Interlaminar feedback connections dominate in macaque inferotemporal cortex: *in vivo* and *in silico* studies

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1. Introduction

- **Hypothesis:** Attention modulates activity in layer 2/3 to increase cortical sensitivity to thalamic inputs.
- **Aim:** To replicate and explore interlaminar sensory information processing using a detailed network model of the macaque inferotemporal cortex.
- **Background:** The functional interactions of neocortical layers remain poorly understood. Computational modeling allows properties such as causality to be investigated more precisely than experimental studies alone.

2. Methods

- **Experiment:** Two macaques performed a visual/auditory discrimination task with attention alternating between the modalities. 14-channel multielectrodes spanning all layers were chronically implanted in inferotemporal cortex (IT). Bandpass-filtered local field potentials (LFPs) and multiunit activities (MUAs) were recorded in both attend-visual and attend-auditory conditions.
- **Simulation:** Event-driven, rule-based neurons were distributed across cortical layers (Fig. 1). Sensory input was modeled as impulses to L4; attention was modeled as increased drive to L2/3.

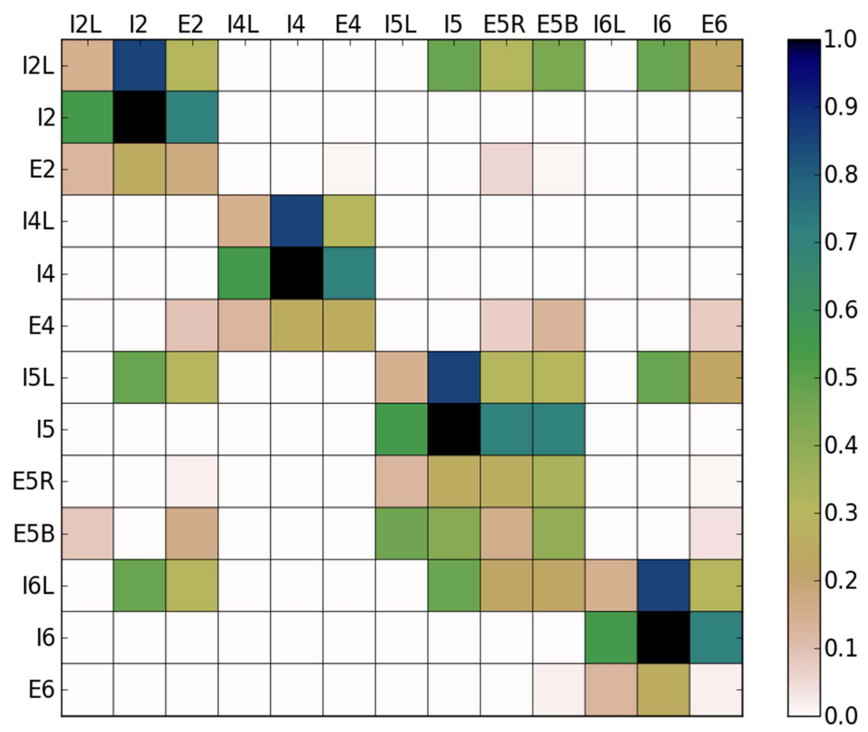

Fig. 1: Connectivity between cell types; color indicates connection strength. Note strong intralaminar connections (along diagonal). E=excitatory pyramidal, I=inhibitory interneuron, L=low-threshold spiking.

3. Results

- **Spectra and evoked responses:** Experimental and simulated spectra (Fig. 2), evoked responses (Fig. 3), and spectrograms (Fig. 4) share several qualitative and quantitative characteristics:
  - Power-law profile, with experimental and simulated exponents of −1.76±0.09 and −1.6±0.1, respectively (r^2=0.92 and r^2=0.94 respectively, for f>10 Hz)
  - Signal-to-noise ratio in evoked responses highest in L4, then L2/3 and L5/6 (in experiment, 0.4, 0.05, and 0.002, respectively; in simulation, 1.2, 0.06, and 0.01)
  - Similar amounts of spectral variability across time: at 5 Hz, coefficients of variation were 0.13 and 0.15 for experiment and simulation, respectively
- **Granger causality:** Attention has large effects on interlaminar Granger causality in the simulations (Fig. 5):
  - Total Granger causality from L4 to L2/3 increased 24% (from 0.61 to 0.75), due to increased excitability in L2/3; causality from L2/3 to L5 increased 27% (from 0.9 to 1.2), due to increased activation of L2/3; and causality from L4 to L5 increased 19% (from 0.44 to 0.53), as a combination of the above effects

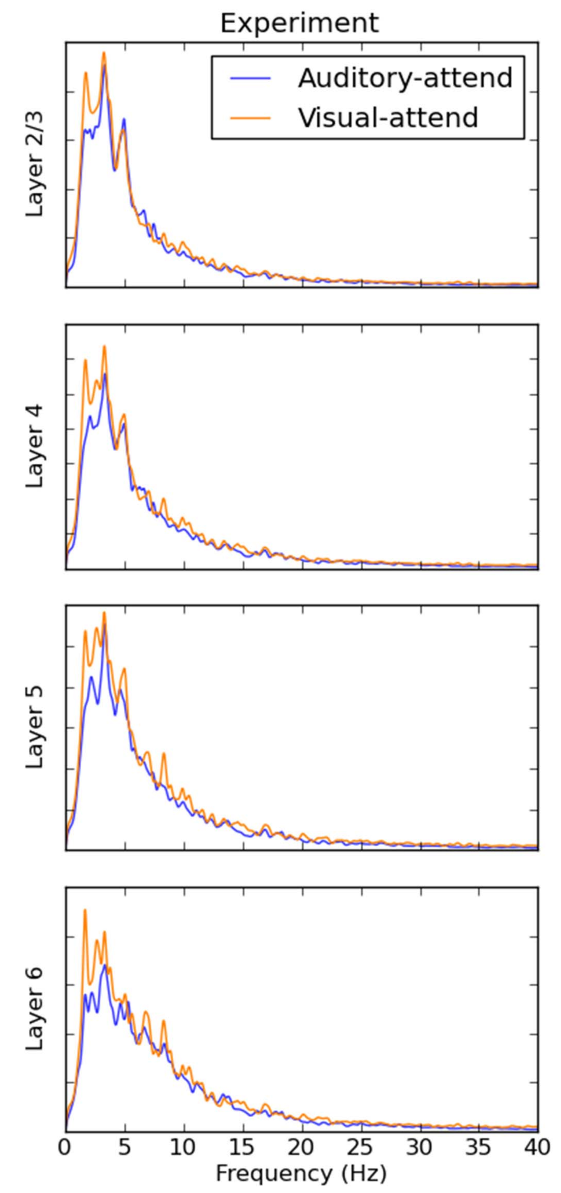

Fig. 2: Experimental and simulated LFP spectra for each layer. Vertical axes show normalized power (μV^2/Hz).

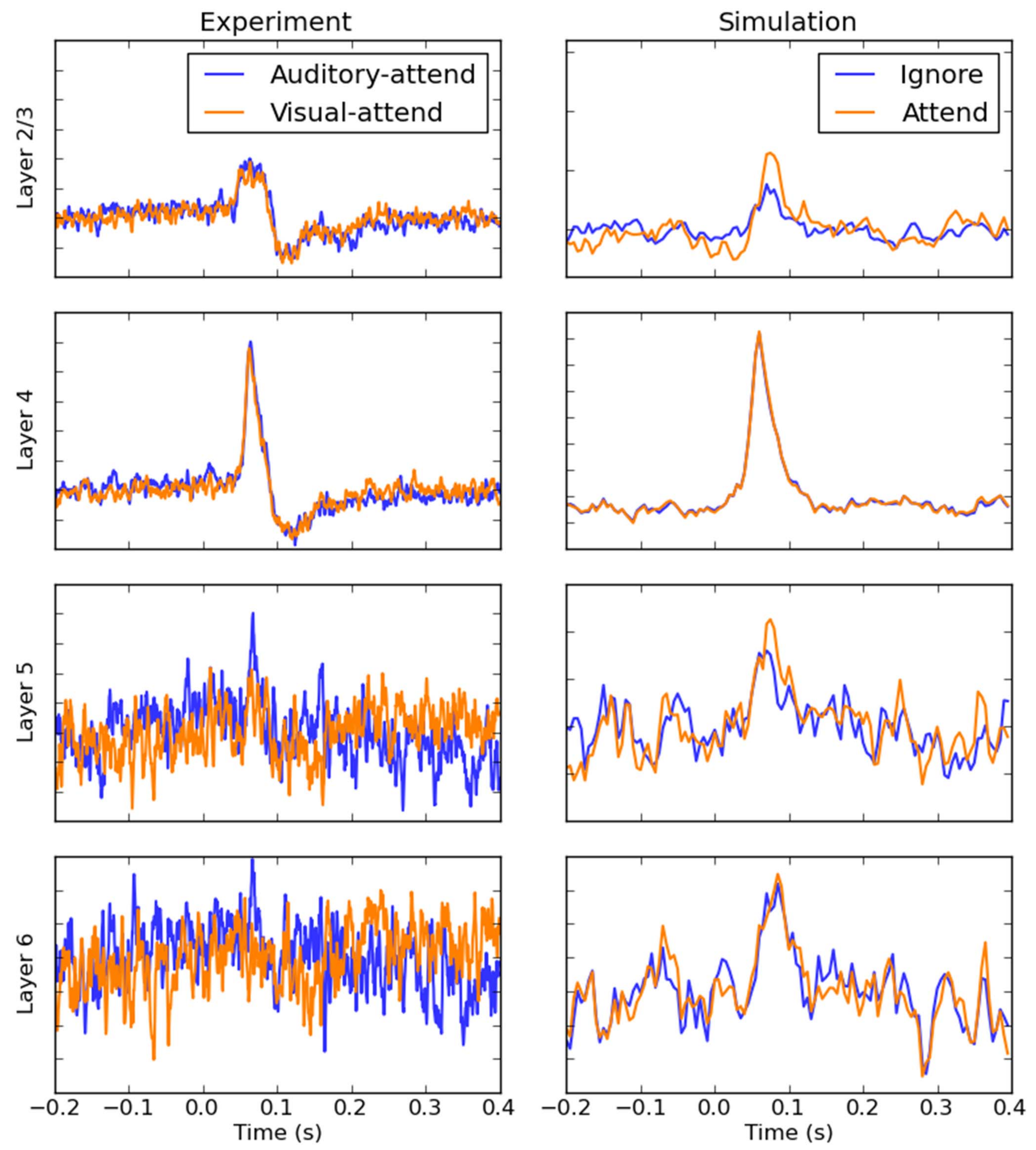

Fig. 3: Experimental and simulated evoked responses for each layer. Vertical axes show normalized voltage (μV).

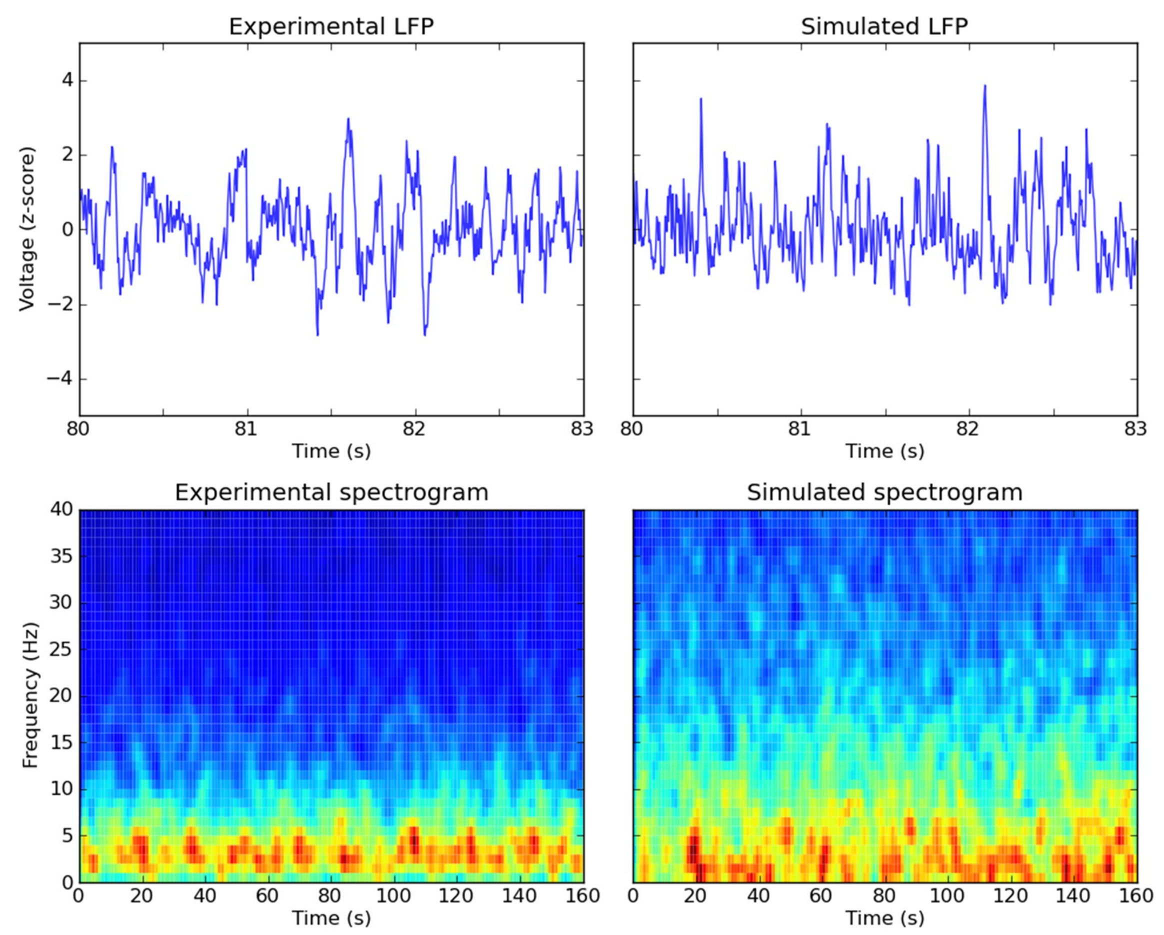

Fig. 4: Multiscale dynamics in layer 2/3: variability across small (top) and large (bottom) scales. Color shows normalized power.

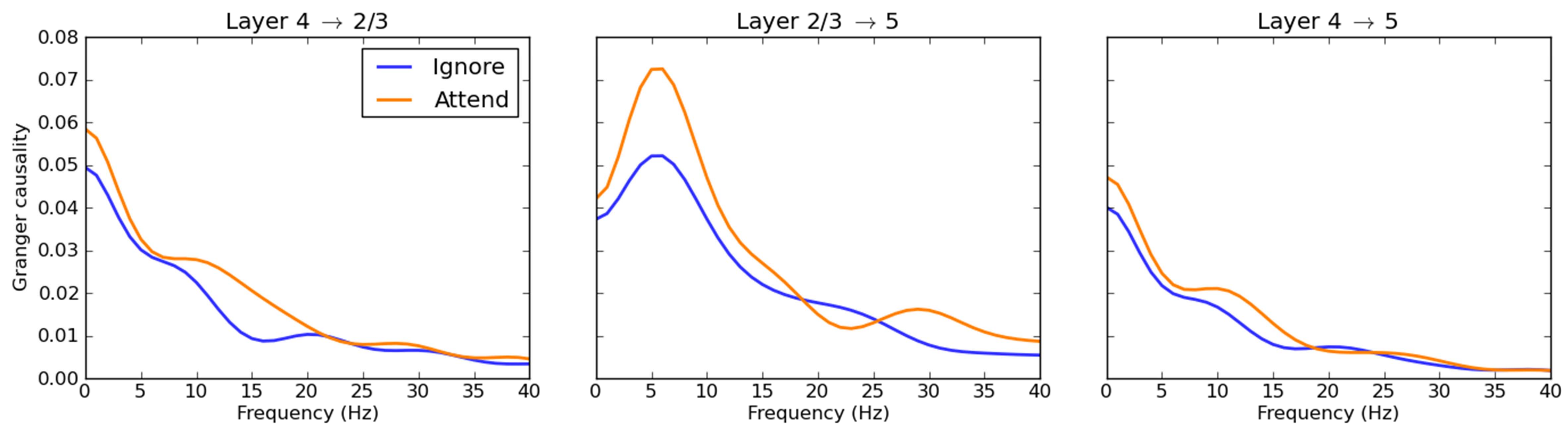

Fig. 5: Simulated Granger causality between cortical layers; in each case, attention increases overall causality, especially at frequencies below 15 Hz. Granger causality from layer 4 to layer 5 results from both direct connections and connections via layer 2/3.

4. Discussion

- Both experiment and the model found that low frequencies (<10 Hz) had highest spectral power, with a roughly exponential decay at higher frequencies (>10 Hz)
- Layer 4 had the highest signal-to-noise ratio impulse response, followed by layer 2/3, with weaker responses in layers 5 and 6
- The model was used to investigate interlaminar causality in greater detail, which showed that attention increases causality from L4 to L2/3 and from L2/3 to L5; direct causality from L4 to L5 was unchanged; the combination of these effects led to an increase in causality from L4 to L5
- This suggests a simple mechanism by which attention could increase responsiveness to incoming sensory stimuli

References

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Further information

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