Saccade-related LFP oscillations set the stage for processing visually evoked spikes

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When inspecting visual scenes, primates perform on average four saccadic eye movements per second, which implies that identification of image components is accomplished in less than 200ms. Thus, individual neurons may contribute only with a small number of spikes for these complex computations, suggesting that information is encoded not only in the firing rate but also in the timing of spikes. To test this hypothesis we analyzed the neuronal activities in V1 in relation to eye movements and fixations performed while monkeys freely viewed natural scenes [1]. LFP oscillations in the visual cortex have recently been suggested to act as a mechanism for converting firing rate code into temporal code [2]. It was also suggested that this mechanism could be used to realize the temporal coding scheme of latency coding, where the latency of the first spikes encode particular stimulus features [3]. We hypothesize that such a mechanism would require the precise timing of early spikes, in particular the very first spikes elicited in a neuron after a stimulus input, i.e. after the onset of a visual fixation.

Thus, we analyzed the relation of single spikes, particularly the first spikes elicited by visual input, to LFP oscillations related to eye movements. By examining the event-related averages of LFP signals and firing rate, we found that there are LFP oscillations in the beta band related to saccade onset (cmp to [4]), while firing rate are time-locked to fixation onset, thus reflecting responses to the visual input. To directly test our hypothesis, we explored the relationship of the timing of individual spikes to the phase of the LFP oscillation by calculating the degree of phase locking (phase locking value, PLV) of the spikes to the evoked beta-oscillation. Relating all spikes elicited during fixation to the oscillation evoked by saccades did not reveal any significant phase locking. However, relating only the first spikes to the oscillation, we obtained significant phase locking with a maximum at about 70 ms after fixation onset. A possible interpretation of this result is that these first spikes are part of a first wave of visually evoked activity and that the saccade-evoked LFP oscillations serve as a reference signal to accurately time these spikes for further processing.

\begin{figure}
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\includegraphics[width=\textwidth]{figure.png}
\caption{(Left) Average firing rate for all spikes and first spikes, and average LFP. (Right) Phase locking value for first spikes. Dark area indicates 95 percentile of the PLV distribution for surrogate data.}
\end{figure}

References
[1] Maldonado et al. (under review)