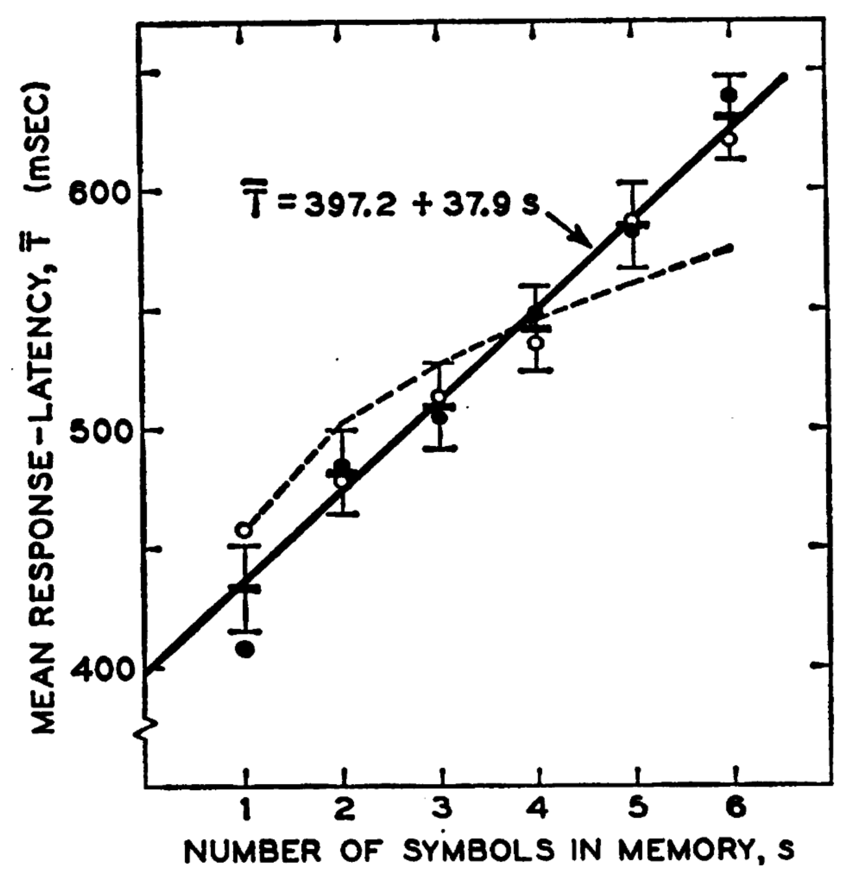
Gamma burst length in the DLPFC predicts memory scan time in Sternberg task

Brzezicka A[1,3]., Kamiński J[1,4]., Mamelak A.N[1]., Rutishauser U[1,2,4]

[1]Department of Neurosurgery, Cedars-Sinai Medical Center, Los Angeles, California, USA. [2]Department of Neurology, Cedars-Sinai Medical Center, Los Angeles, California, USA.
[3]Department of Psychology, University of Social Sciences and Humanities , Warsaw, Poland. [4]Division of Biology and Biological Engineering, California Institute of Technology, Pasadena, California, USA

Introduction

Comparing incoming stimuli to the content of memory is a fundamental function of cognition. In 1966 Sternberg proposed that scanning short-term memory for a target takes the form of an exhaustive serial search (Sternberg, 1966), with an increases of 38 ms for each additional element held in memory. Based on this discovery theoretical work suggested gamma oscillations as a neural mechanism for this „memory scanning" process. Here we tested the involvement of gamma oscillations in memory scanning during a 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 dorsolateral prefrontal cortex (DLPFC) during a modified Sternberg task (Fig. 1) with three levels of memory load and pictures as study material (Kaminski et al, 2017, Brzezicka et al., 2019).

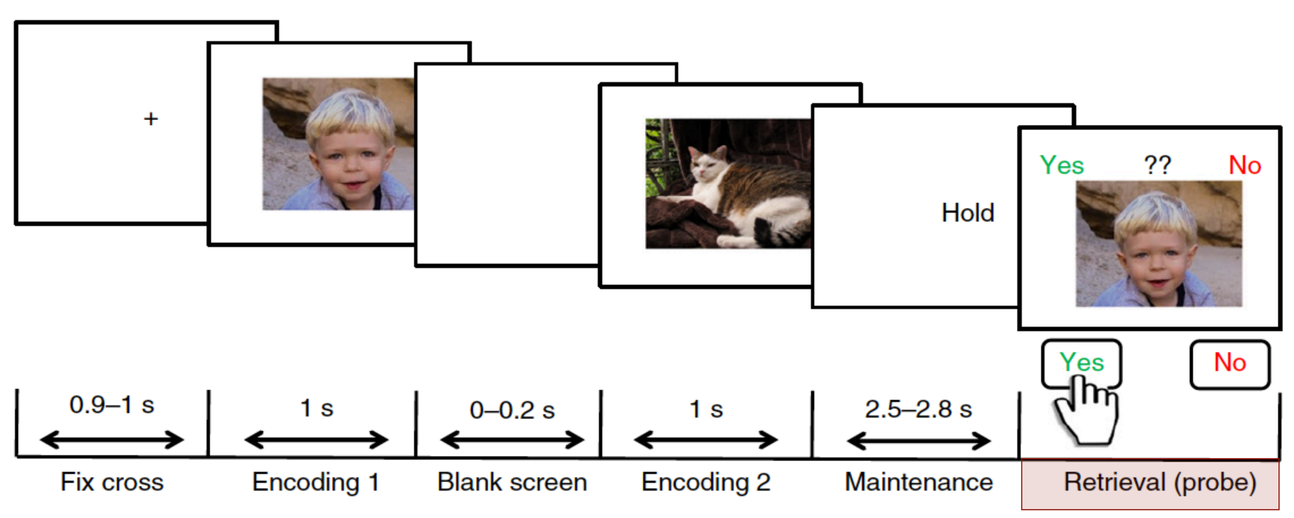
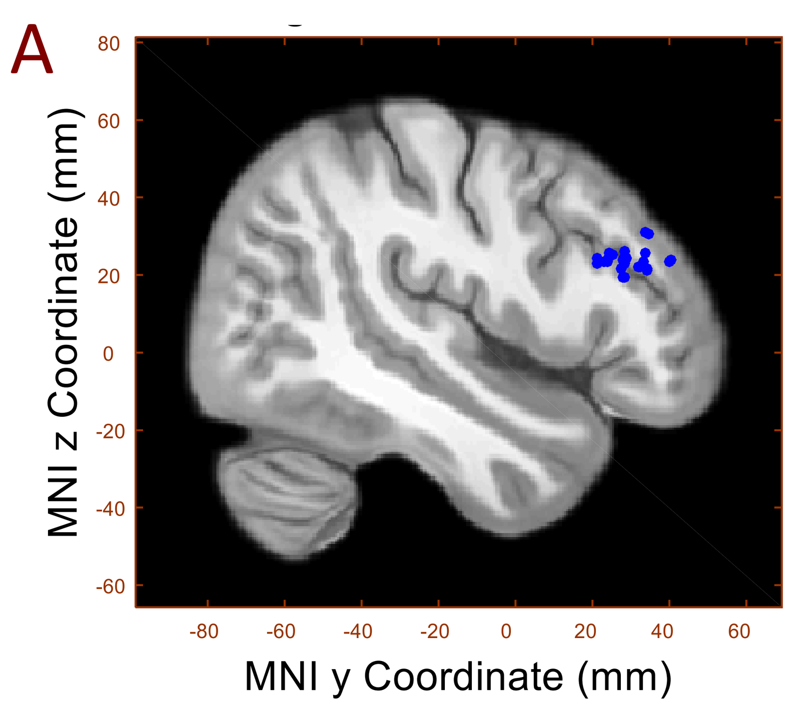


Fig. 1. Overview of the Sternberg task. Signal from the retrieval period (shaded red) was used for the analysis presented here.

A



B

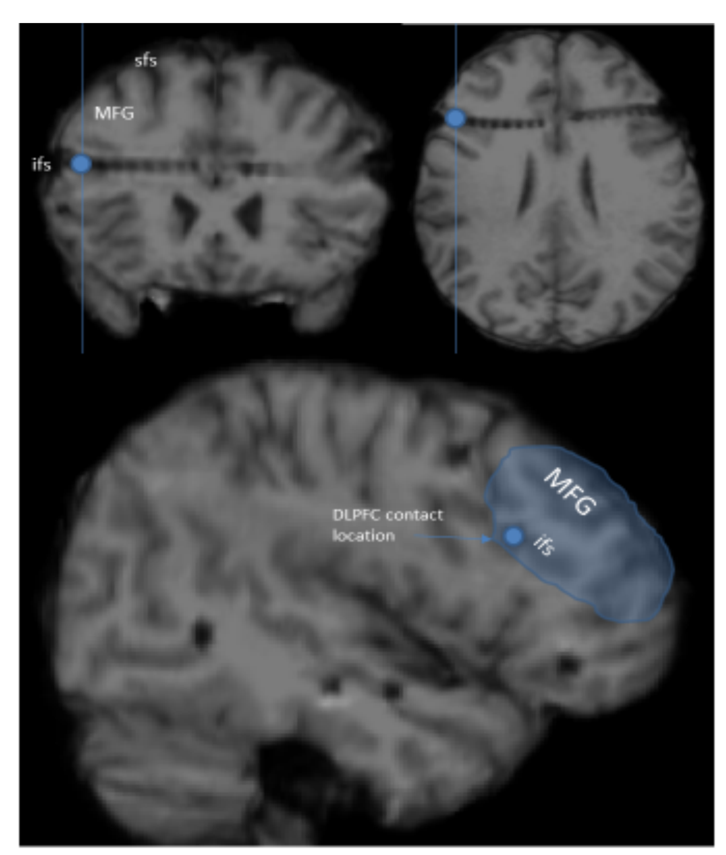


Fig. 2. Overview of anatomy. A. We identified 50 DLPFC contacts with average MNI coordinates **X: 44; Y: 28; Z: 24.** B. Example DLPFC contact in an individual brain. *MFG: medial frontal gyrus; ifs: inferior frontal sulcus; sfs: superior frontal sulcus*

Results

Gamma power

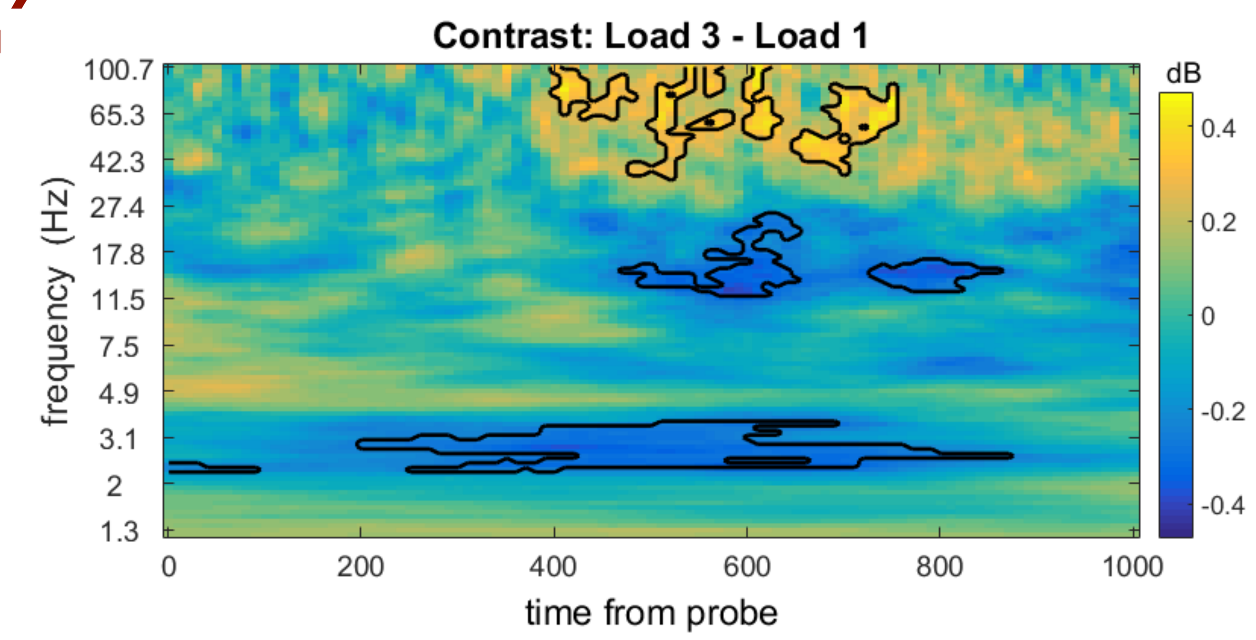


Fig. 3. Load-dependent changes in LFP power during retrieval.

Analysis of signal power changes during information retrieval revealed load-related modulation in gamma band power in the DLPFC (Fig. 3). The length of this modulation is load dependent: increase of gamma power last longer in higher loads (Fig. 4).

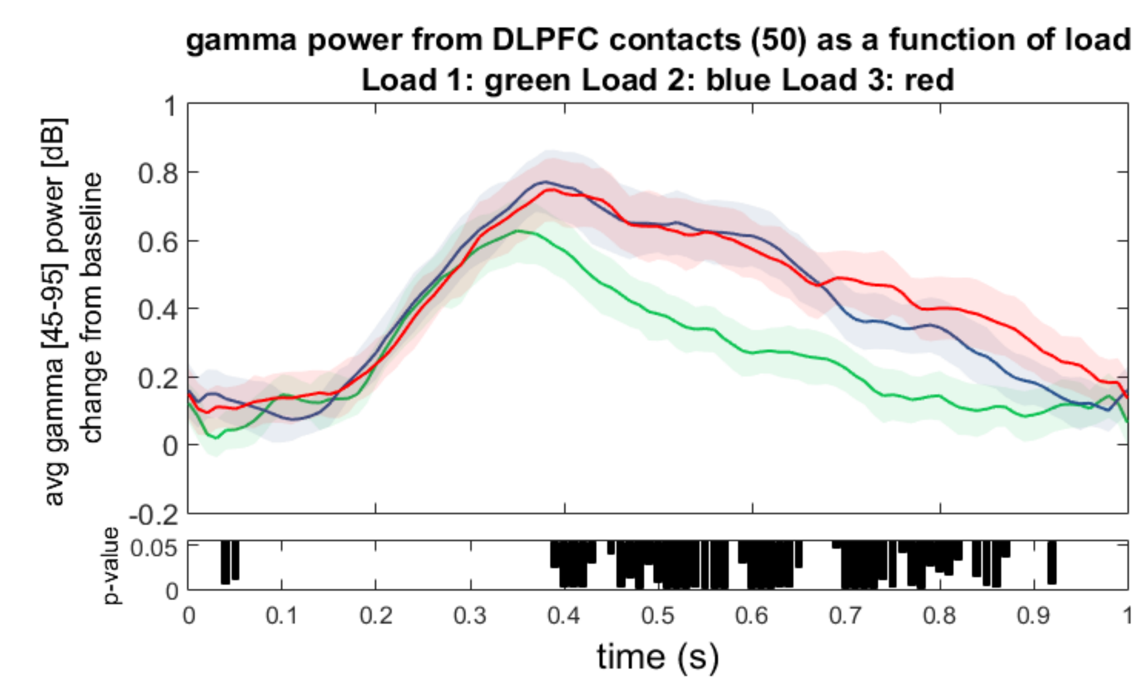


Fig. 4. Load-dependent gamma power elongation.

Gamma bursts

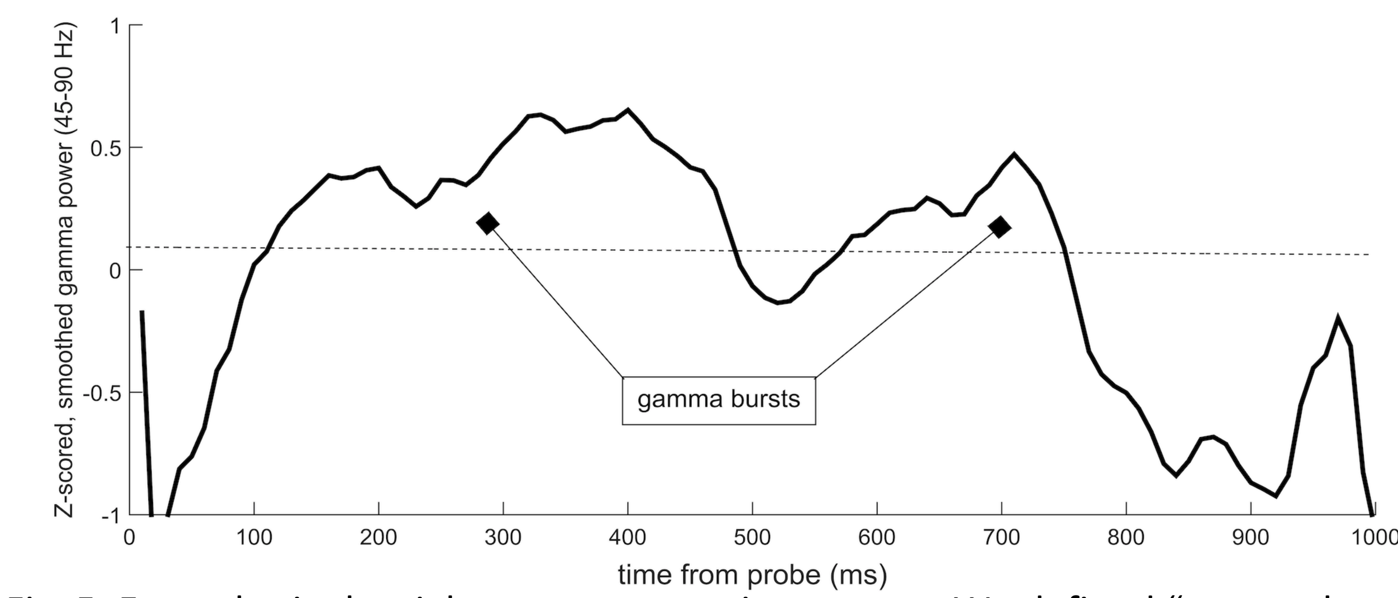


Fig. 5. Example single trial gamma power time course. We defined "gamma bursts" as periods with gamma power elevation (>0.1SD) lasting at least 100 ms.

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, the load-related change in RT was correlated with load-related burst duration change (Fig. 6A), indicating that the duration of gamma bursts could be a manifestation of the memory search process.

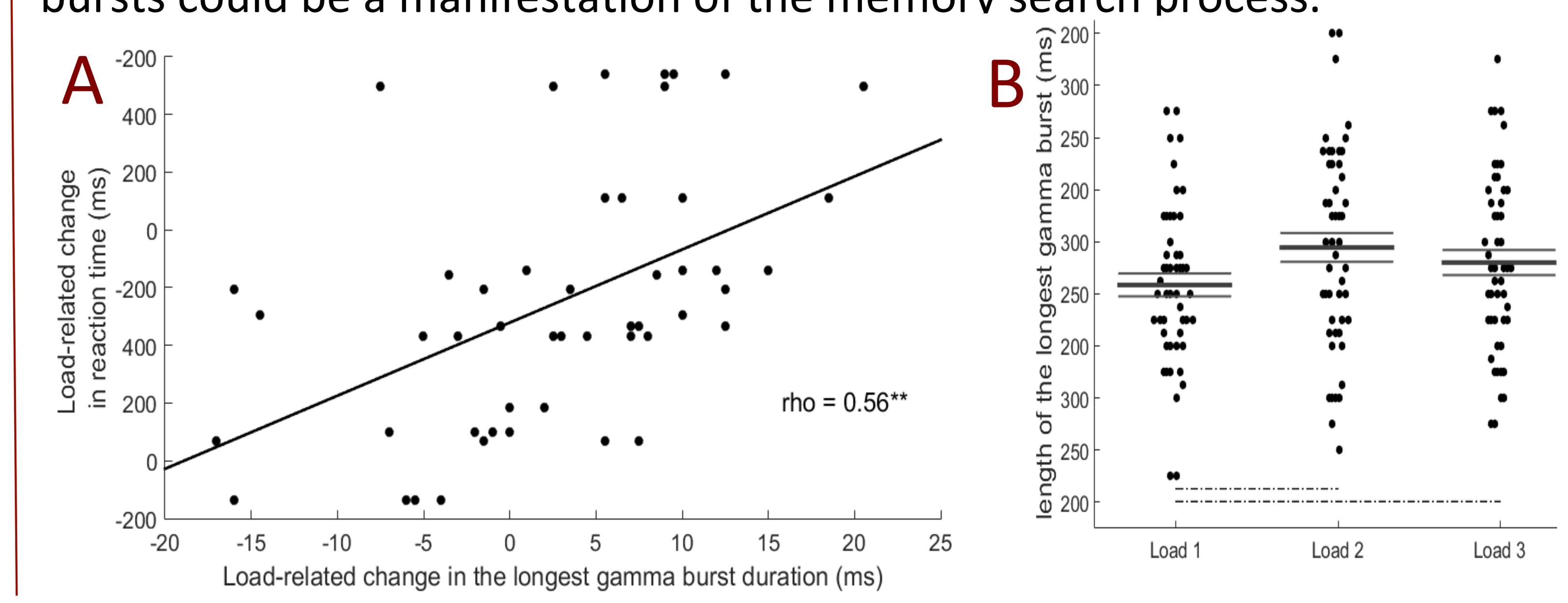


Fig. 6. Gamma bursts. A. Load-dependent changes in RT correlate wit load-dependent changes in burst duration. B. Load-dependent changes in burst duration.

Discussion

Our results confirm predictions from theoretical models that suggest gamma oscillations are a neural reflection of memory scanning time (e.g. Jensen and Lisman, 1998). We observed load-related gamma power increases and elongation during information retrieval (Fig. 4). Also we found that the duration of the longest gamma burst and reaction time are correlated. Similarly, load-related RT changes correlated with load-related changes in the duration of the longest burst (Fig. 6A). Together this data provide evidence for the involvement of gamma in the DLPFC 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.

Funding: The McKnight Foundation and NIMH (R01MH110831)