Dynamics of Information Flow in the Gamma Frequency Band (~40 Hz) of the EEG During Wakefulness and Sleep

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Introduction.

Cognitive processes depend on recurrent corticocortical interactions. Oscillations within the gamma frequency band (30 to 45 Hz) of the EEG are associated with these processes. In addition to the sensory flow from the periphery to higher cortical areas, known as “bottom-up” processing, there is also “top-down” processing, in which hierarchically higher areas modulate the bottom-up flow. Top-down refers to the brain's ability to use expectations, attentional focus, and other cognitive factors to dynamically influence bottom-up sensory processing. However, the precise directionality of the information flow (bottom up or top down) encoded by gamma band oscillations remains unknown.

Objective.

To investigate the direction of information flow in the gamma band during wakefulness and sleep.

Material and methods.

Cats were implanted with electrodes in various cortical regions, to record the EEG during wakefulness and sleep. To assess the directionality of information flow of the gamma band, we quantified the phase shifts of the peaks of the gamma oscillation envelopes and conducted Granger causality analysis (statistical test used to determine if one time series could predict the other). These analyses were performed under baseline conditions as well as during auditory stimulation with both simple (clicks) and complex and variable sound stimulation (CVS, melody excerpts of 200 ms).

Conclusions.

During wakefulness, distinct patterns of information flow emerge depending on the nature of the auditory stimuli. Specifically, bottom-up processing predominates in response to simple, sound stimuli, whereas top-down processing prevails in the case of complex and variable sounds, as well as under baseline conditions. The directional pattern of information flow is lost during sleep.

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Figure 1. Quantification of the directionality of phase shifts in the envelopes of filtered gamma oscillations. **A**. Top. Position of the recording electrodes. Bottom. Raw (left), gamma filtered (middle) and gamma envelopes (right) recordings. **B.** Method for quantification of the directionality.

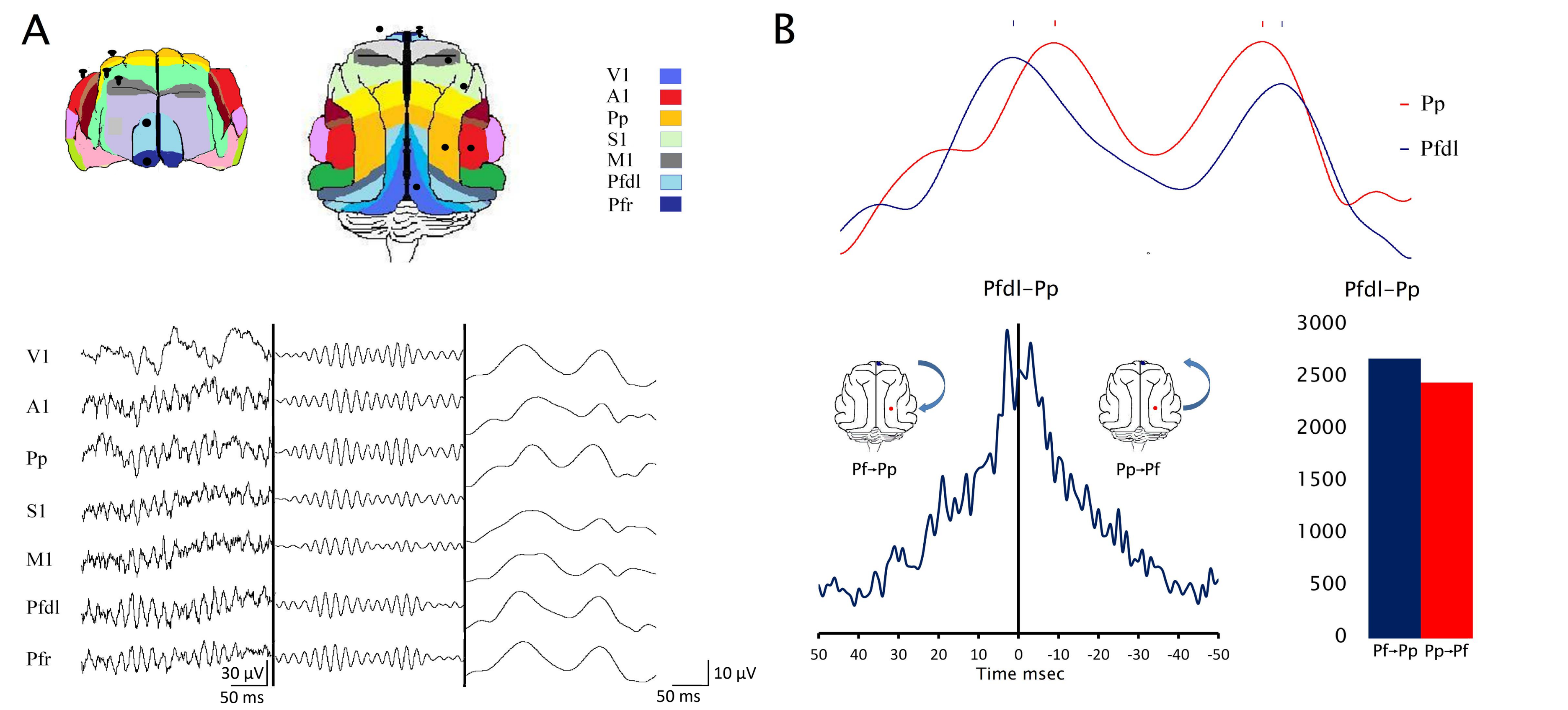

Figure 2. Top-down gamma directionality predominates in baseline conditions during wakefulness. The gamma directionality disappears during sleep. **Left.** Granger Causality spectrum and number of events of the peaks of the envelopes of the gamma oscillations in each directionality of the prefrontal Vs. posterior-parietal cortices derivation during wakefulness and sleep. **Right.** Schematic directions of the information flow among cortical areas during wakefulness.

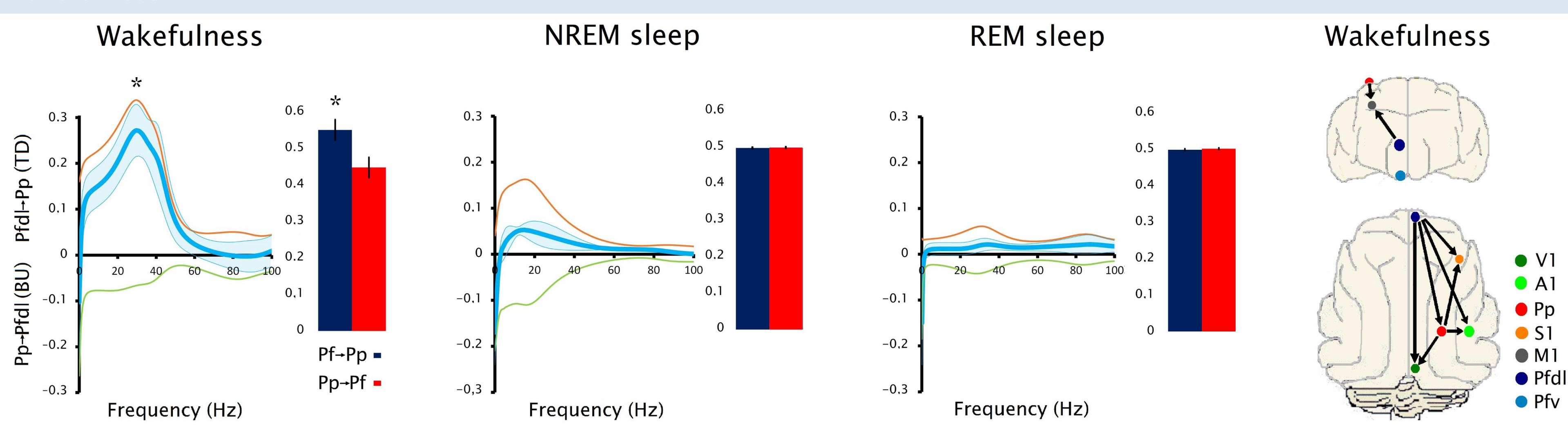

Figure 3. Late gamma response following click or CVS auditory stimulation. . A. Raw recordings and spectrograms following clicks and complex variable stimuli (CVS), **B.** Average of the dorso-lateral prefrontal cortex (PFdl) and posterior-parietal cortex (Pp) power spectrograms following “clicks” or CVS stimulation during wakefulness.

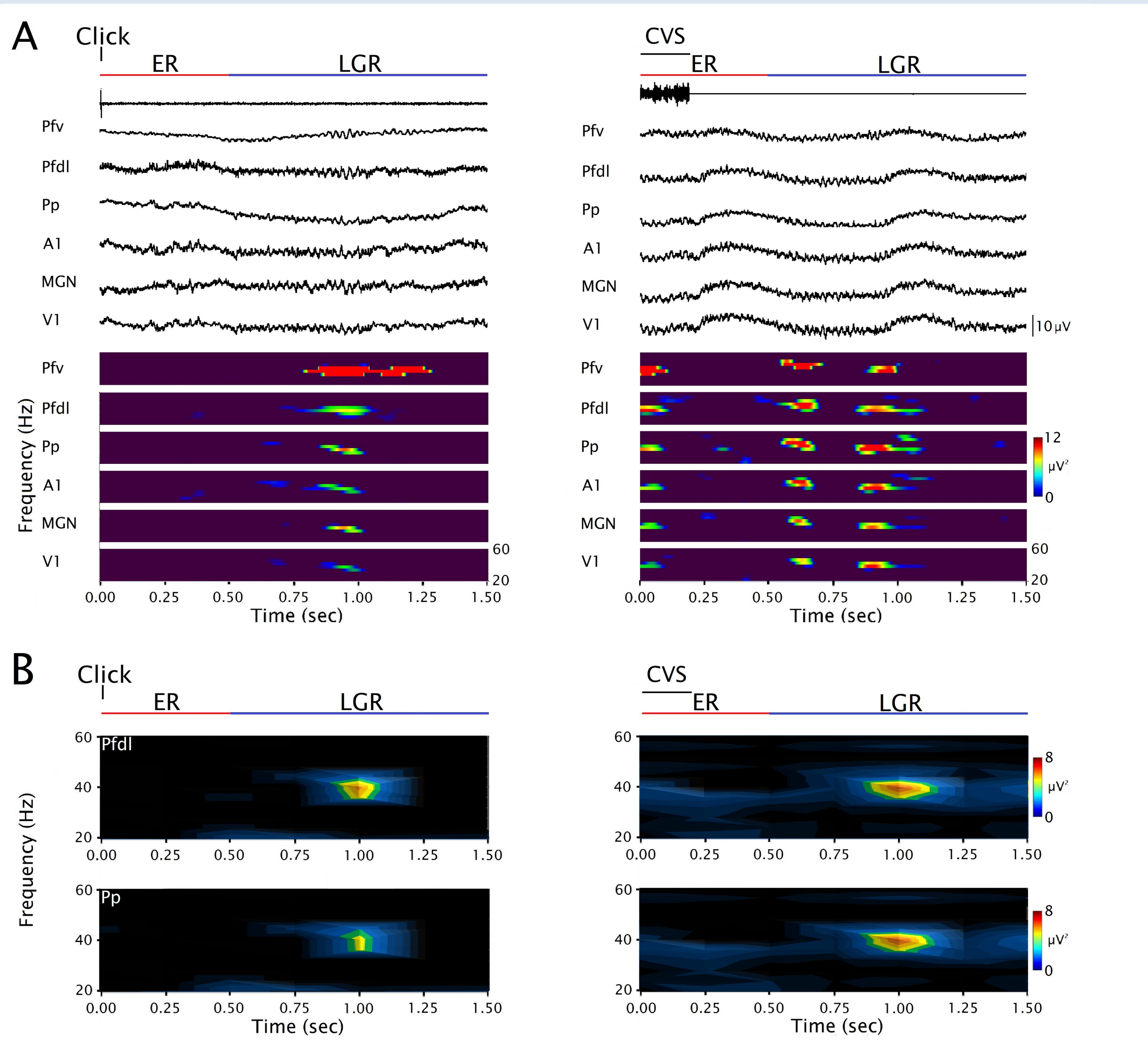

Figure 4. Directionality of the late gamma response (LGR) induced by Clicks (top) or CVS (bottom). Left. Granger Causality spectrum of the prefrontal (Pf) and posterior-parietal (Pp) cortices during the sound induced gamma response during wakefulness. **Right.** Schematic directions of the information flow among cortical areas during wakefulness. The gamma directionality is lost during sleep (not shown).