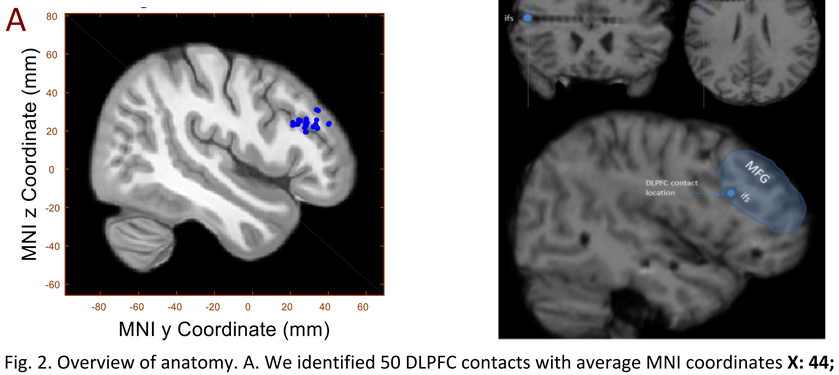


Fig. 2. Overview of anatomy. A. We identified 50 DLPFC contacts with average MNI coordinates **X: 44; Y: 28; Z: 24.** B. Exemplary DLPFC contact in an individual brain. *MFG: medial frontal gyrus; ifs: inferior frontal sulcus; sfs: superior frontal sulcus*

Results

Gamma power

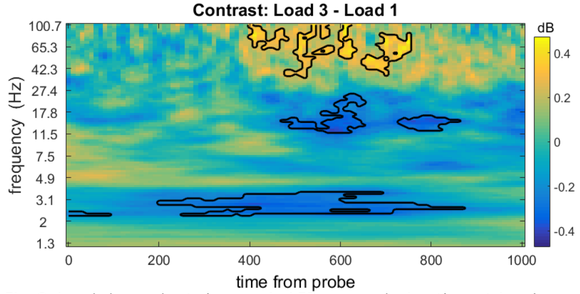


Fig. 3. Load-dependent changes in LFP power during the retrieval.

First, we calculated time to frequency changes in signal power during information retrieval and we saw a clear load-related modulation in gamma band in DLPFC channels (Fig. 3). This modulation's length is also load-dependent and increase of gamma power is longer in higher loads (Fig. 4).

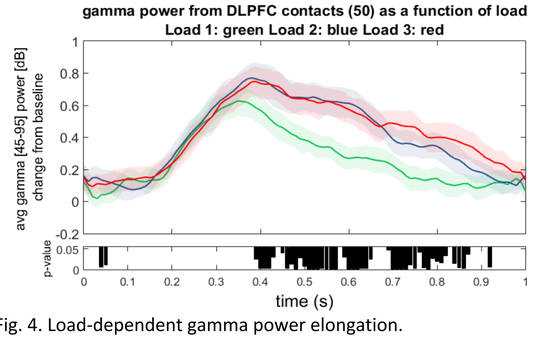


Fig. 4. Load-dependent gamma power elongation.

Gamma bursts

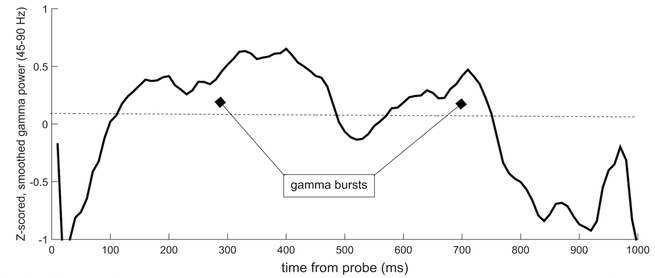


Fig. 5. Single trial's gamma time course. We defined "gamma bursts" as periods with gamma power elevation (>0.1SD) lasting at least 100 ms).

We calculated the duration of the first and the longest gamma bursts (threshold set at 0.1 SD of power and >100ms duration) and number of bursts during the probe (Fig. 5). The duration of the longest burst was load-dependent (Fig. 6B) and correlated wit the median RT (rho = .37**). Moreover, load-related change in RT was correlated with load-related burst duration change (Fig. 6A), evidencing that duration of gamma bursts could be manifestation of memory search process.

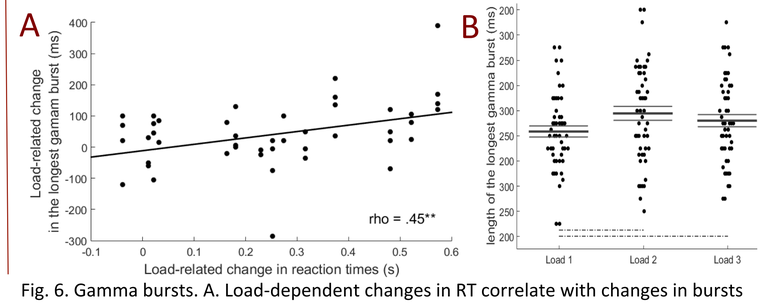


Fig. 6. Gamma bursts. A. Load-dependent changes in RT correlate with changes in bursts duration (positive trials only). B. Load-dependent changes in bursts duration.

Discussion

Presented results confirm predictions from theoretical models suggesting gamma oscillations as a neural reflection of a memory scanning time (e.g. Jensen and Lisman, 1998). We observed not only a load-related elongation of gamma power during information retrieval (Fig. 4) but we also demonstrated that the duration of the longest gammaburst and reaction time are correlated (Fig. 6A). Similarly, load-related change in RT correlated with load-related change in the longest burst duration (Fig. 6B). Together this data provide strong evidence for the DLPFC gamma band involvement in the STM search process

Literature: Kamiński, J., Sullivan, S., Chung, J. M., Ross, I. B., Mamelak, A. N., & Rutishauser, U. (2017). Persistently active neurons in human medial frontal and medial temporal lobe support working memory. Nature Neuroscience, 20(4), 590-601./ Brzezicka, A., Kamiński, J., Reed, C. M., Chung, J. M., Mamelak, A. N., & Rutishauser, U. (2019). Working memory load-related theta power decreases in dorsolateral prefrontal cortex predict individual differences in performance. Journal of cognitive neuroscience, 31(9), 1290-1307. /Jensen, O., & Lisman, J. E. (1998). An oscillatory short-term memory buffer model can account for data on the Sternberg task. Journal of Neuroscience, 18(24), 10688-10699. /Sternberg, S. (1966). High-speed scanning in human memory. Science, 153(3736), 652-654.

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