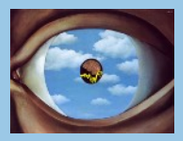
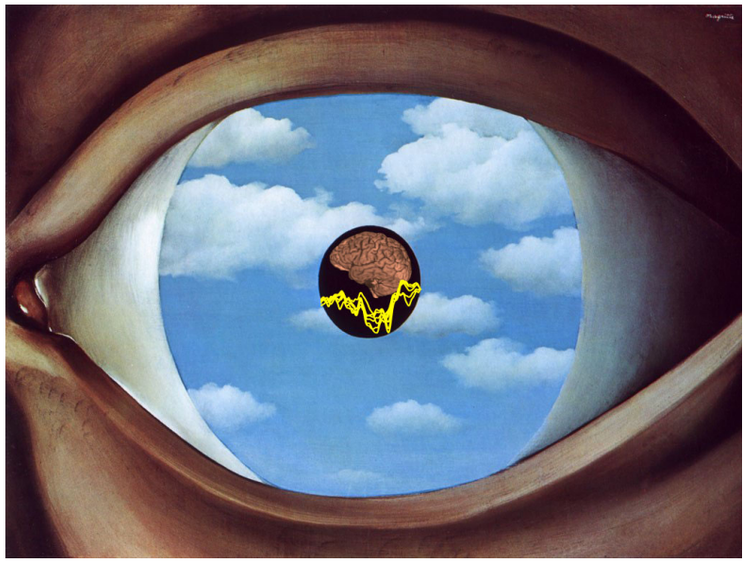


# The retina as a window to the brain
# *Retinal high-frequency oscillations drive corresponding rhythms in visual cortex*



Sarang Dalal
Center of Functionally Integrative Neuroscience
Aarhus University
sarang@cfin.au.dk

# ERG-MEG Opening Credits

Tzvetan Popov

Mathis Kaiser

Britta Westner

Monika Zeiller

Daniel Wong

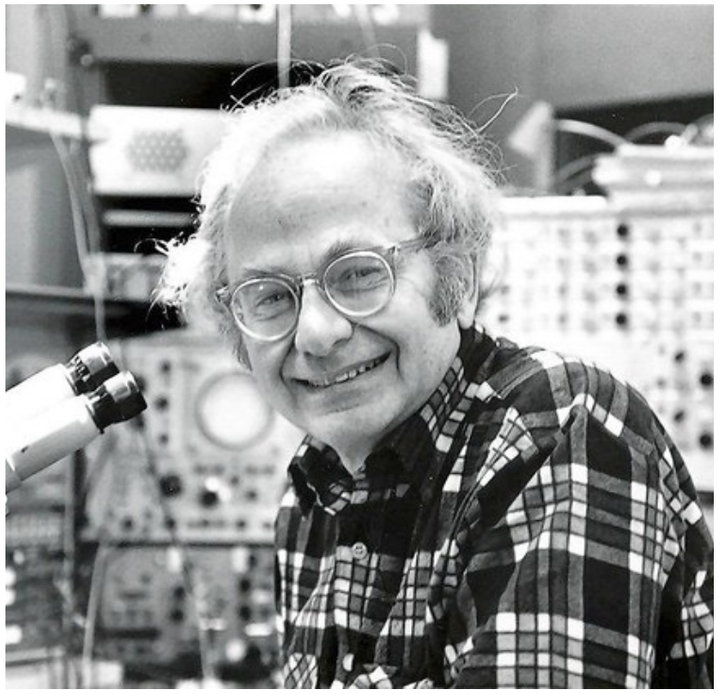
Ursula Lommen

erc

Zukunftskolleg
free • creative • connecting

neuron
Network of European Funding for Neuroscience Research

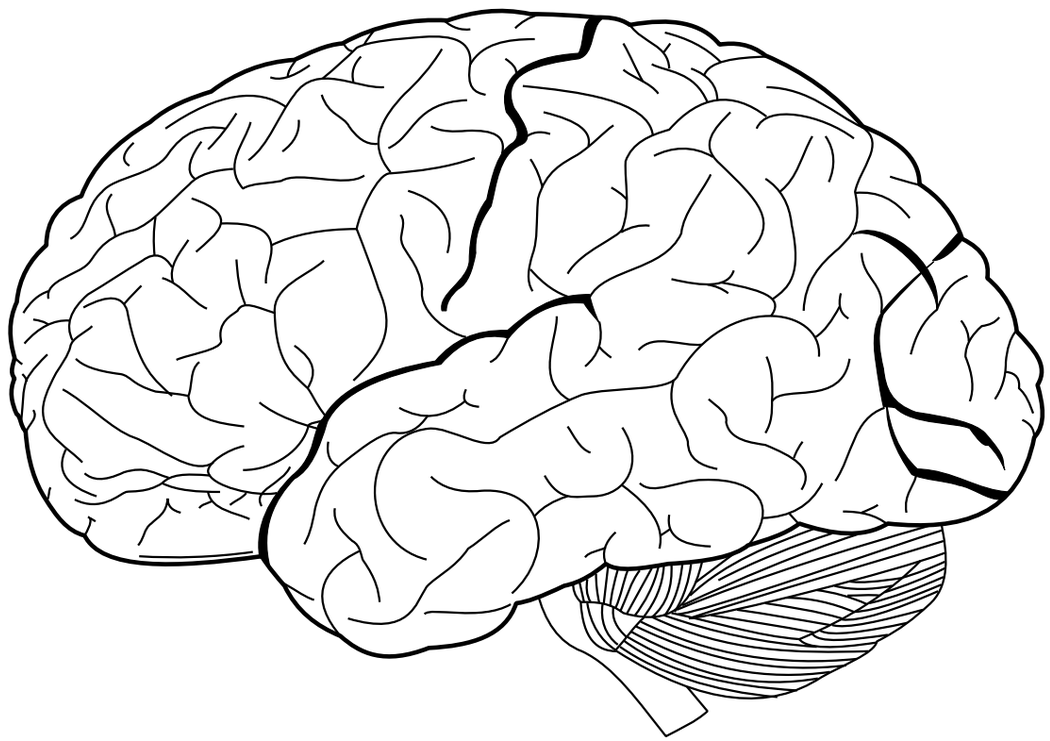
Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg



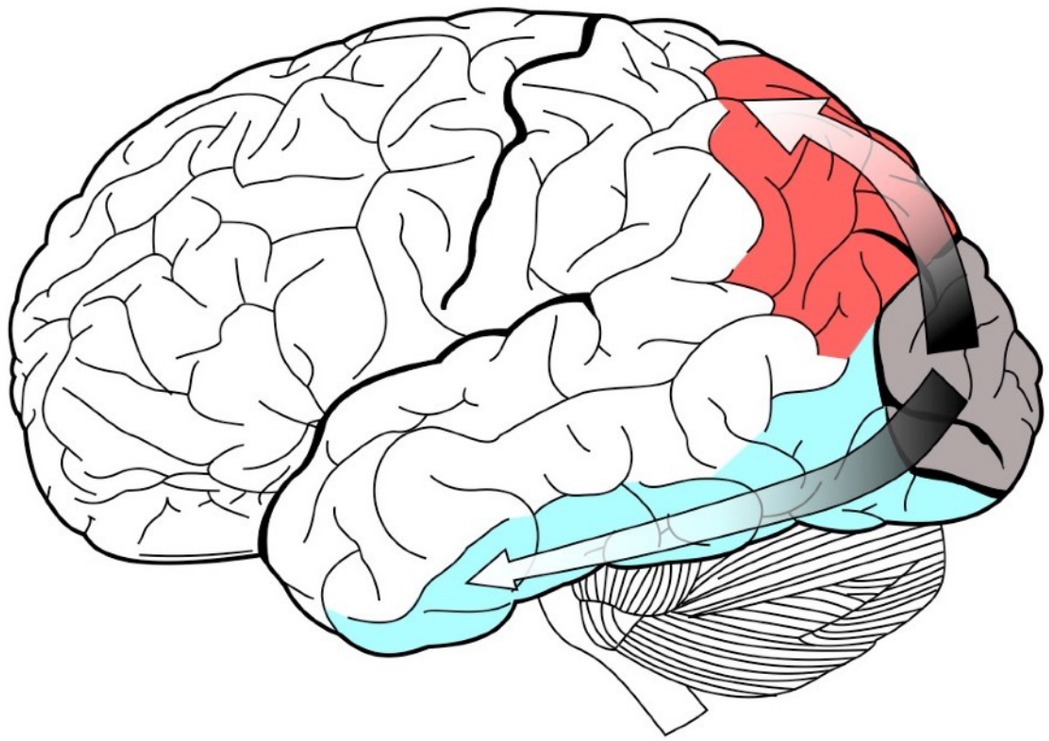
*"The **retina is part of the brain**, having been sequestered from it early in development but having kept its connections with the brain proper through a bundle of fibers – the optic nerve."*

*– David Hubel*

# Traditional Framework of Visual Processing

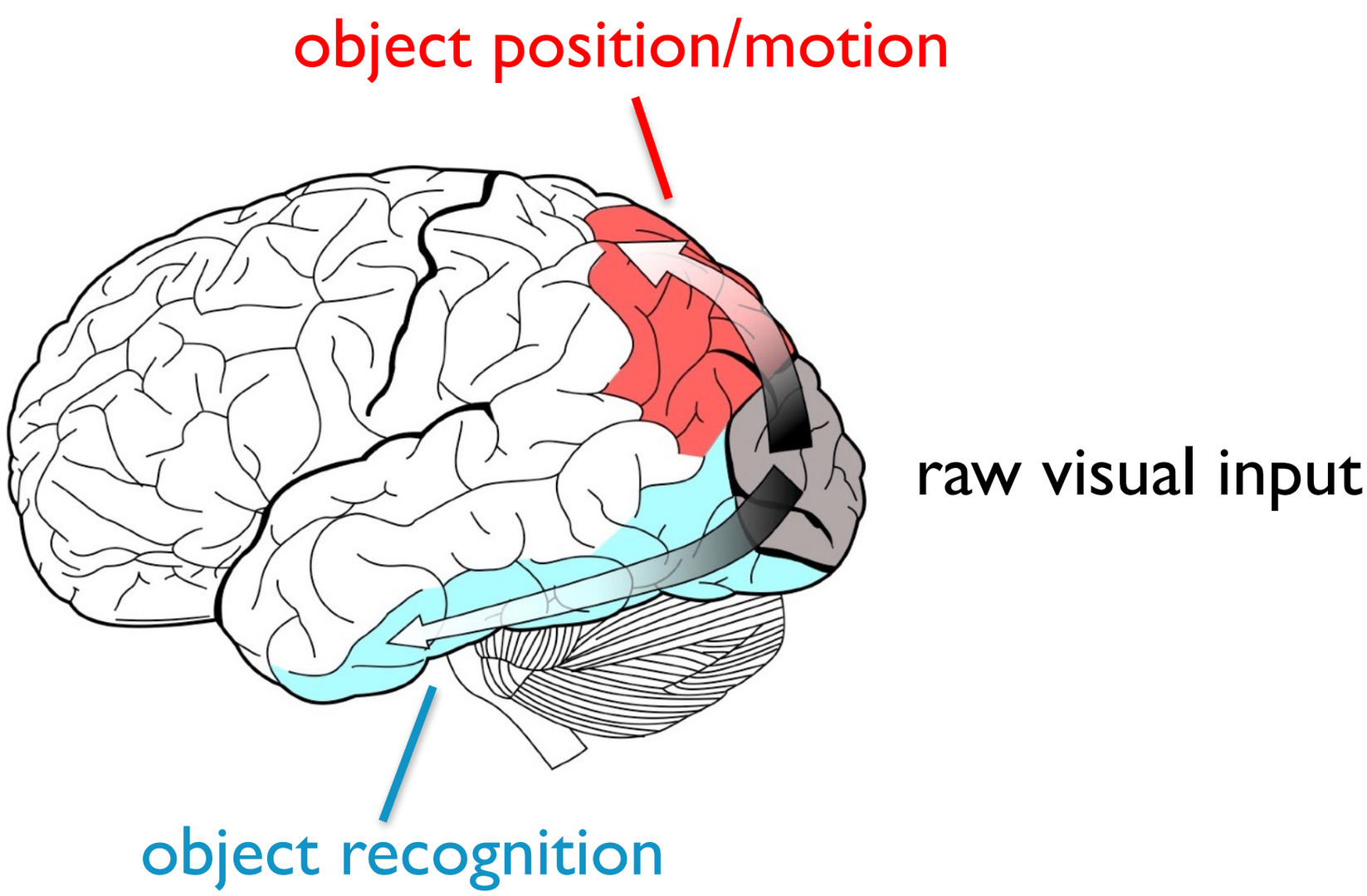


# Traditional Framework of Visual Processing

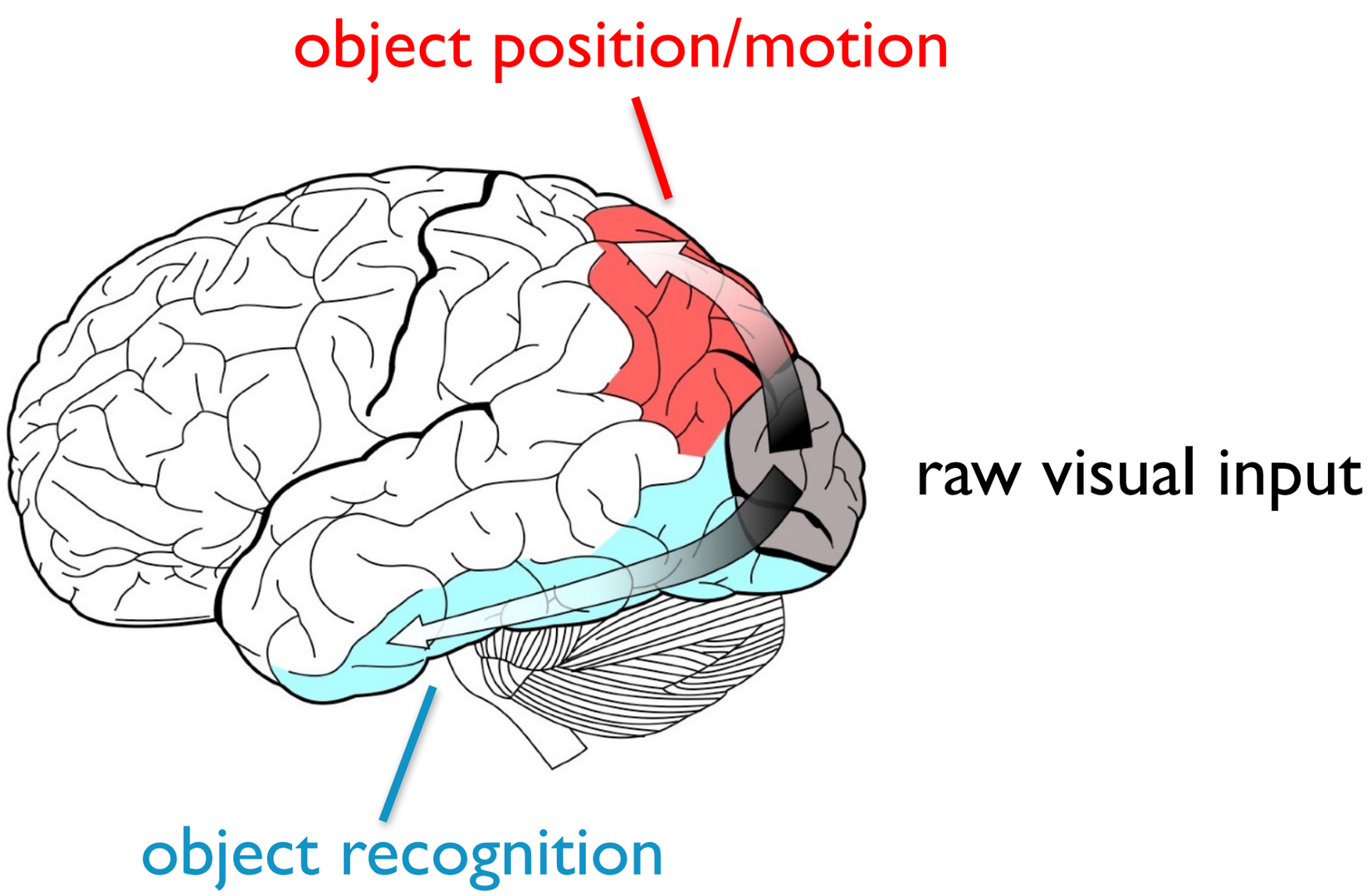


raw visual input

# Traditional Framework of Visual Processing

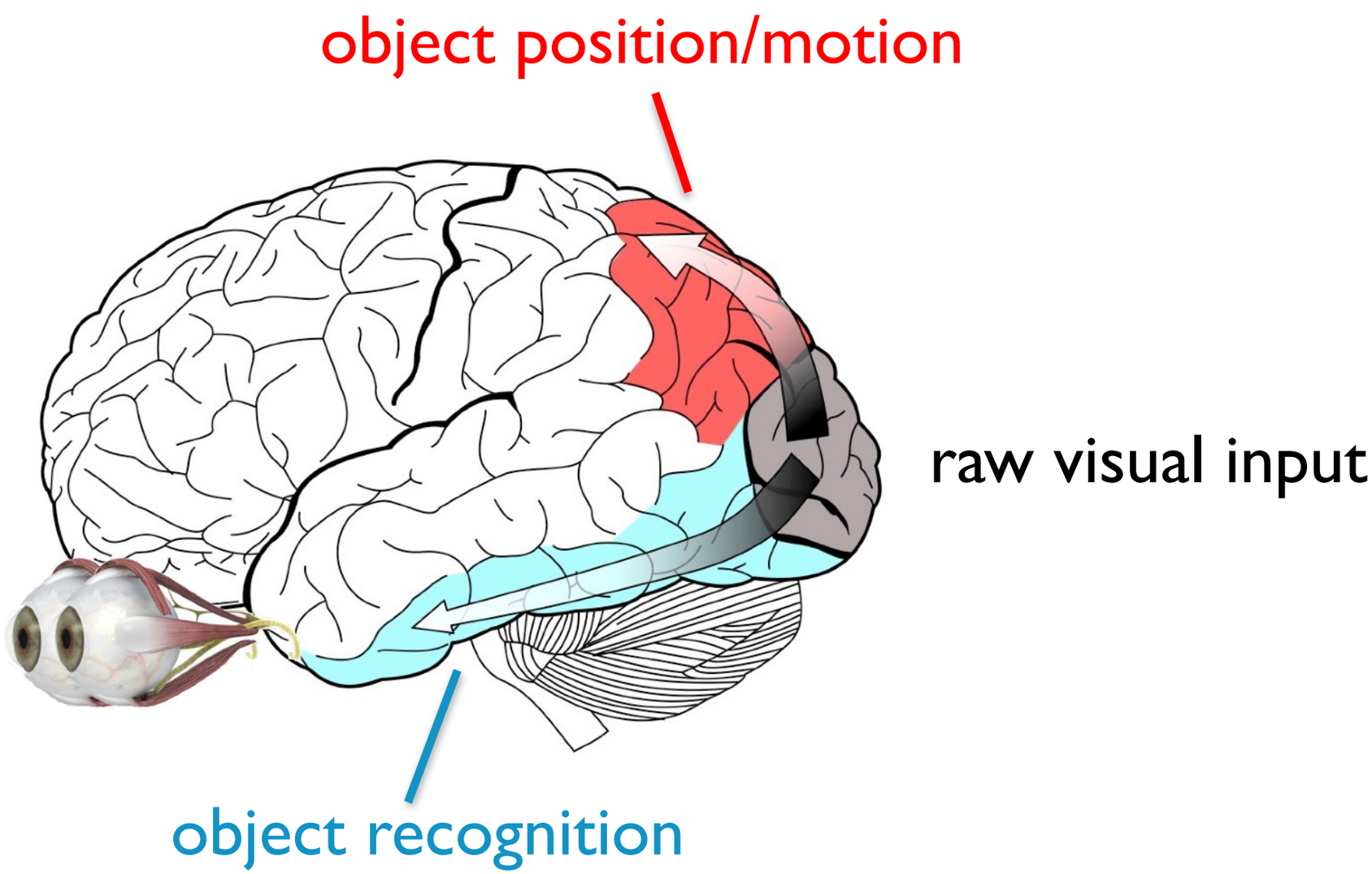


# Traditional Framework of Visual Processing



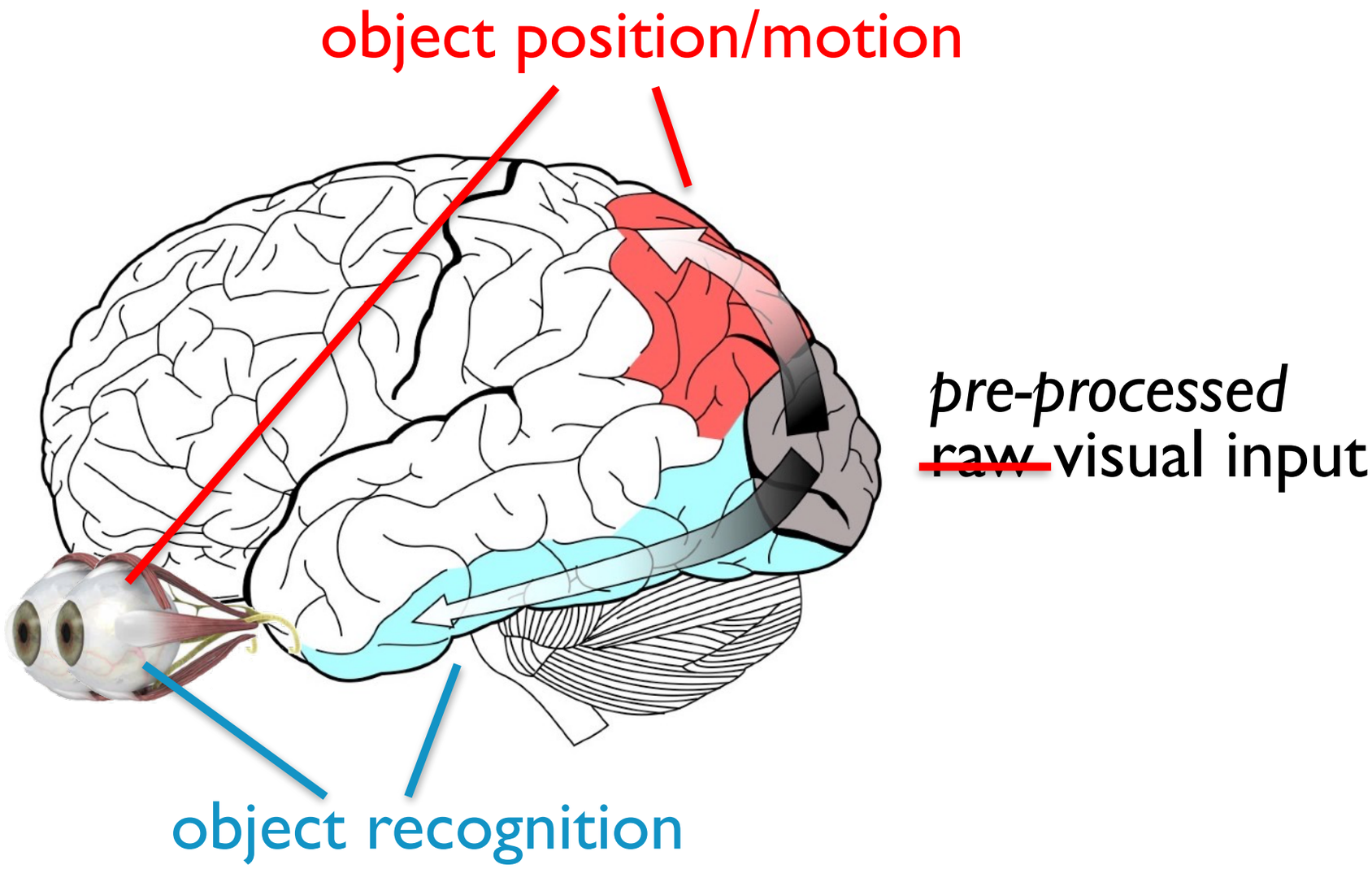

This is an overly **corticocentric** view that assumes the retina only passively relays visual information

# Traditional Framework of Visual Processing



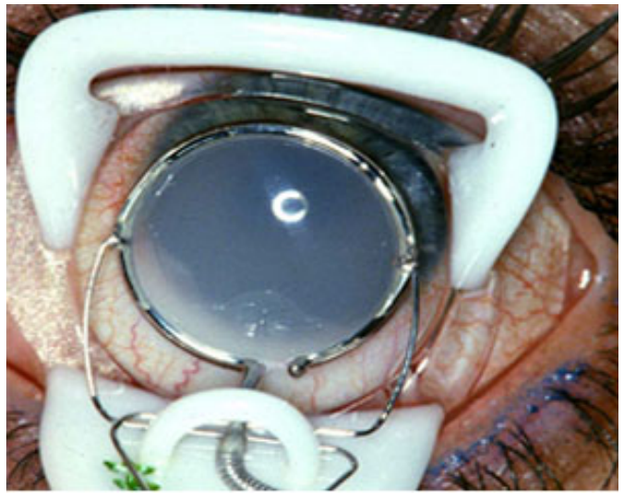

This is an overly **corticocentric** view that assumes the retina only passively relays visual information

# Traditional Framework of Visual Processing



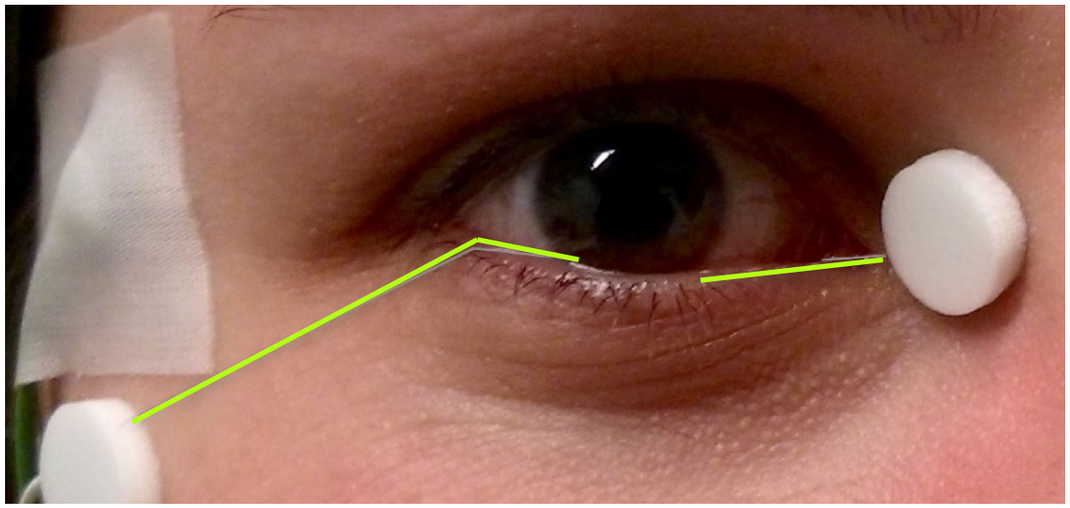

This is an overly **corticocentric** view that assumes the retina only passively relays visual information

# The Electroretinogram (ERG)



ERG is routine in eye clinics – but medically preferred electrodes are not appropriate for healthy volunteers

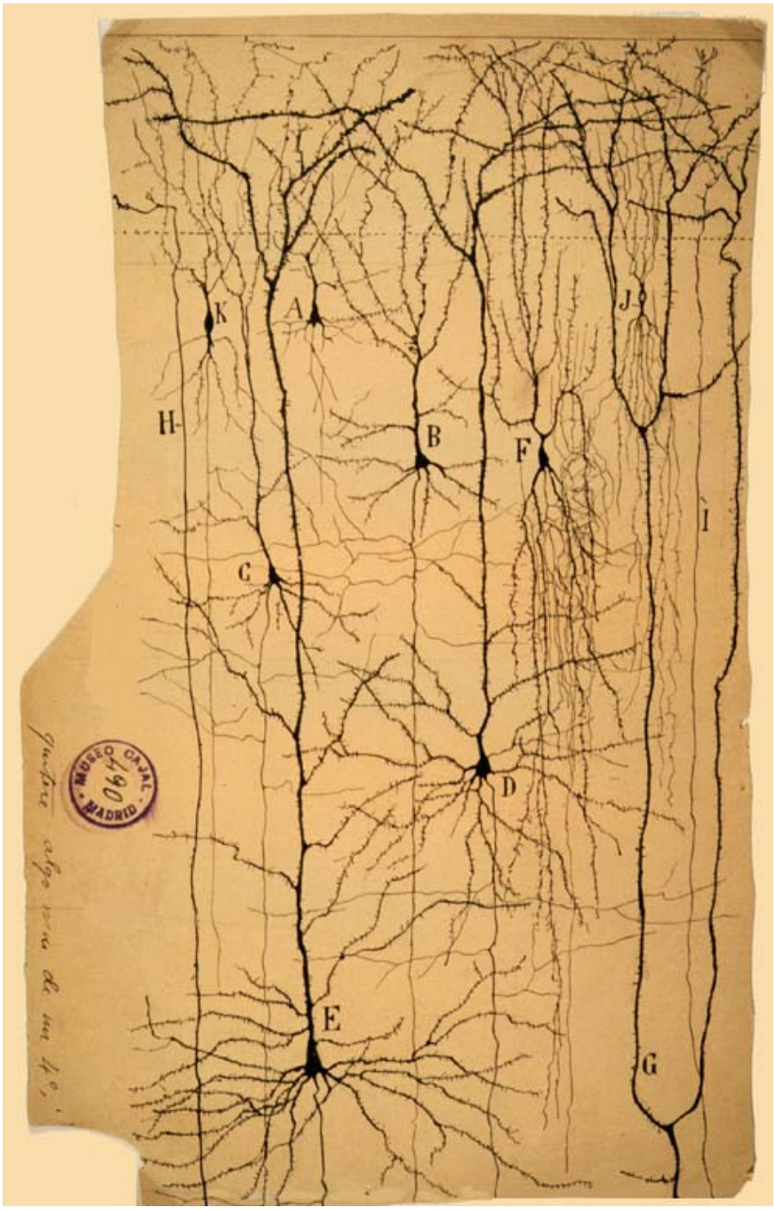
Lesser known but far more comfortable alternative, often used for children: the **DTL fiber electrode**



# Retinal Morphology & Potentials

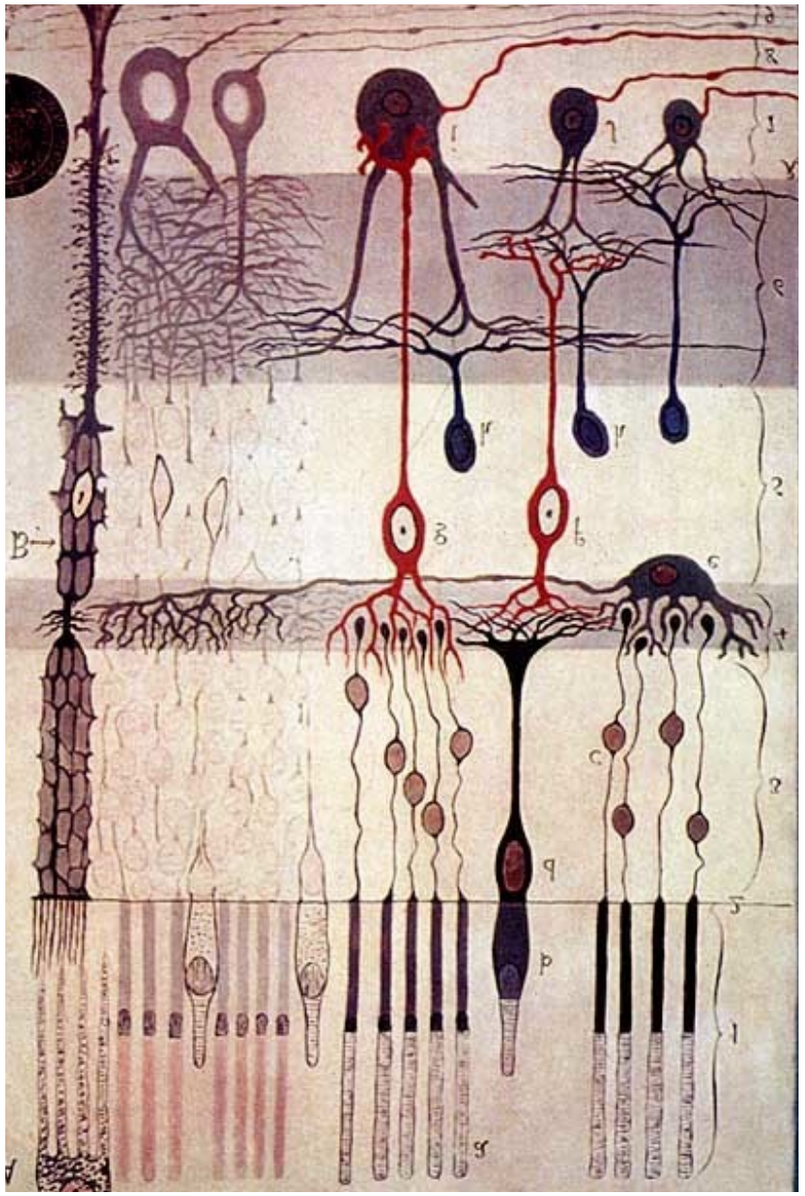
**MEG/EEG**

cortical structure

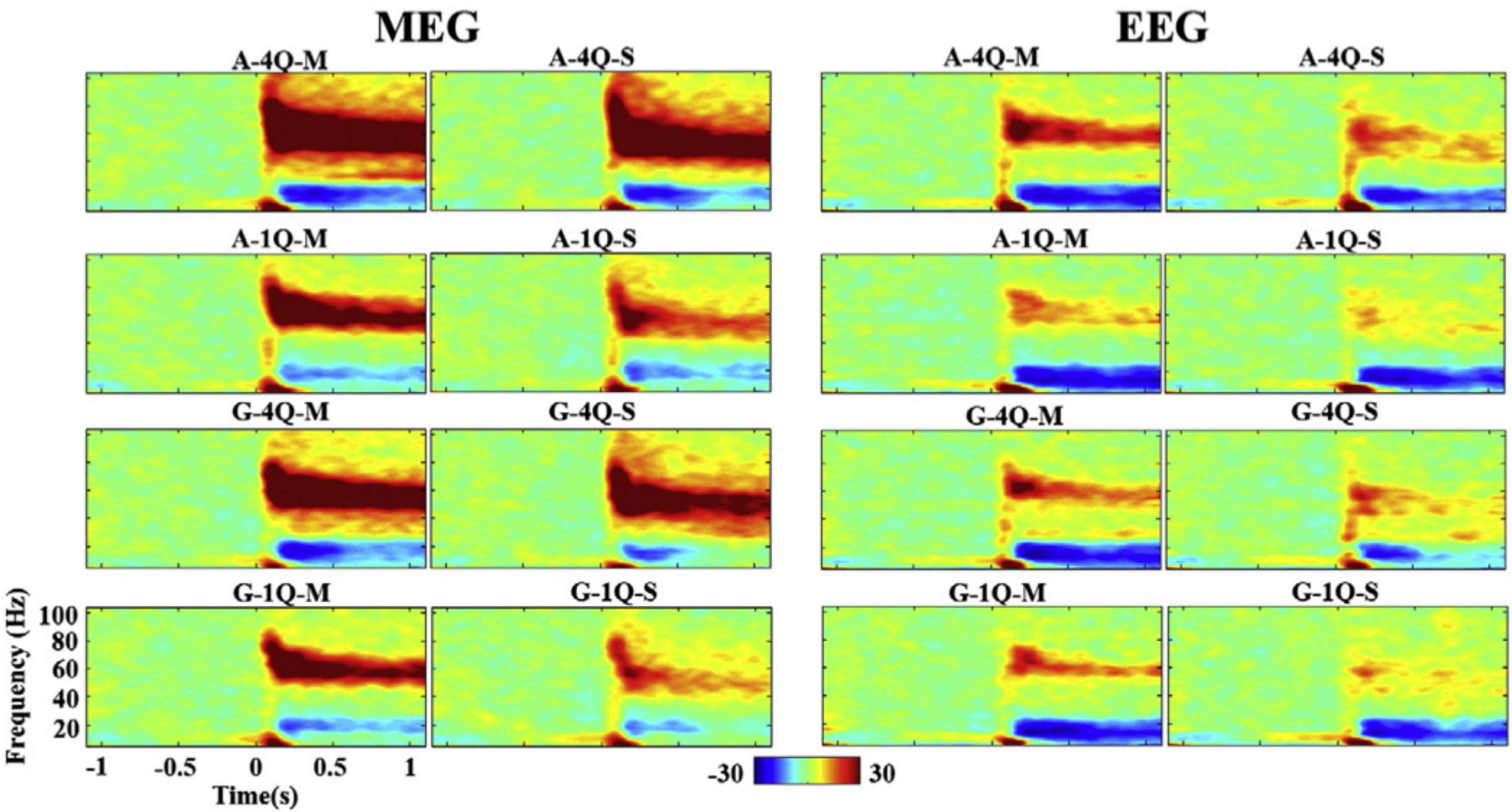



**ERG**

retinal structure

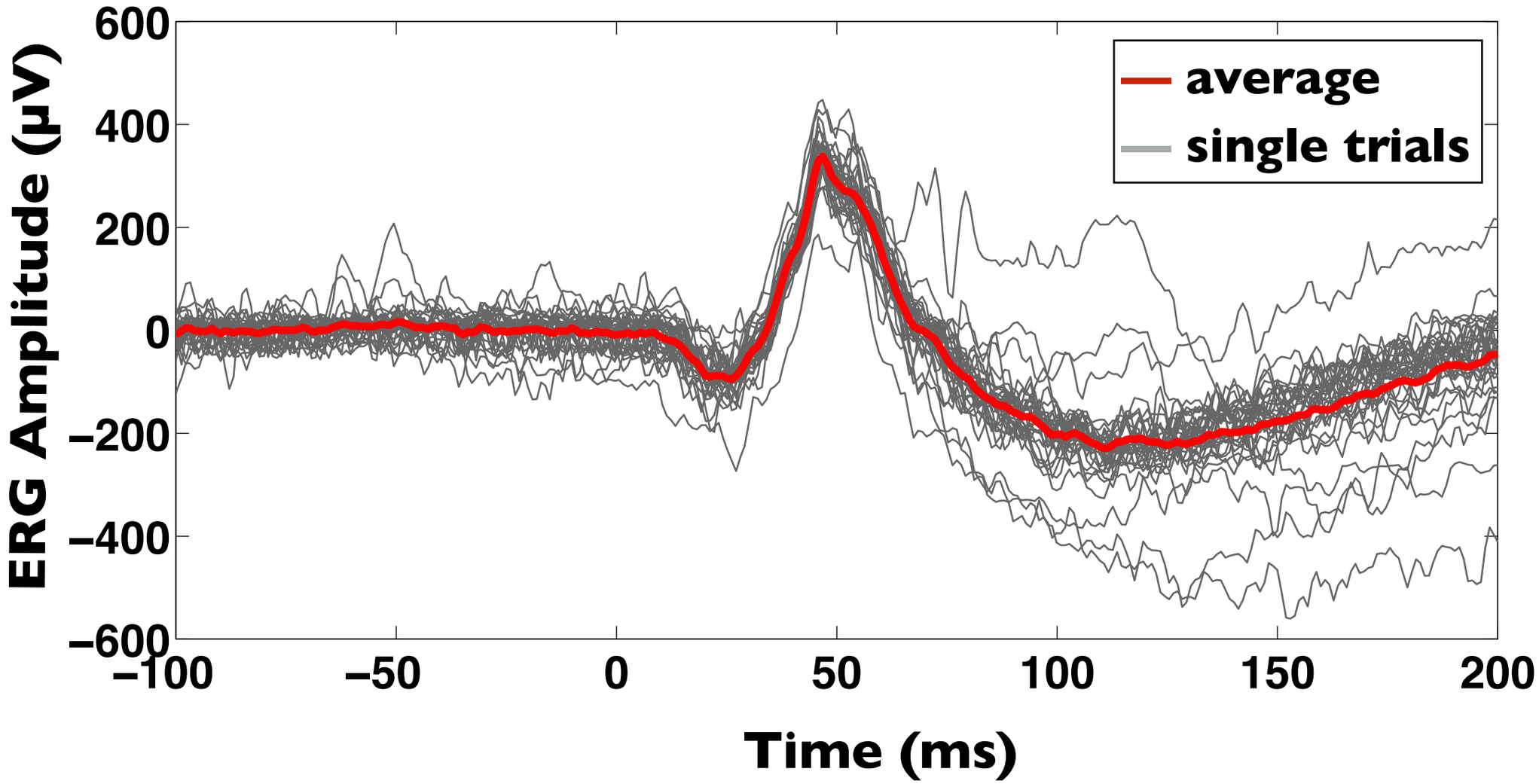


# MEG >> EEG for Visual Gamma



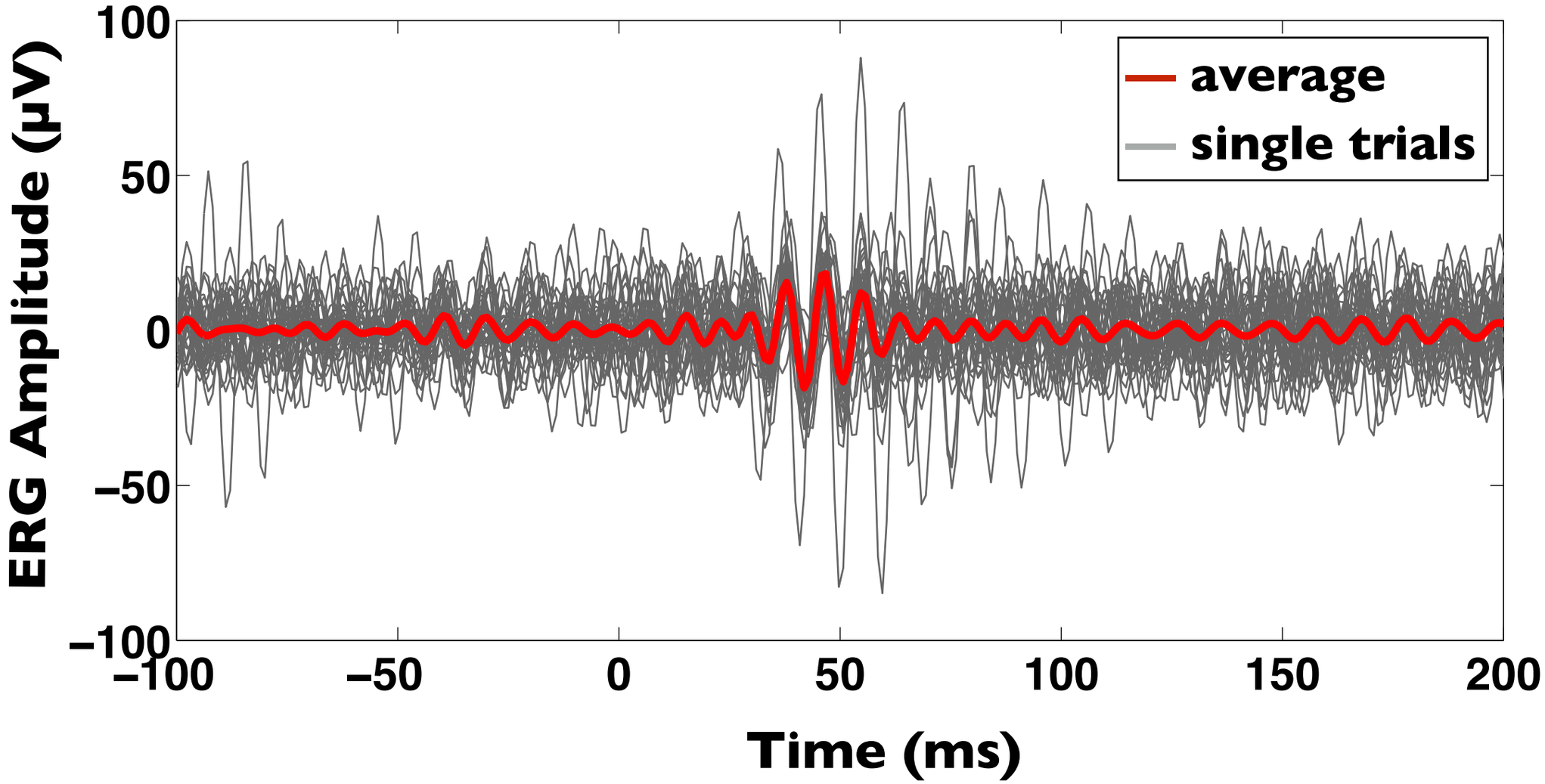

Muthukumaraswamy et al., 2013

# ERG has huge SNR




- Huge SNR, high amplitude signals reminiscent of intracranial EEG
- This makes single-trial analyses possible!

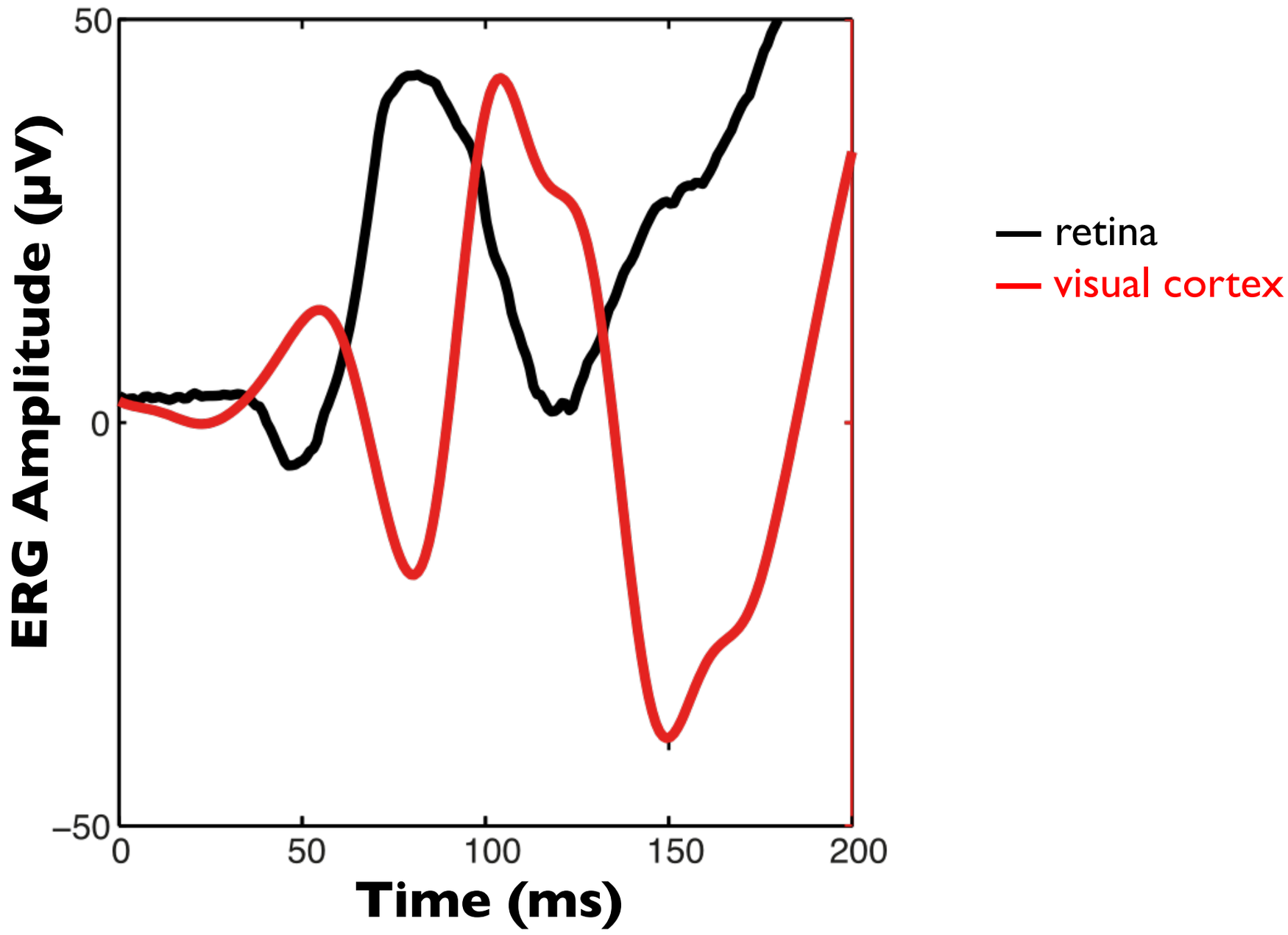
# ERG has huge SNR




- Huge SNR, high amplitude signals reminiscent of intracranial EEG
- This makes single-trial analyses possible!

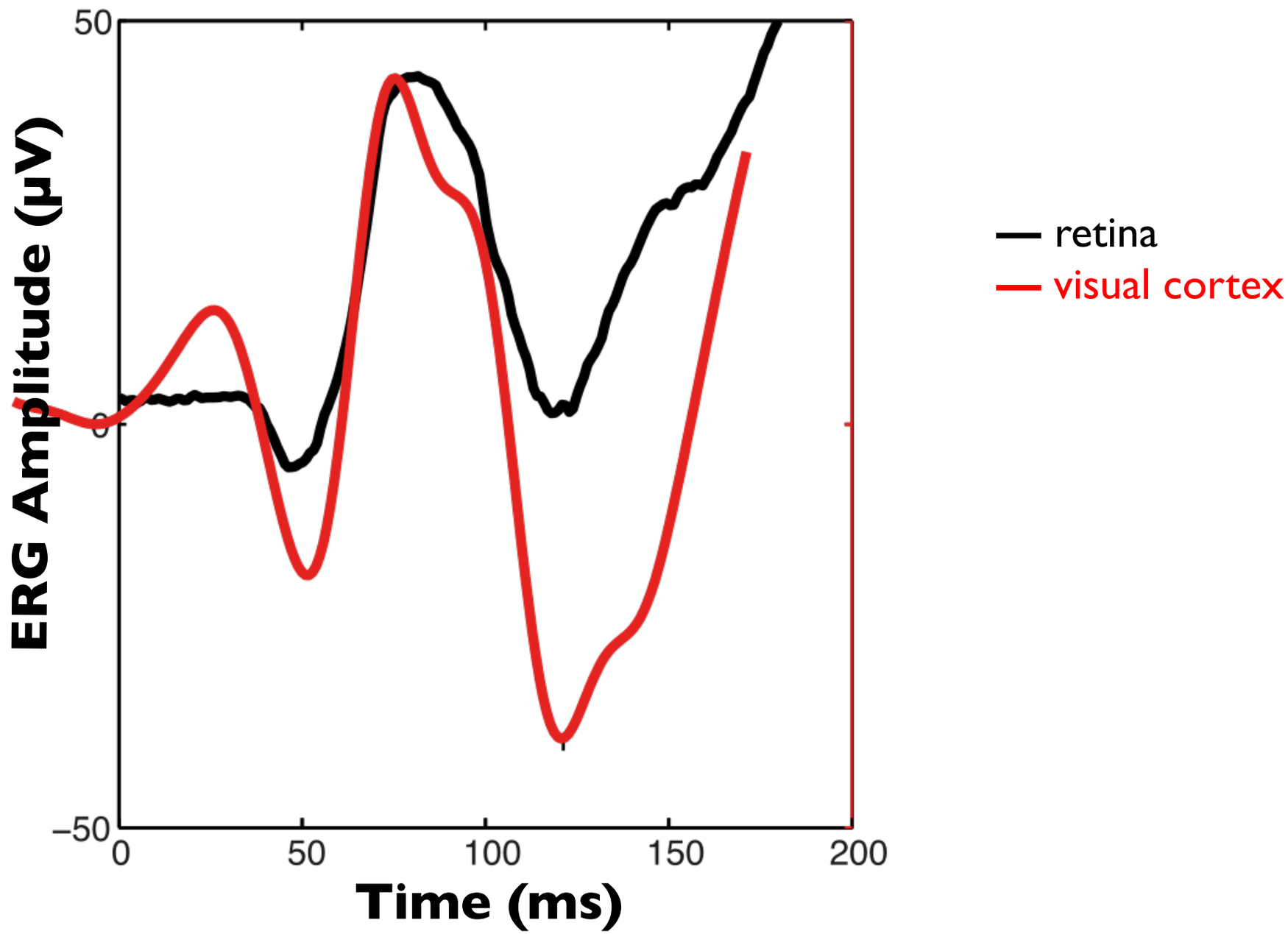
# ERG & MEG

- First study to combine DTL electrode with MEG
- Sanity check: visual cortex follows retina by 35 ms



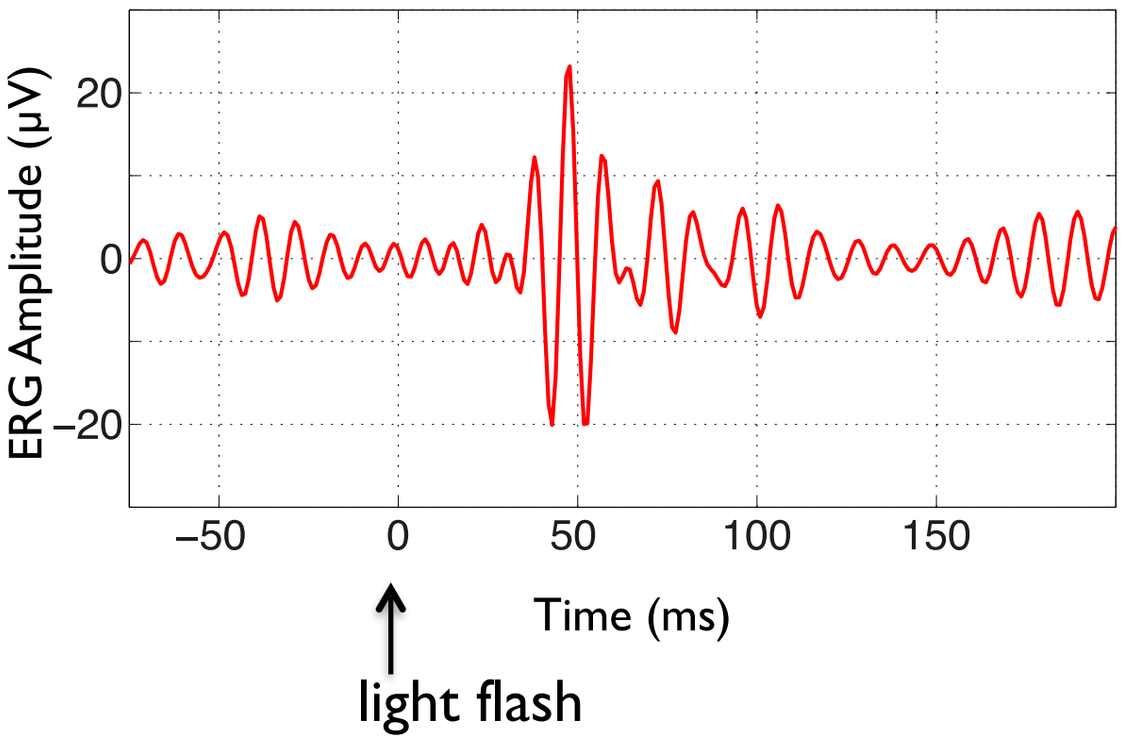
# ERG & MEG

- First study to combine DTL electrode with MEG
- Sanity check: visual cortex follows retina by 35 ms

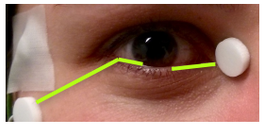


# Retinocortical Coherence

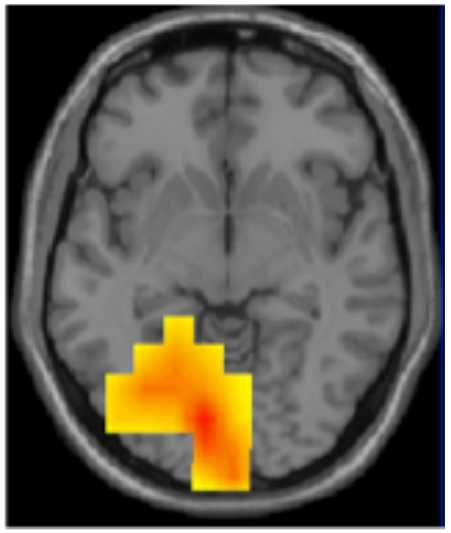
**ERG (filtered 100-120 Hz)**




**ERG** **MEG**



+

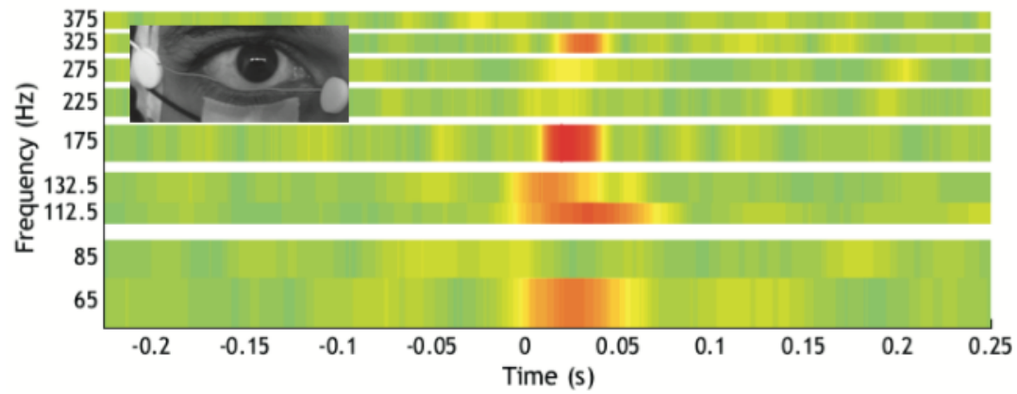


retina↔cortex information flow

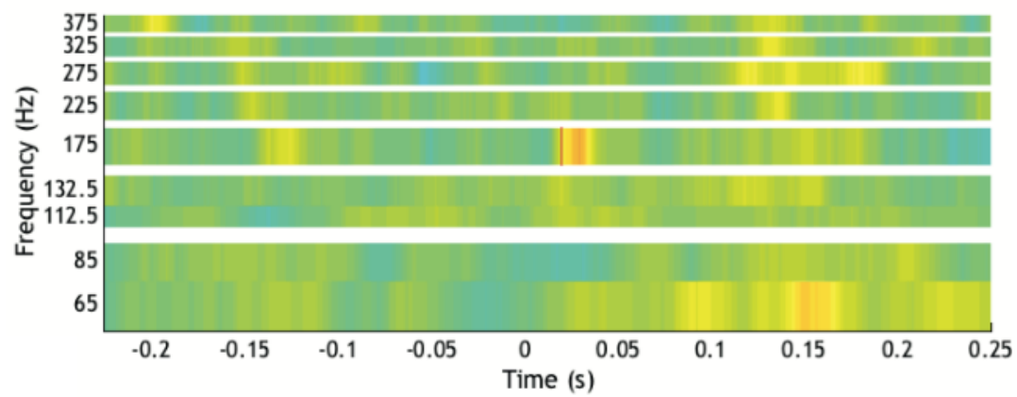
*retinocortical coherence*

N = 6, $p < 10^{-4}$

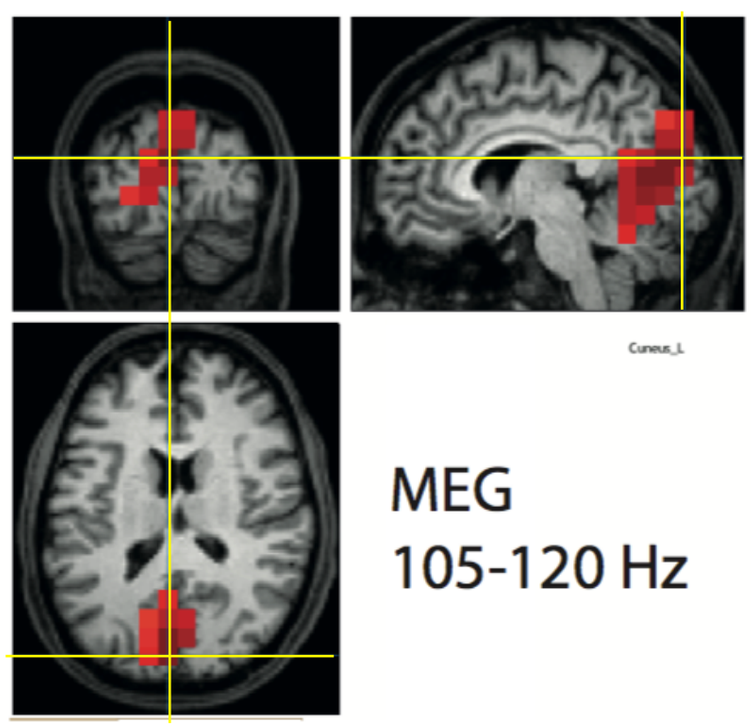
**ERG**



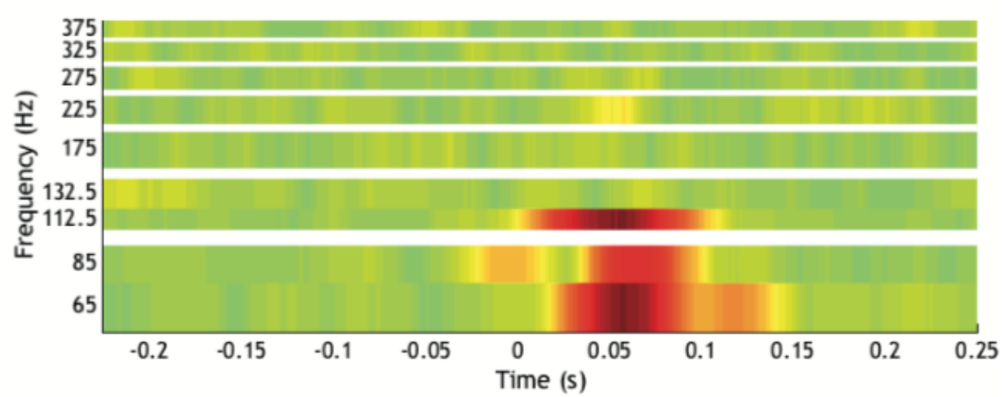

Phase-locking value



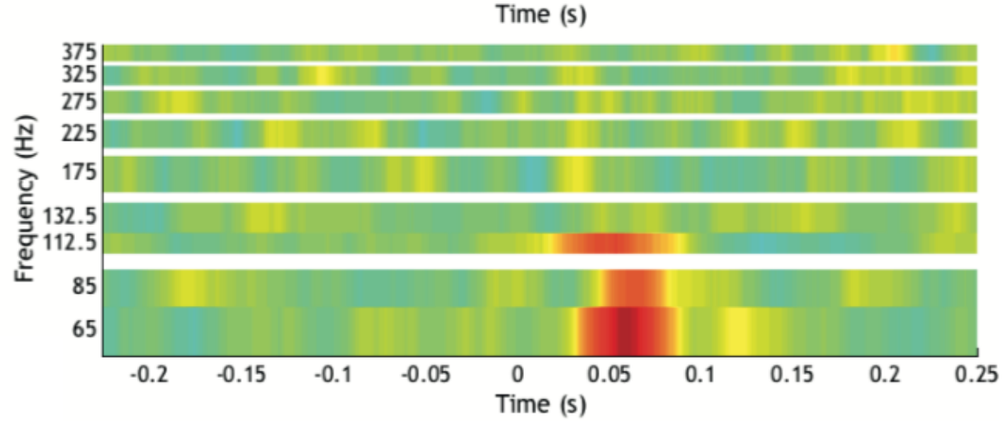

Analytic amplitude
(T-statistic across trials)



MEG
105-120 Hz

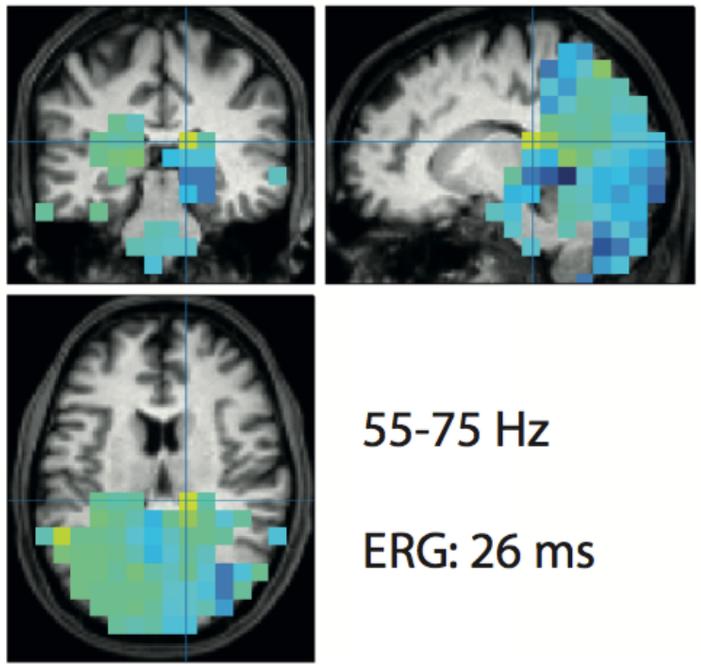



Phase-locking value



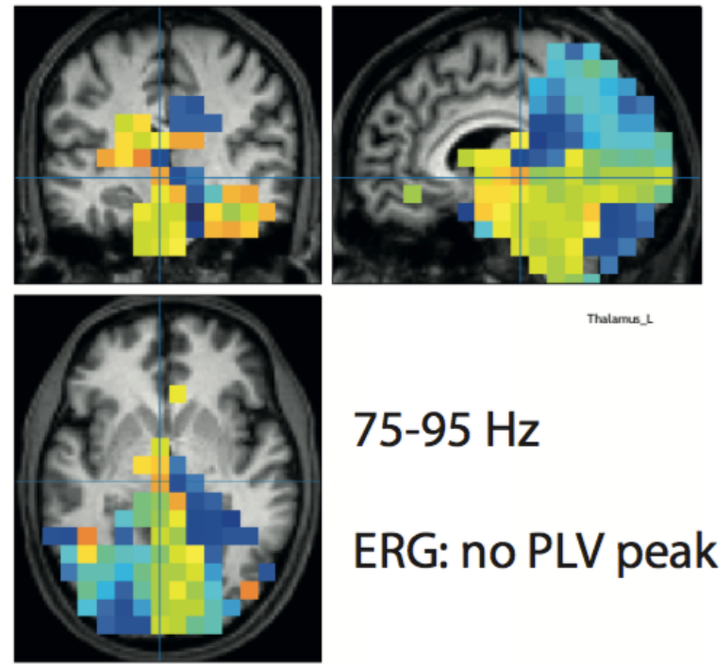

Analytic amplitude
(T-statistic across trials)

# Propagation times across the visual pathway



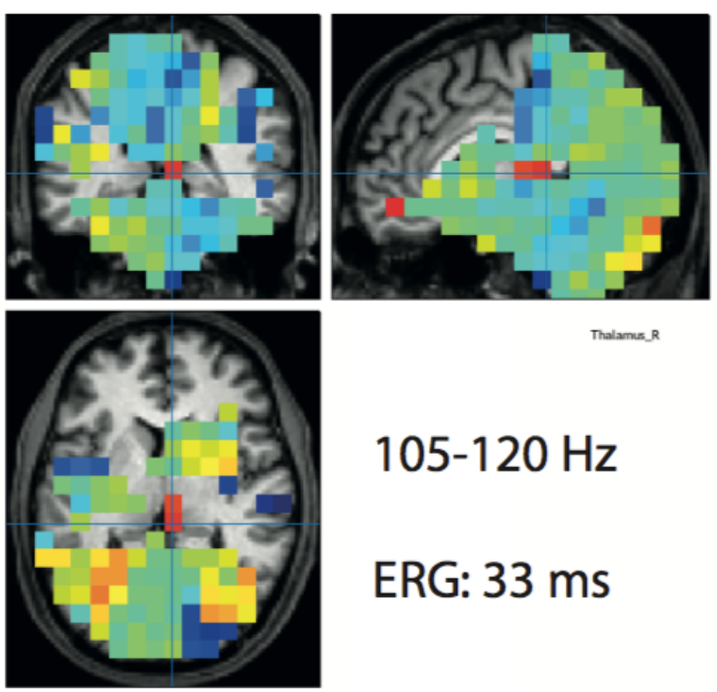
55-75 Hz

ERG: 26 ms



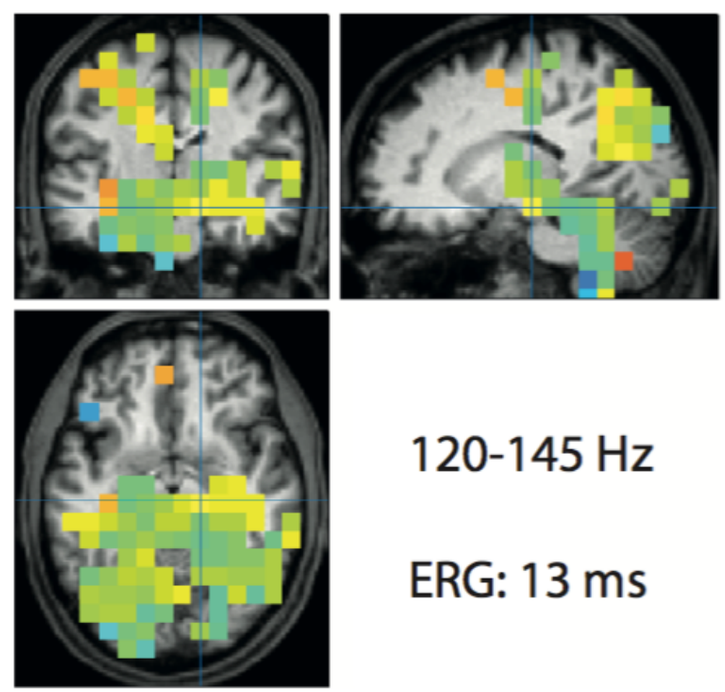

75-95 Hz

ERG: no PLV peak




105-120 Hz

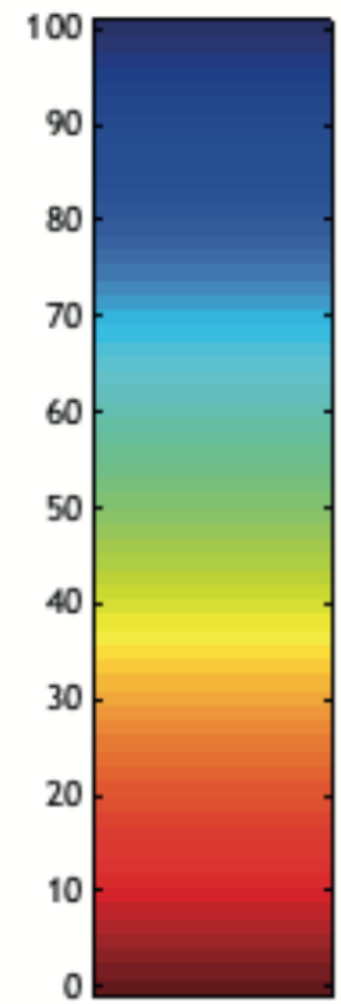
ERG: 33 ms



120-145 Hz

ERG: 13 ms

**latency of max PLV (ms)**
**(NOT power!)**




**slower**

**faster**

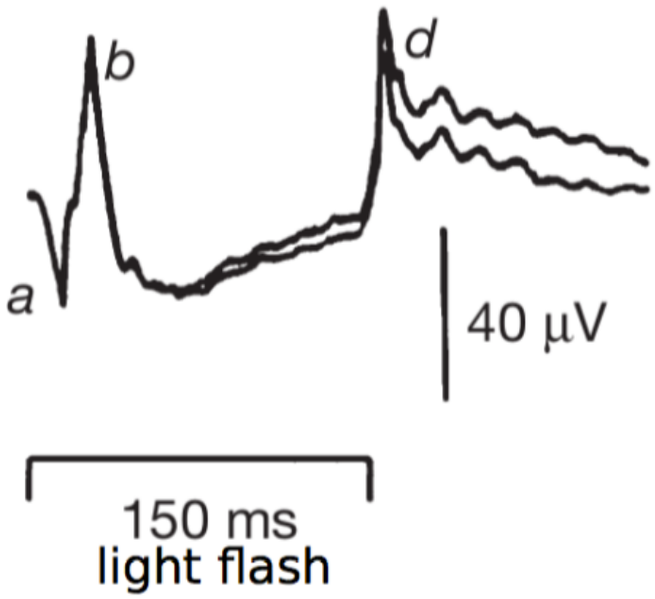
# Response to stimulus offset

The Journal of Neuroscience, June 8, 2011 • 31(23):8654 – 8658

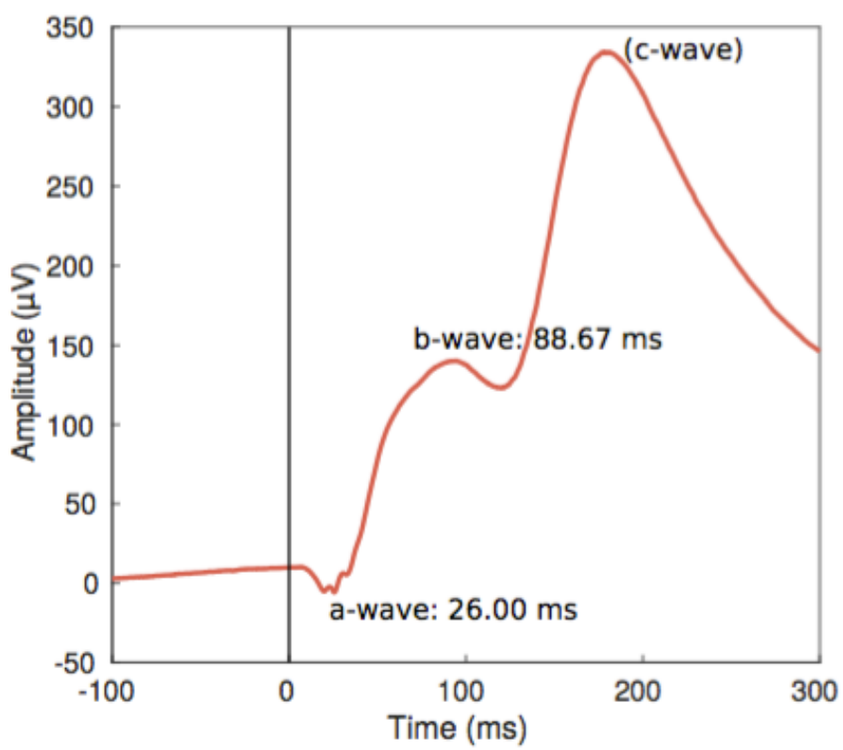
## Darks Are Processed Faster Than Lights

Stanley Jose Komban, Jose-Manuel Alonso, and Qasim Zaidi

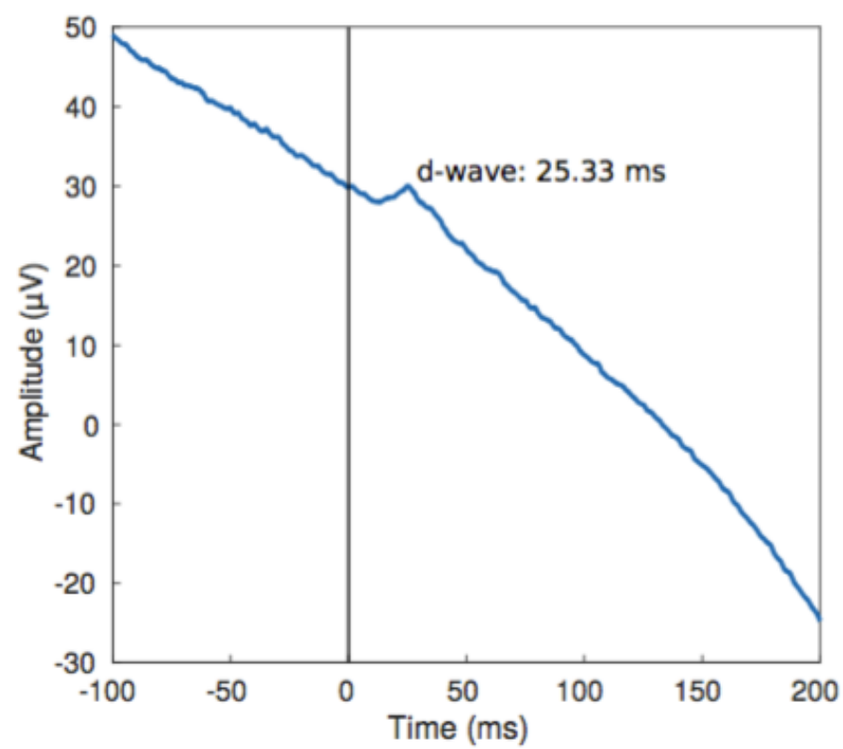
- largely assumed to be cortical phenomenon
- but the retina has dedicated circuitry for "darks"!



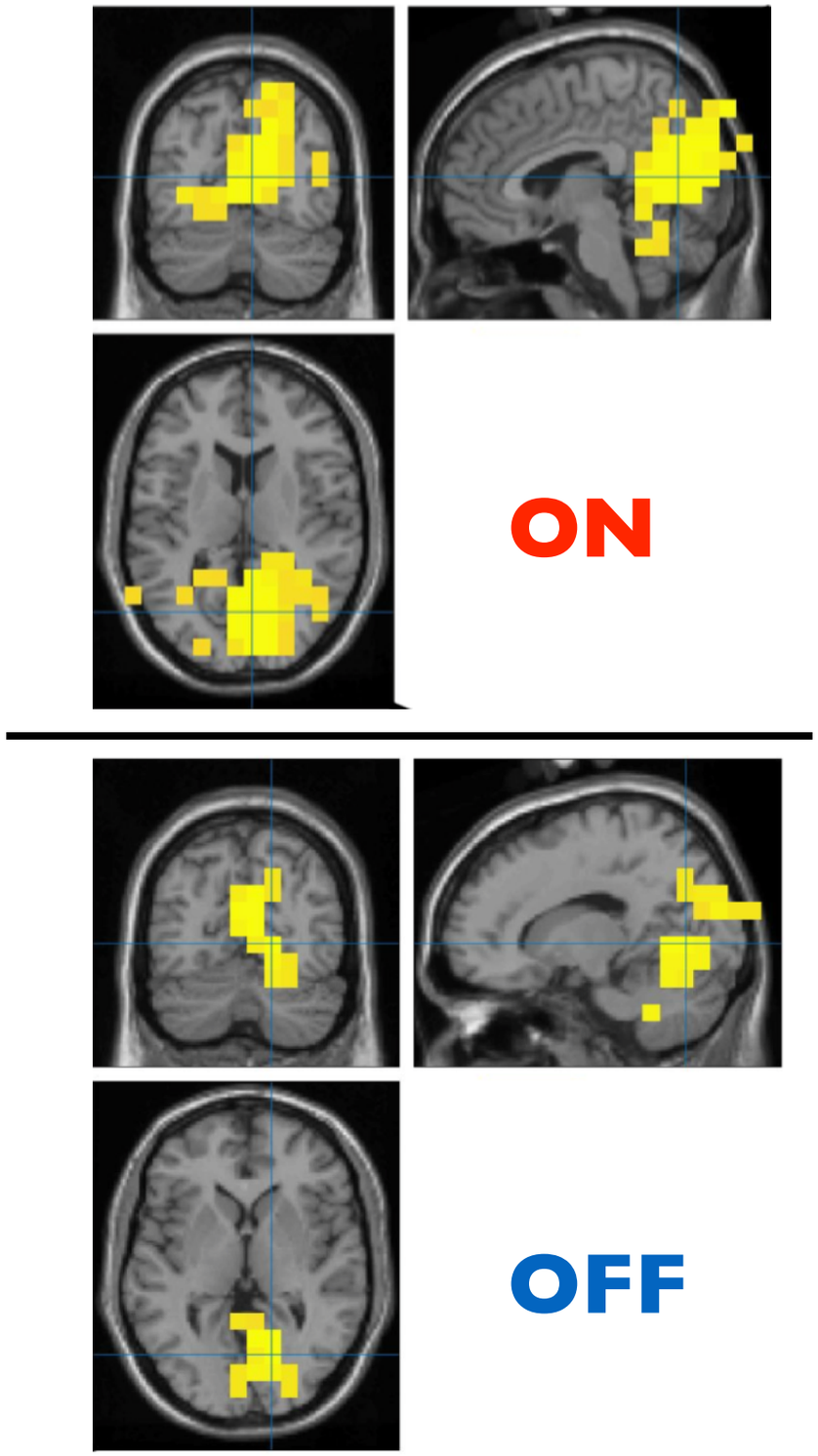

Light on

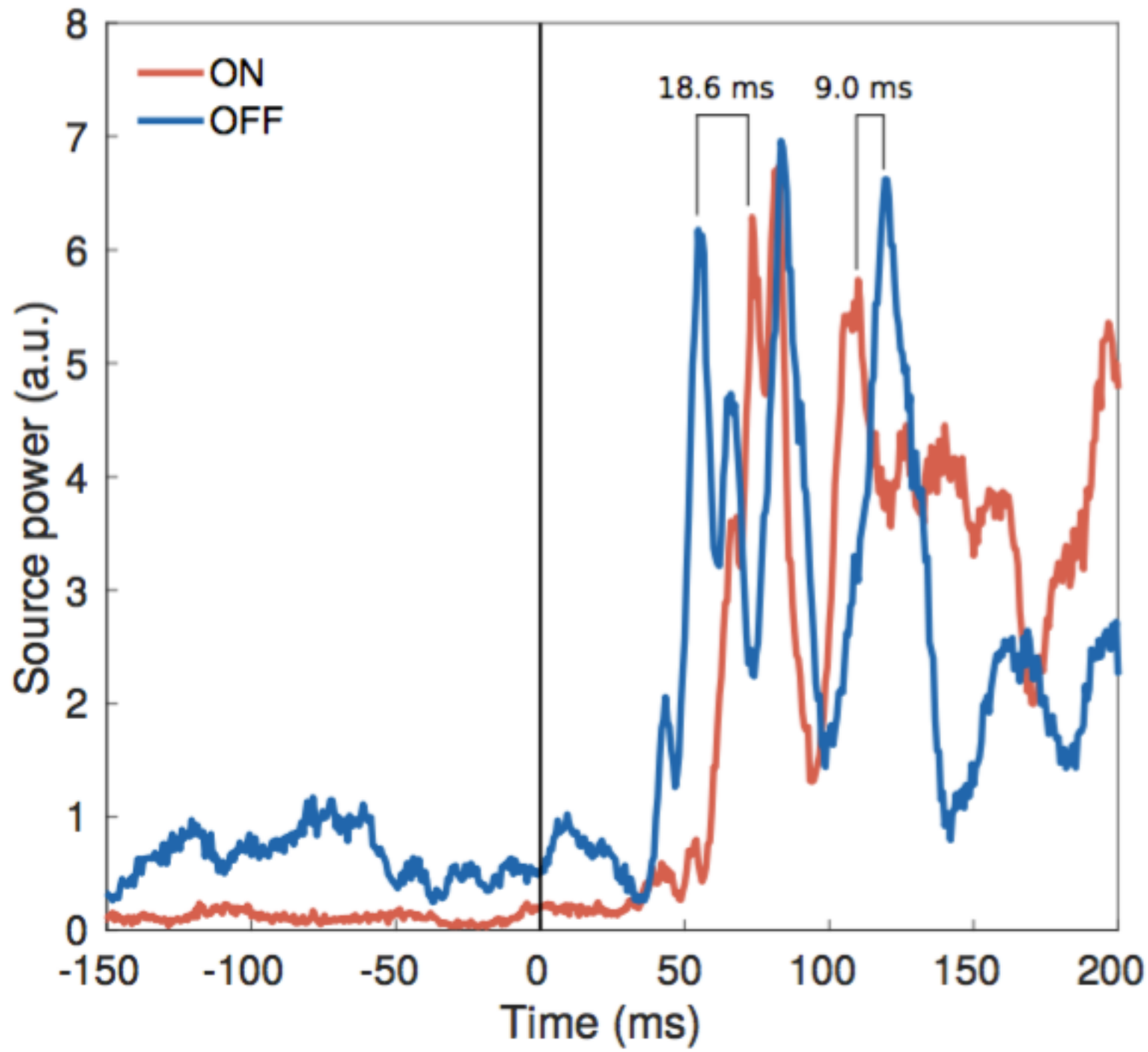



Light off

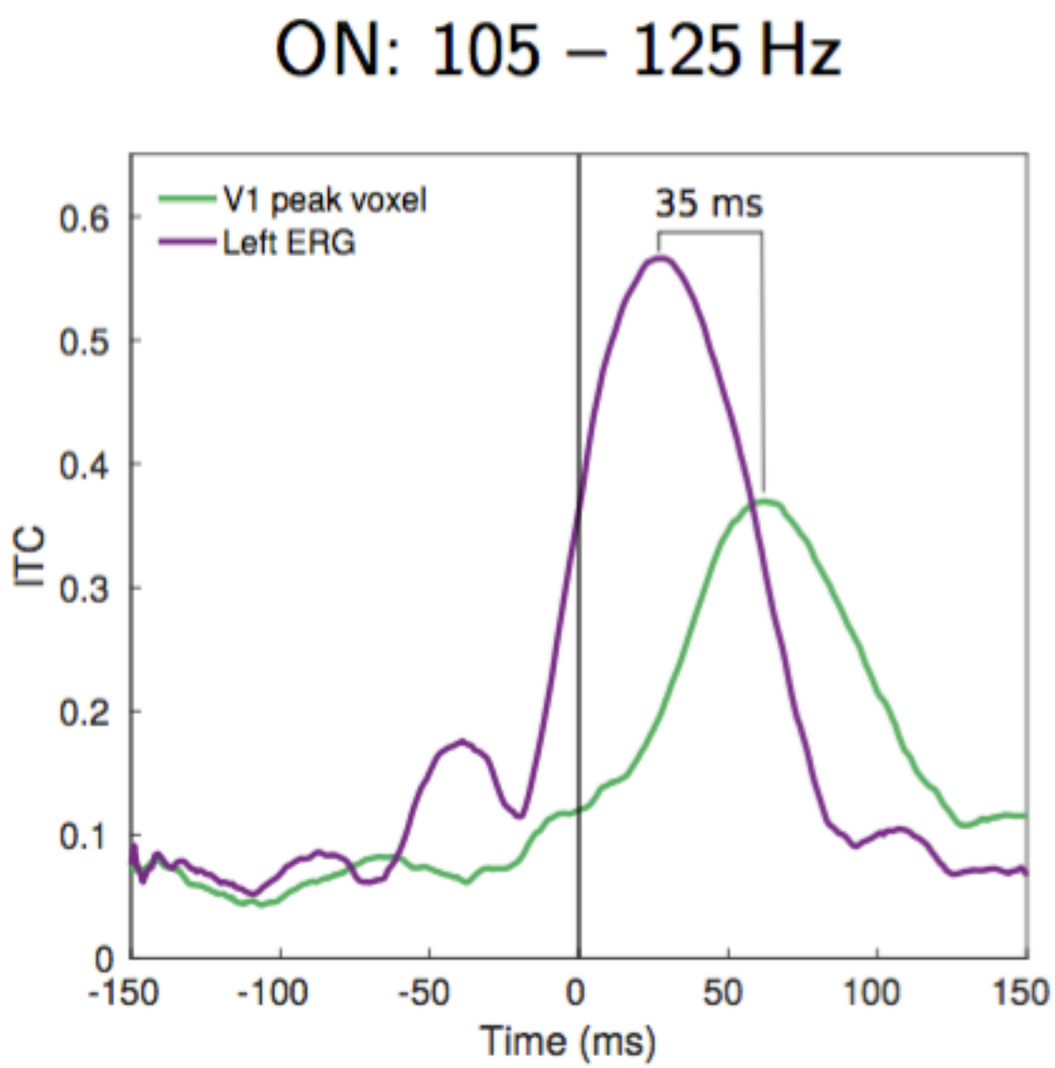


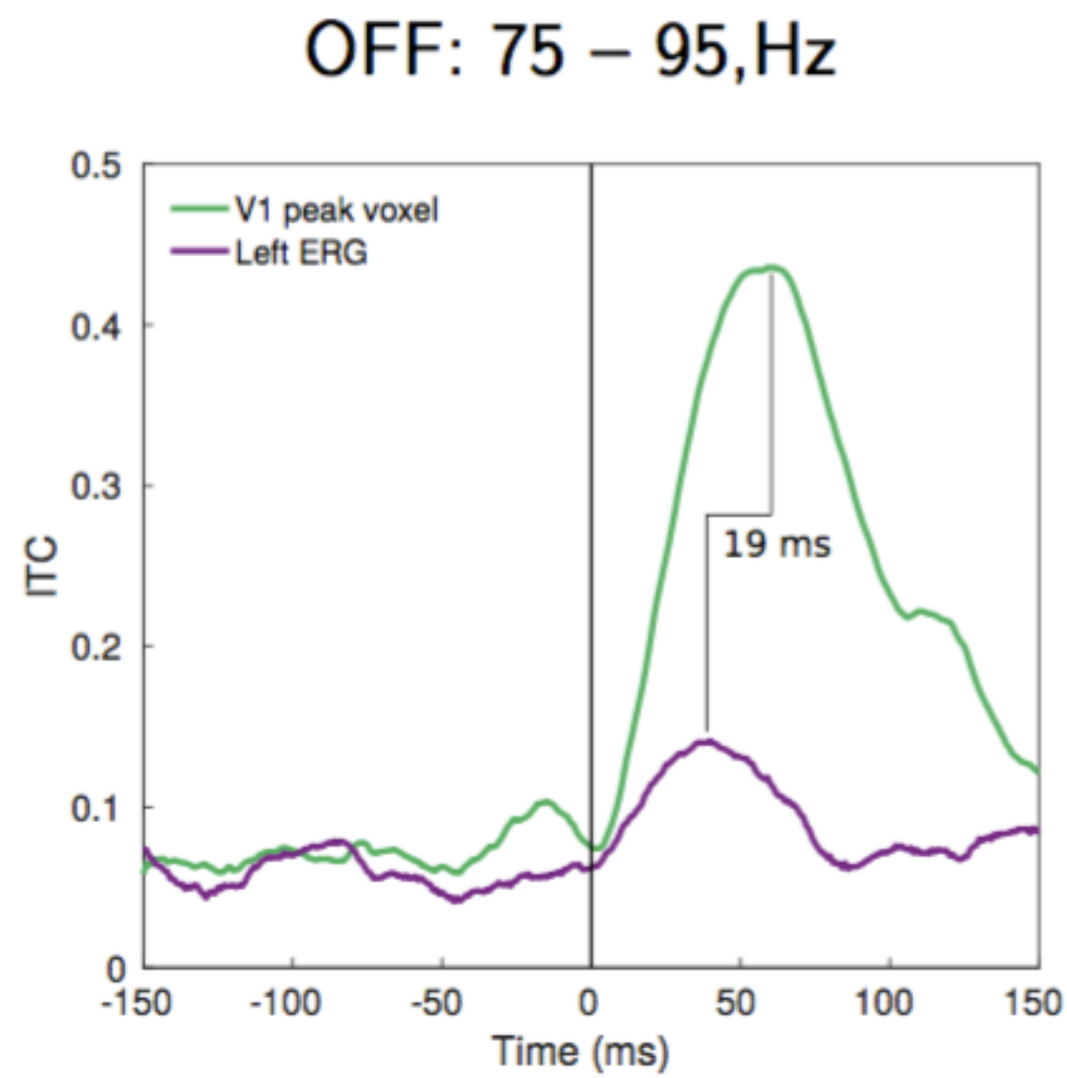

# Response to stimulus offset



# Response to stimulus offset



2008 VOL 319 SCIENCE

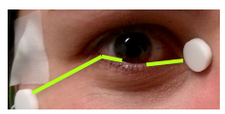
# Rapid Neural Coding in the Retina with Relative Spike Latencies

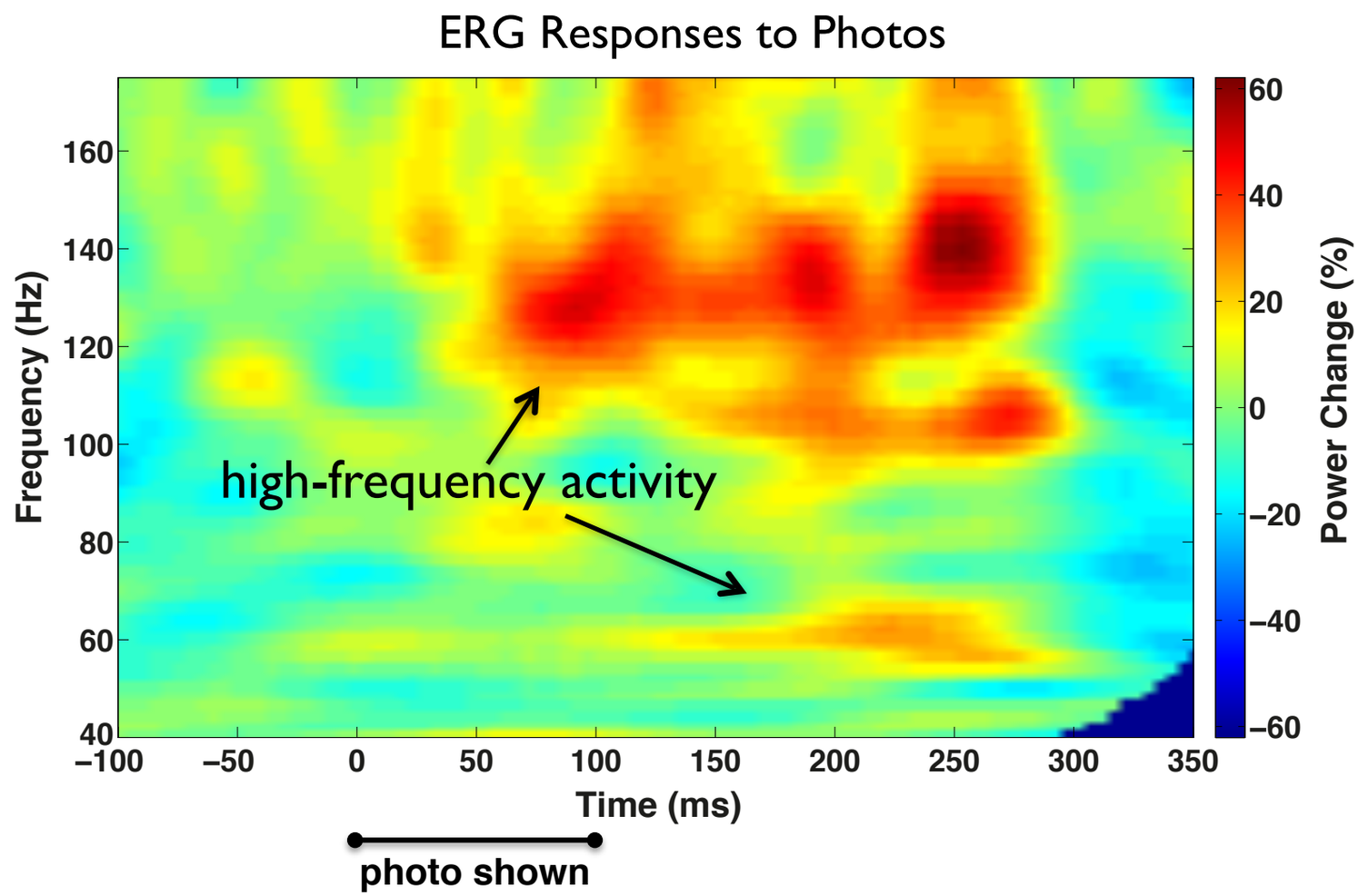
Tim Gollisch* and Markus Meister†

Responses of a fast OFF ganglion cell to a flashed natural image.


- the timing of retinal responses in the salamander vary with image properties
- thought to code image features for later interpretation by the cortex
- does this happen in humans?

# How do image properties affect retinal responses?



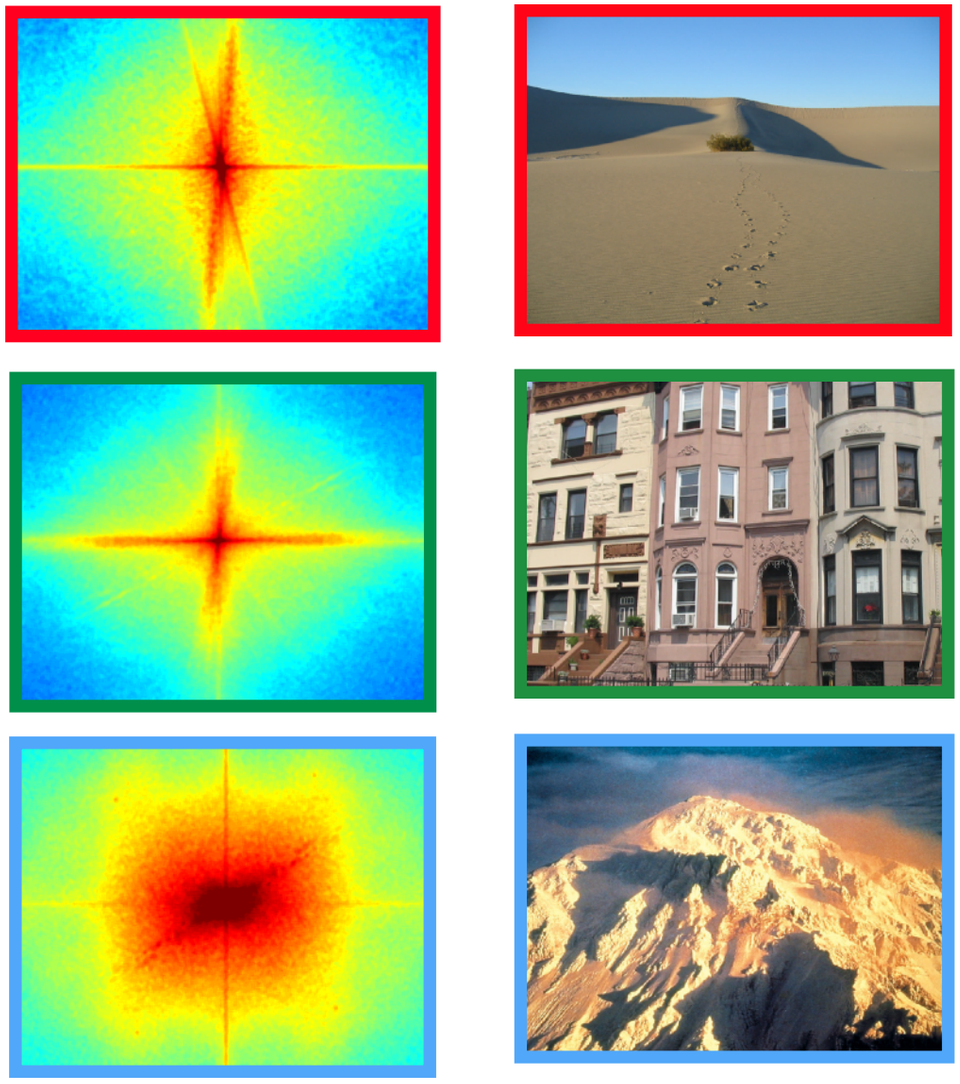



*Insight* Photos stimulate high-frequency responses in the retina; *profile very reminiscent of cortical responses*

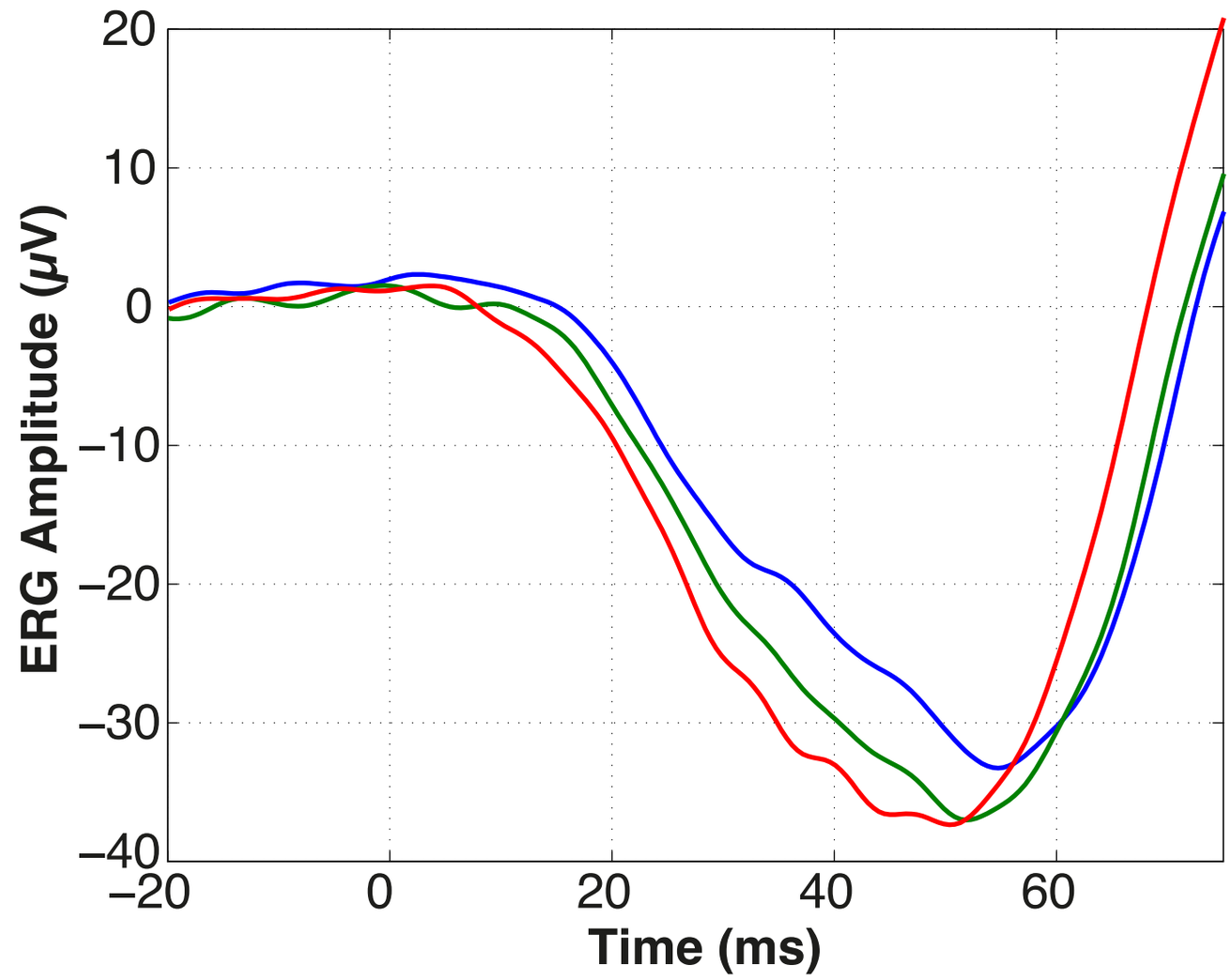
*Hypothesis* These retinal oscillations will also drive cortical oscillations

# How do image properties affect retinal responses?

**Spatial Frequency Spectrum**



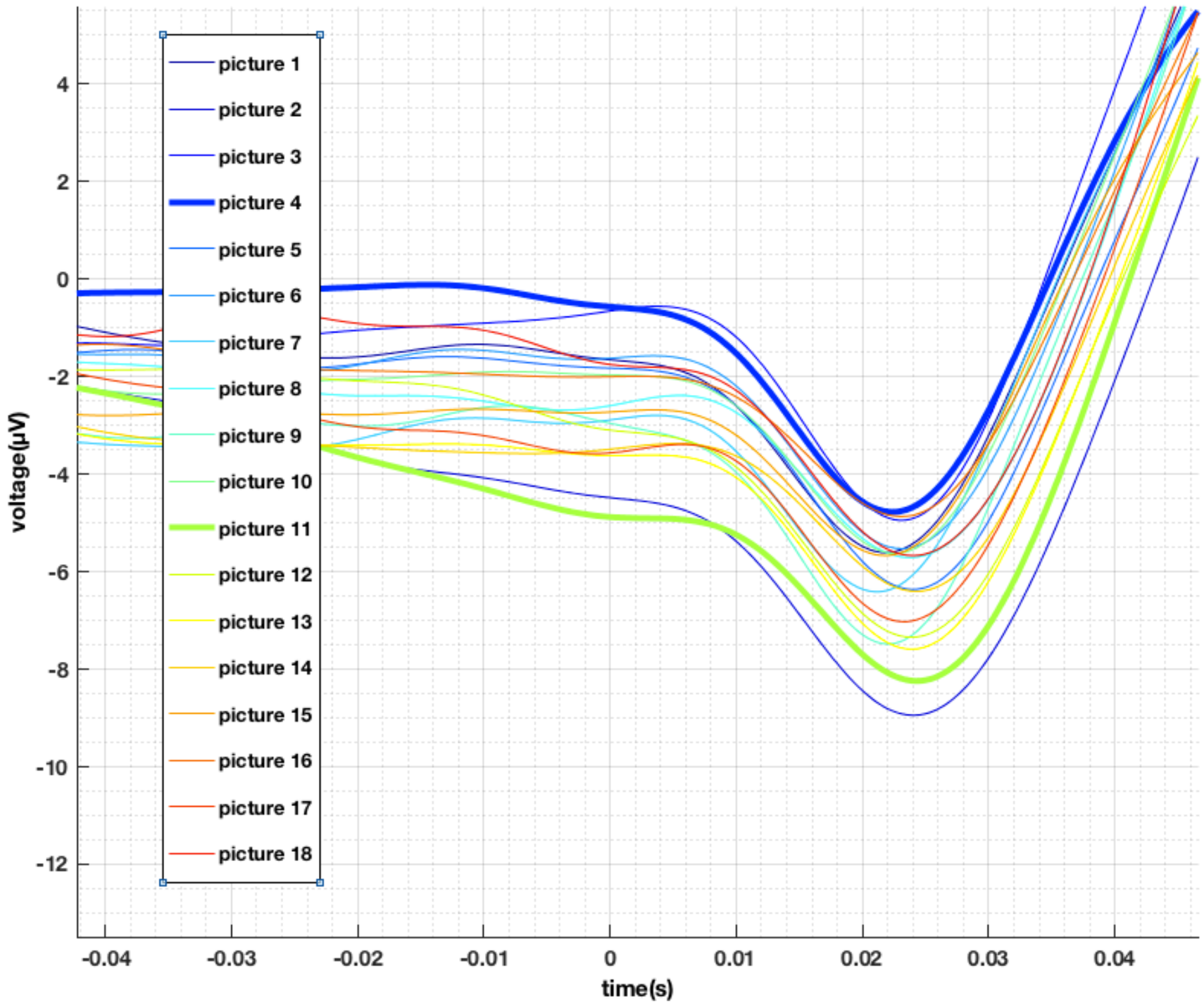
**Retinal Responses**




*Insight* Variable cortical timing often interpreted as local neural computation – but this variability may be inherited from the retina

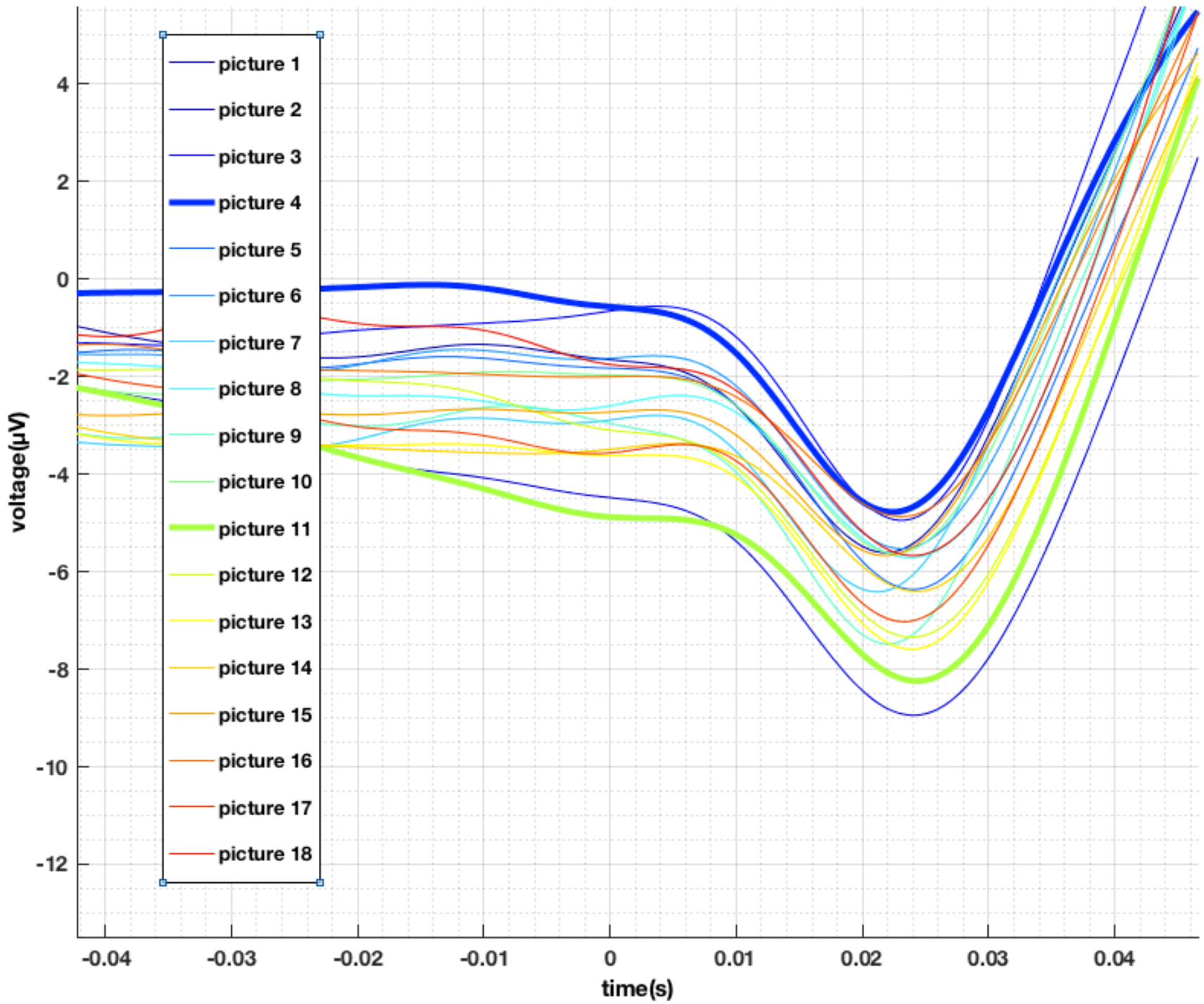
*Hypotheses* 1) Spatial frequency content determines precise response timing
2) Cortical responses will inherit corresponding delays

# How do image properties affect retinal responses?



# How do image properties affect retinal responses?

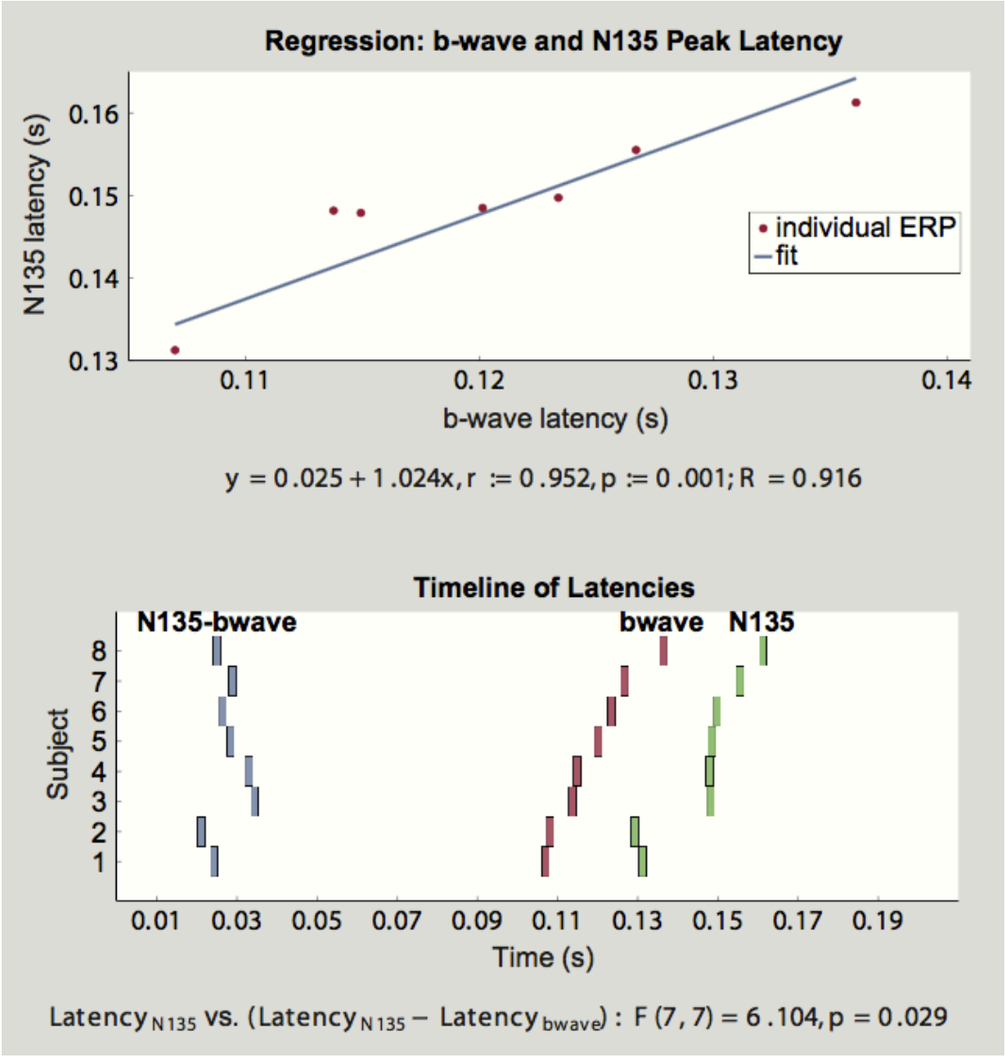
## Preliminary ERG results with IAPS photos



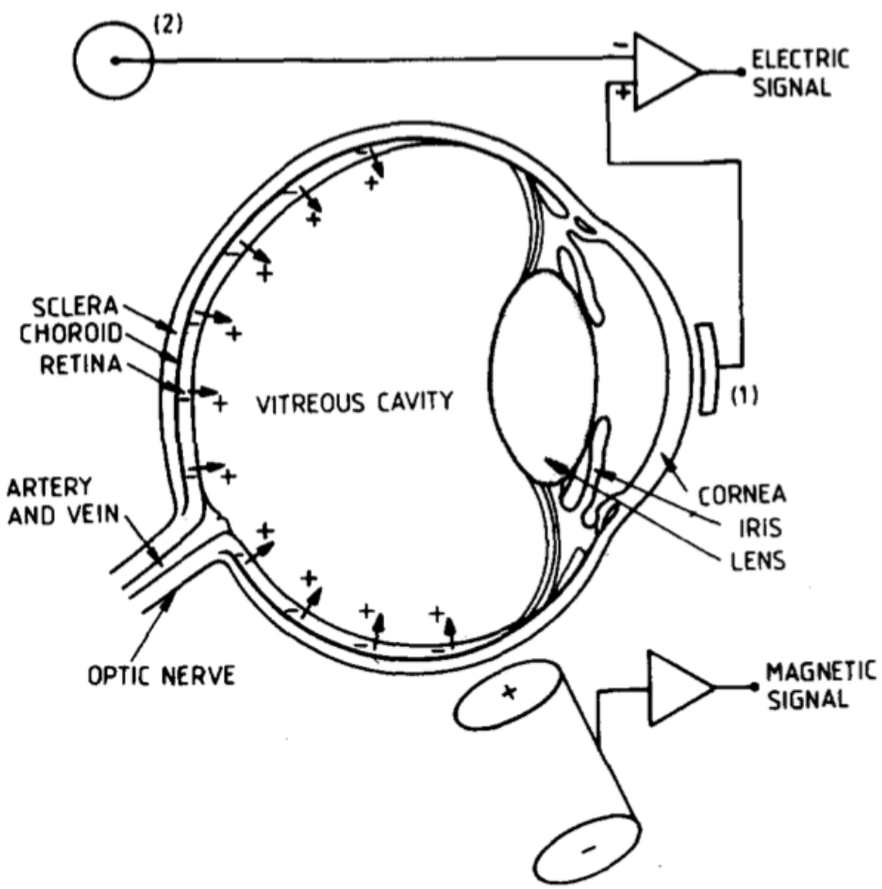
# Retinal triage of picture processing: Insights into retino-cortical interaction

**Monika M. Zeiller [1], Britta U. Westner [1,2], Sarang S. Dalal[2,1]**

1 Department of Psychology, University of Konstanz, Germany
2 Center of Functionally Integrative Neuroscience, Aarhus University, Denmark

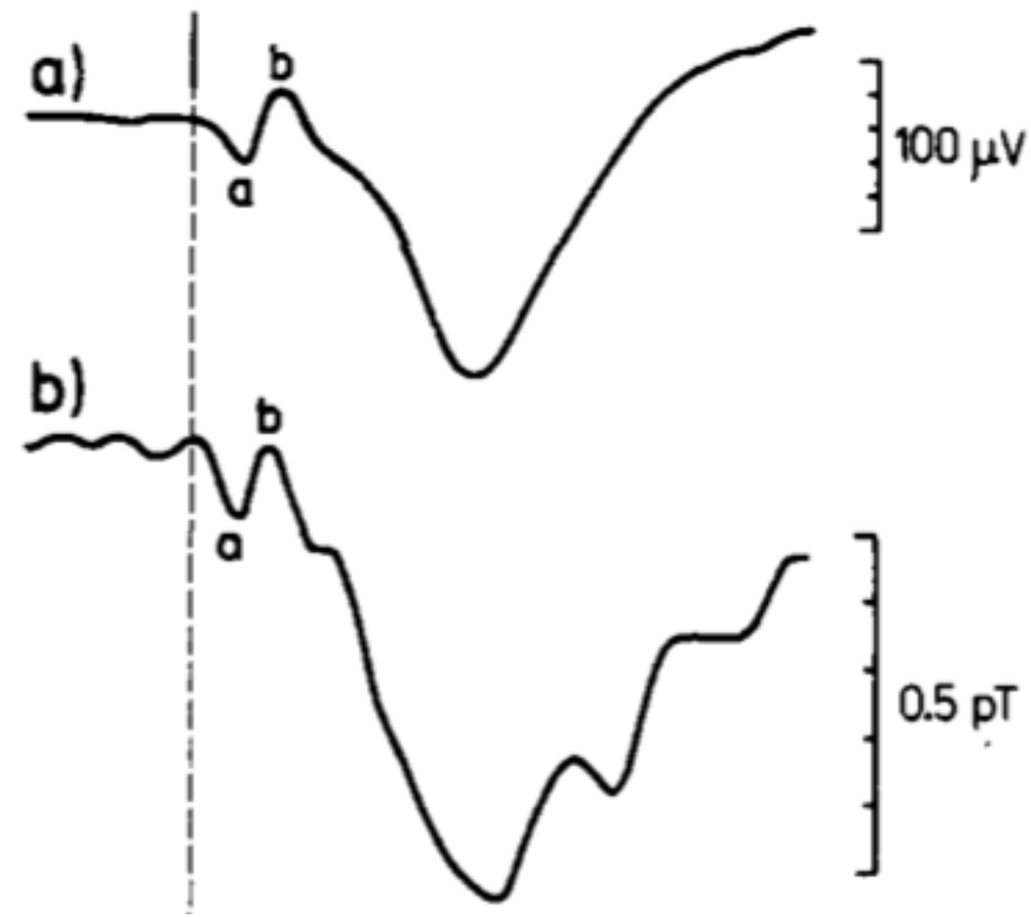


# Magneto*retino*graphy




ERG

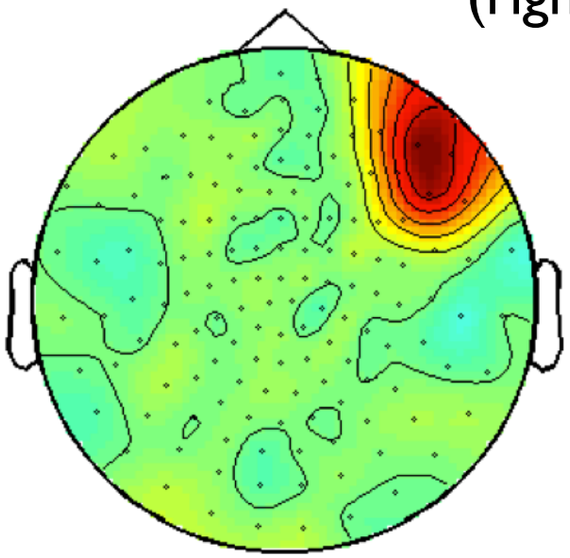
MRG



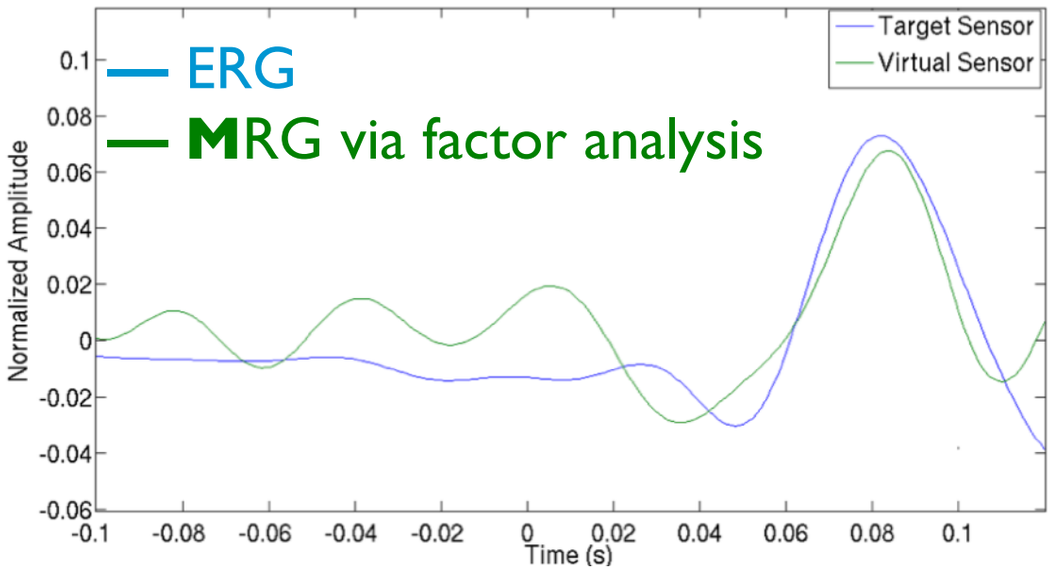

Katila et al., 1981

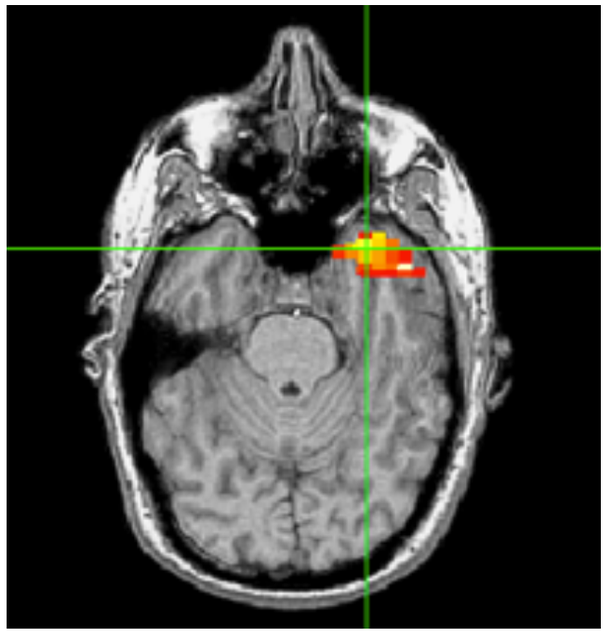
# Magneto***retino***graphy

topography of retinal response
(right eye)

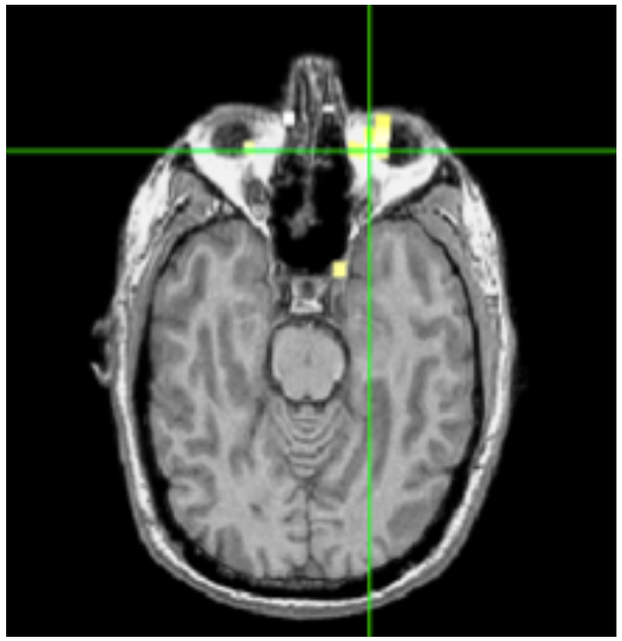


lead field modeled with factor analysis



False source
(without eyes in VOI)



With custom lead field and
eyes included

# Conclusions & Questions

*The retina – an accessible part of the human brain – performs sophisticated processing and its contribution must be considered along with cortical responses*

- For *neural timing* to be a robust marker of **local computation**, the entire visual pathway must be probed – starting at the retina
- High-frequency retinal oscillations appear to drive corresponding visual cortical activity
- Might the timing and frequency of these oscillations code features of more complex imagery?
- Does cortex or thalamus talk to the retina?
- Findings will advance our understanding of how neural systems – in general – can process and communicate information

# Thanks!

**Tzvetan Popov**

**NEMOlab**

**Monika Zeiller** Tommy Clausner Wibke Naumann Claudia Leupold **Britta Westner** Sabine Leske Maité Crespo García **Mathis Kaiser** **Daniel Wong**

**postdocs and PhD students wanted for new retina-cortex projects - start dates through Spring 2018**


ÅARHUS—2017
EUROPEAN CAPITAL OF CULTURE

Martin Dietz

Alexandra Vossen

**cfin.au.dk/nemo**
**sarang@cfin.au.dk**