Dissecting gamma phase and amplitude-specific information routing in V4 of macaque during selective attention

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Communication through coherence (CTC) postulates that stimulus information transmission is enhanced between oscillating neural populations in a favorable phase relationship, and suppressed otherwise. For example, in the case of visual cortical gamma-band synchronization during selective attention, V1 spikes arriving to V4 during its excitability peaks should be much more likely to elicit further spikes, resulting in effective signal gating; V1 spikes arriving during excitability troughs should fail or at least be less effective in evoking further activity. Further, it has been observed that average gamma power increases with attention, however, this increase appears to occur in bursts, rather than a constant clear oscillation. Hence, if the CTC hypothesis holds, one should expect gamma phase and amplitude dependent modulations in stimulus information routing in V4.

To explore this idea, we analyzed neural data from a previous study [1], recorded from V4 superficial layers in macaques performing a visual spatial attention task. The task required the animals to attend one of two dynamic stimuli over an extended time period. Crucially, each stimulus was superimposed with its own fluctuating luminance signature, irrelevant to the behavioral task. This allowed us to quantify the information content I of each stimuli conveyed by the physiological signal, by computing spectral coherence between each stimuli's luminance signal and V4 activity. To assess modulation effects at multiple population scales, we analyzed both LFP and spiking activity. Using gamma-band activity extracted from LFP, we dissected both LFP and spiking neural activity into phase/amplitude-specific components. We then computed the information contribution of each stimuli to these components, giving us the opportunity to assess phase/amplitude signal gating effects.

The results show that information routing is definitively modulated by the gamma phase for both LFP and spiking activity. In the LFP signal, we found the information routing at excitability peaks I_{peak} is significantly higher than at excitability troughs I_{trough} for both attended and non-attended stimuli (Fig 1A). We did not see this effect with spiking activity, which still shows significant gamma phase modulation but without a preference for a specific phase across recording sessions. When we compared the stimuli content during high gamma activity $I_{high\gamma}$ against low gamma activity $I_{low\gamma}$, we found that the spiking activity exhibits significant gating increase for the attended stimulus and decrease for the non-attended stimulus (Fig 1B), however, we do not find this effect in the LFP.

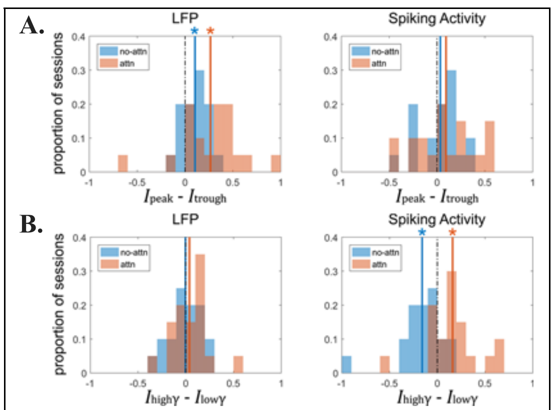

Figure 1. *A. Peak vs trough gamma phase modulation*
B. High vs low gamma power modulation

In summary, our study confirms basic predictions on the nature of selective information processing, namely its modulation in dependence on phase and amplitude of LFP gamma activity. Surprisingly, consistent phase modulation is only found in LFPs, while consistent amplitude modulation is only seen in spiking activity, indicating that the mechanisms implementing CTC are not yet understood. In particular, our results strongly motivate a refinement of current CTC models, requiring an approach encompassing different levels of complexity capable to reproduce local spiking and global population activity from different laminar sources.

1. Grothe I, Rotermund D, Neitzel SD, Mandon S, Ernst UA, Kreiter AK, Pawelzik KR. **Attention selectively gates afferent signal transmission to area V4.** *bioRxiv*. 2015, 019547.

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