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Dynamic causal modelling of retino-cortical connectivity

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Objective

While nearly all visual research in humans has focused on visual cortical regions, surprisingly little is known about the human retinal network. This is important if we want to understand how the retina and the visual cortices are coupled via the LGN, both in terms of their relative spectral behaviour, their timing and the ensuing axonal conduction delays.

Visual paradigm

- Full-field bright white light flash in a dark MSR
- ProPixx projector (VPixx Technologies, Canada)
- Stimulus duration: 1 ms
- Inter-trial interval: 1000 ms
- 200 trials

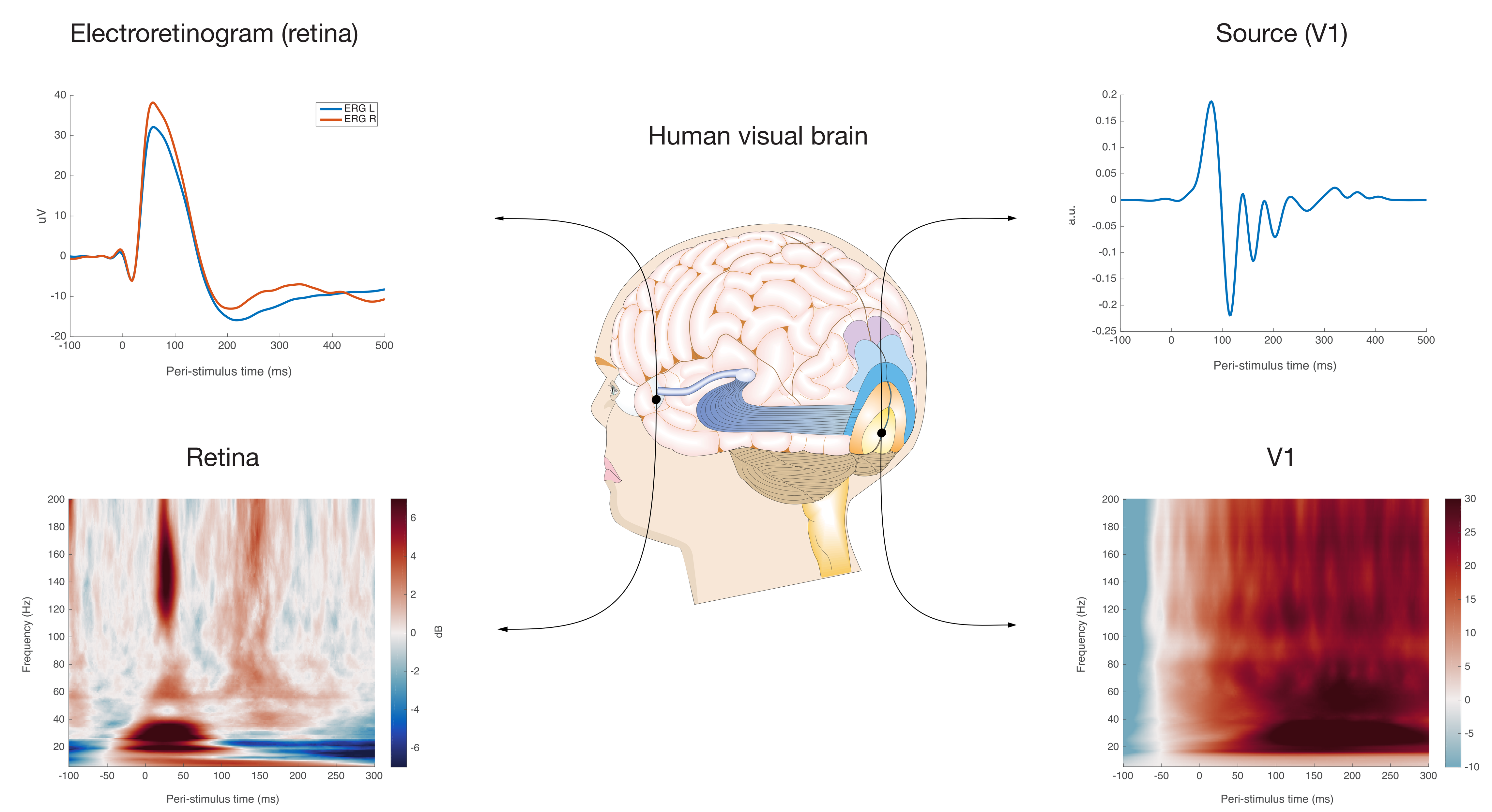
Methods

We used a combination of non-invasive electro-retinography (ERG) of the retina, using a corneal silver/nylon electrode (DTL Plus Electrode, Diagnosys, USA) and MEG of cerebral cortex (Elekta Neuromag Triux) in 11 healthy human adults. Following source analysis of fused magnetometers and planar gradiometers (Henson *et al* 2009) using an Empirical Bayesian beamformer (Belardinelli *et al* 2012) implemented in SPM12 (r7219), the ERG and MEG source-space data were analysed using Dynamic causal modelling (DCM). We used DCM for induced responses (Chen et al 2008) to evaluate the Bayesian model evidence for frequency-specific coupling, compared to cross-frequency coupling between the human retina and V1. We further used DCM for cross-spectral densities (Friston et al 2012) to estimate the coupling strength, conherence and the underlying conduction delay during visual flash stimulation, treating the LGN as a (hidden) relay. Here, we present the results from a single subject.

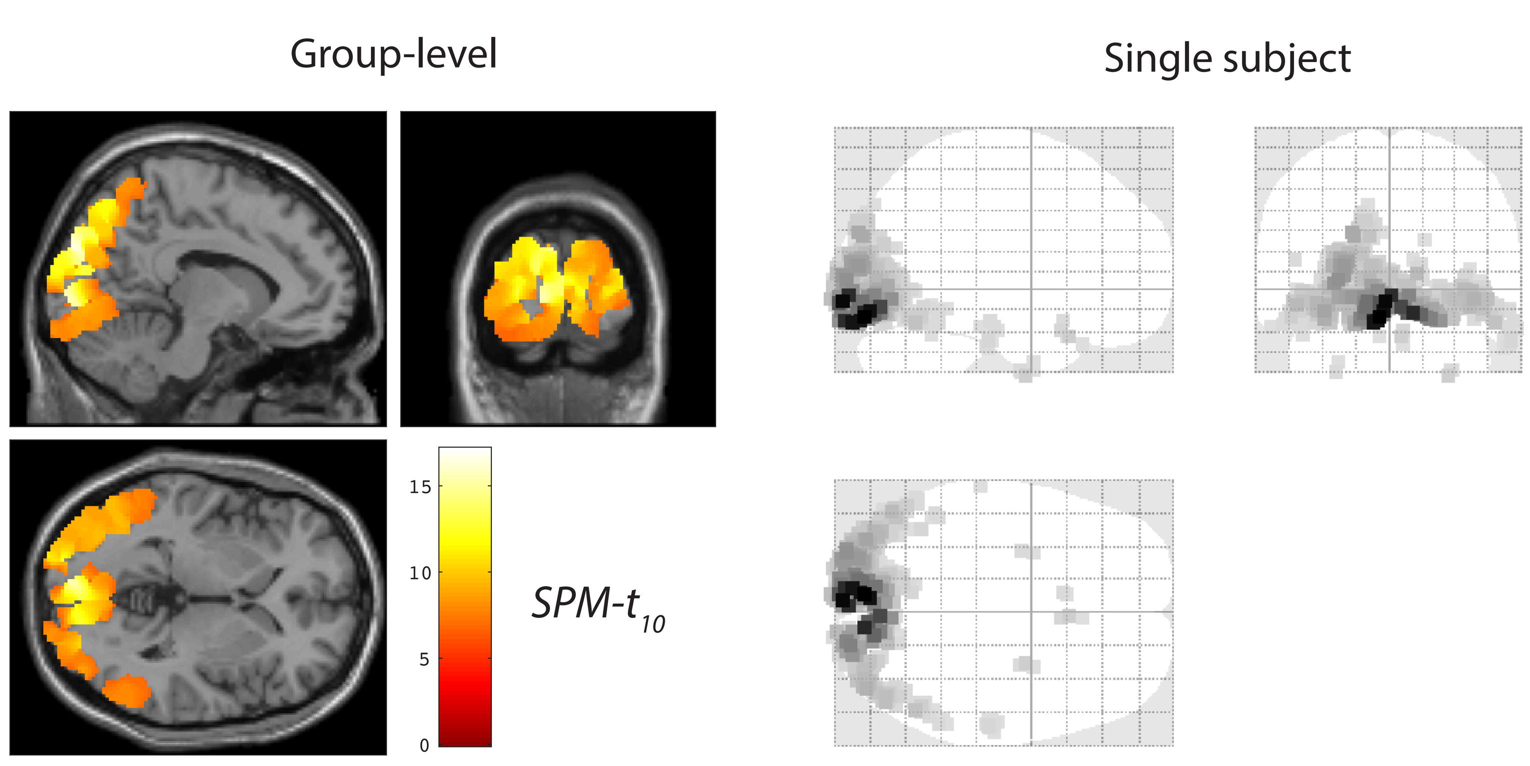
Conclusions and future research

Combining recordings from the human retina with electromagnetic recordings, we were able to show that feedforward projections (via the LGN) are likely to operate in both a frequency-specific manner and through cross-frequency coupling. We were able to obtain a realistic estimate of the conduction delay between retina and V1 (ffytche et al. 1995). Our future research will include a biologically realistic neural-mass model of the human retina for DCM of CSD. This will be important in characterizing diseases that affect both early and late connectivity in the visual system, including diabetic retinopathy and optic neuritis, as well as blindsight, extinction and neglect syndromes.

Evoked and induced reponses

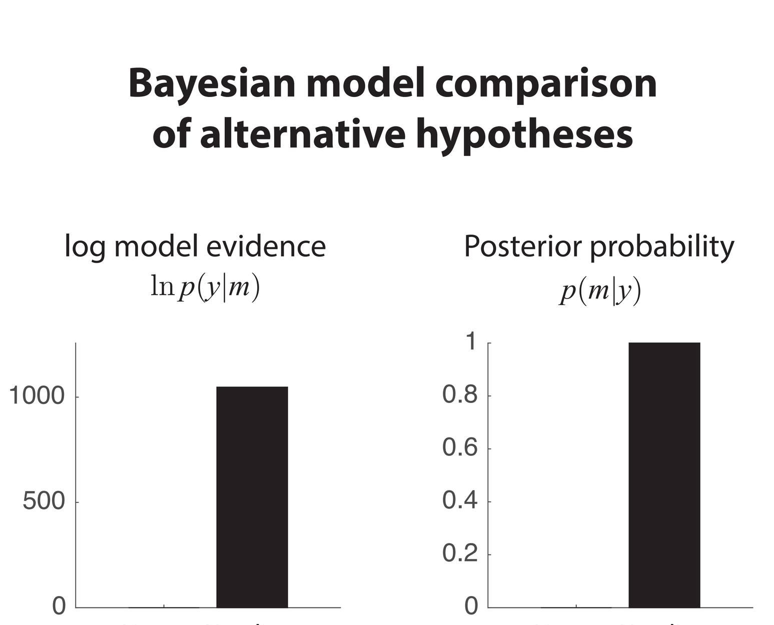


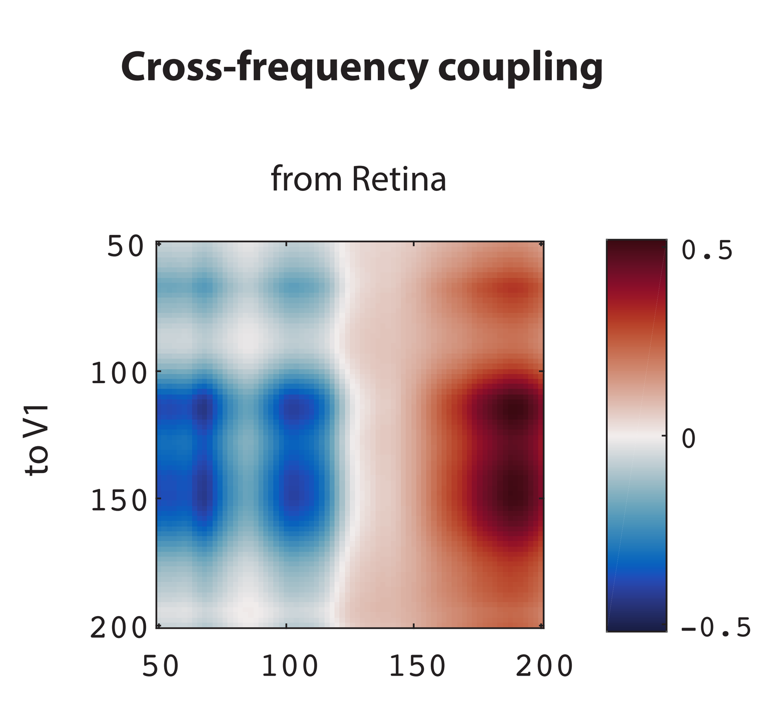
V1 source estimates for DCM



Source estimates summarized between 6-200 Hz and 0-200 ms for each subject using a wavelet projector

DCM of induced responses *(single subject)*



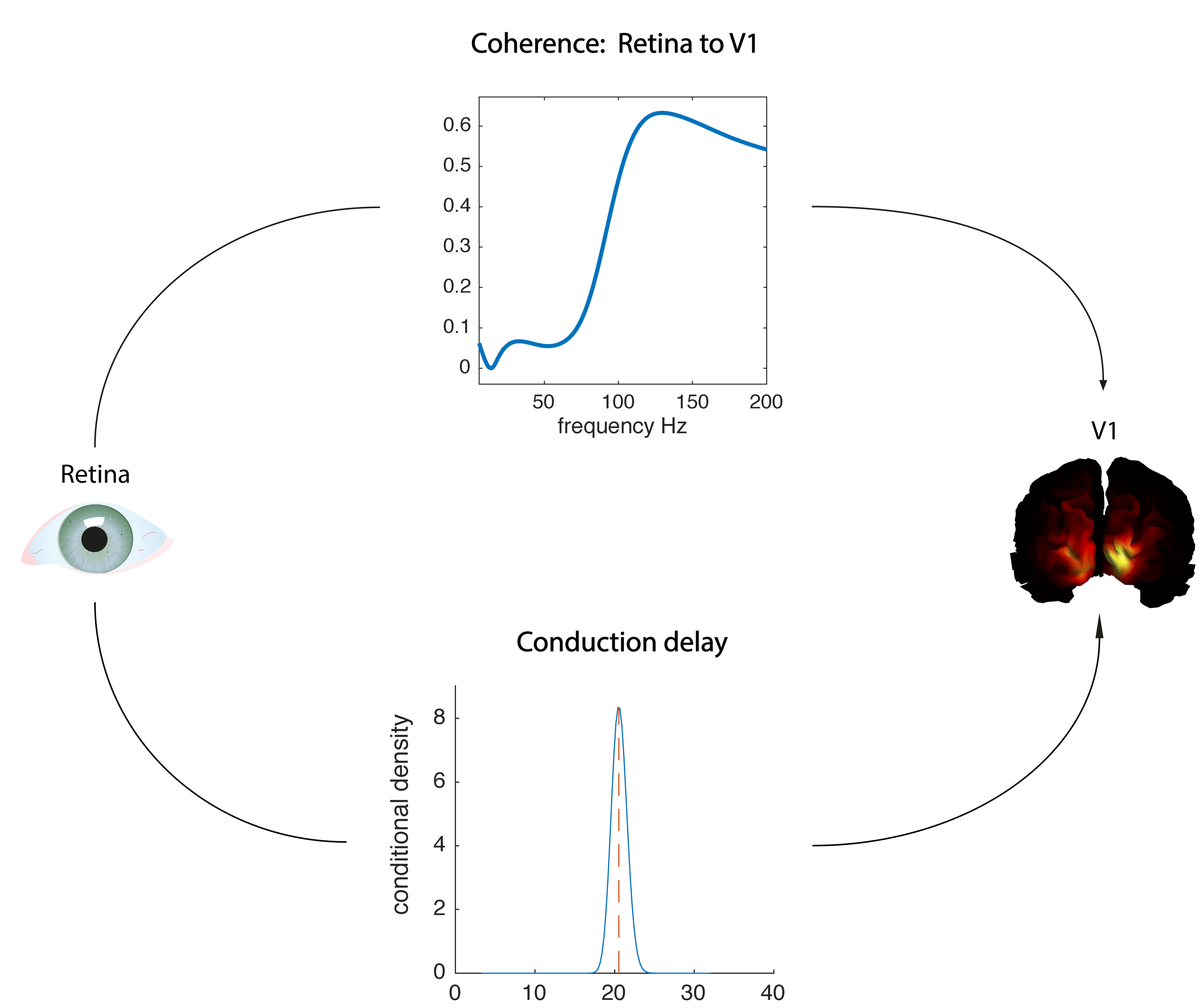


Linear: frequency-specific coupling between retina and V1

Non-linear: cross-frequency coupling between retina and V1

DCM of IR : Bayesian model comparison showed evidence for coupling across frequencies compared to frequency-specific coupling only. The coupling matrix revealed that high gamma responses in the retina (150-200 Hz) seem to drive high gamma in V1 (100-160 Hz). The direction of coupling between frequencies is from retina (x-axis) to V1 (y-axis)

DCM of cross-spectral density *(single subject)*



DCM of CSD : The estimated coupling strength between retina and V1 was 5.58 in relation to a prior coupling strength of 1 (Posterior probability > 0.99). The conherences between retina and V1 show that the spectral dependencies live in the high gamma range (100-200 Hz). Finally, the estimated conduction delay of 21 ms conforms to the latencies reported in the literature (see Shigiahara et al 2016 for summary).

References

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