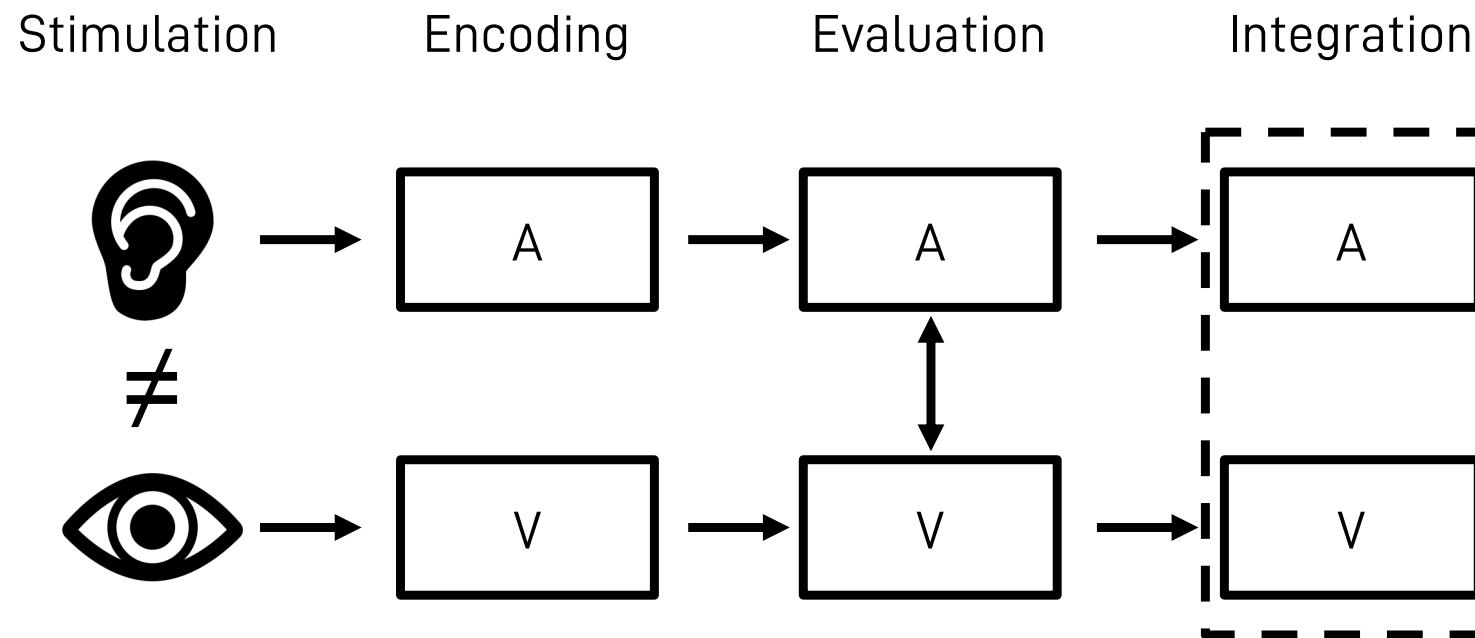


Brain-state dependent stimulus processing and perception



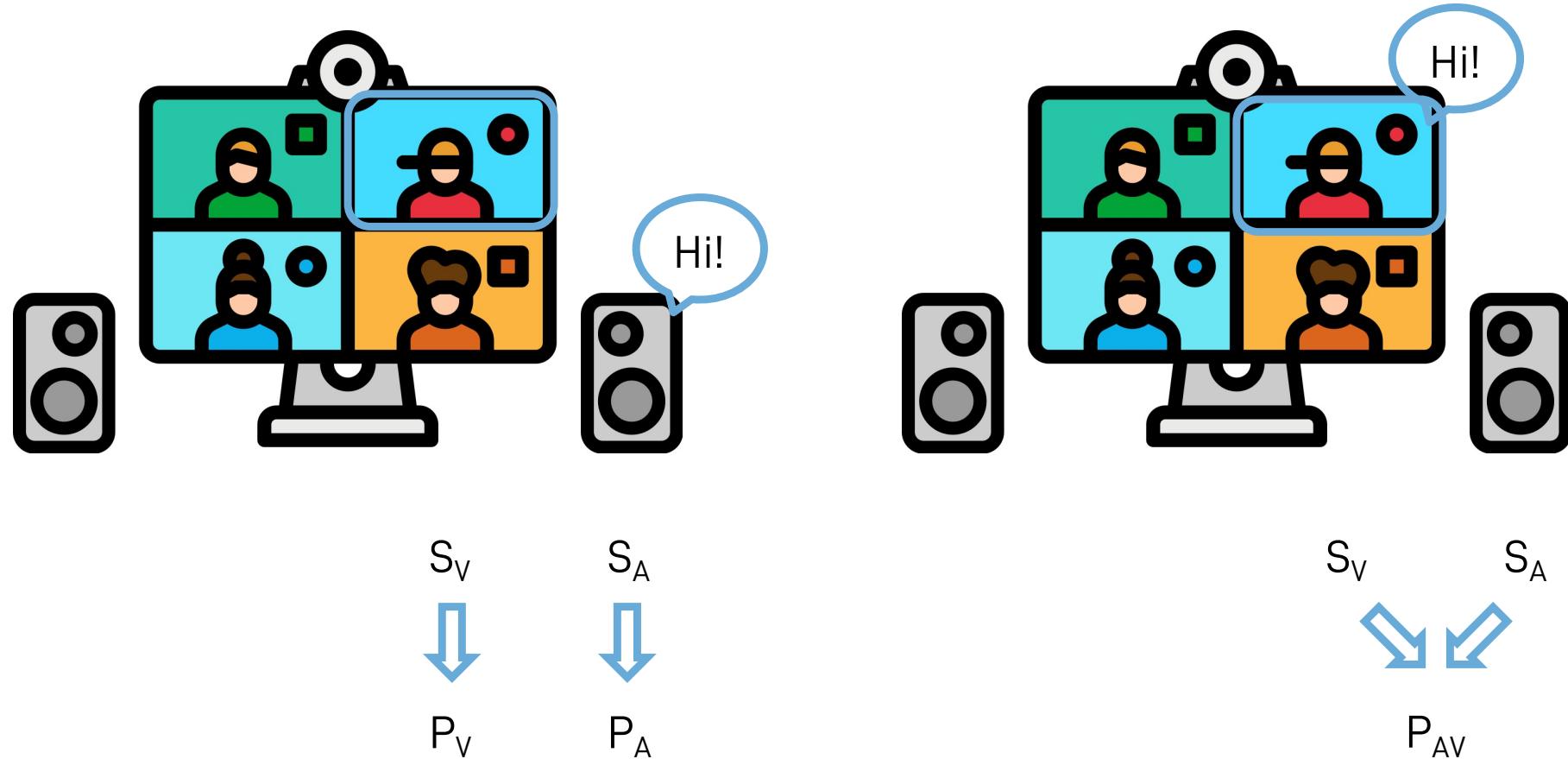
Dr. Julian Keil

Biologische Psychologie

www.biopsych.uni-kiel.de | keil@psychologie.uni-kiel.de | [@drjuliankeil](https://twitter.com/drjuliankeil)

<https://github.com/juliankeil/Slides/blob/master/Keil-CRC1461>

Perceptual Decision Making

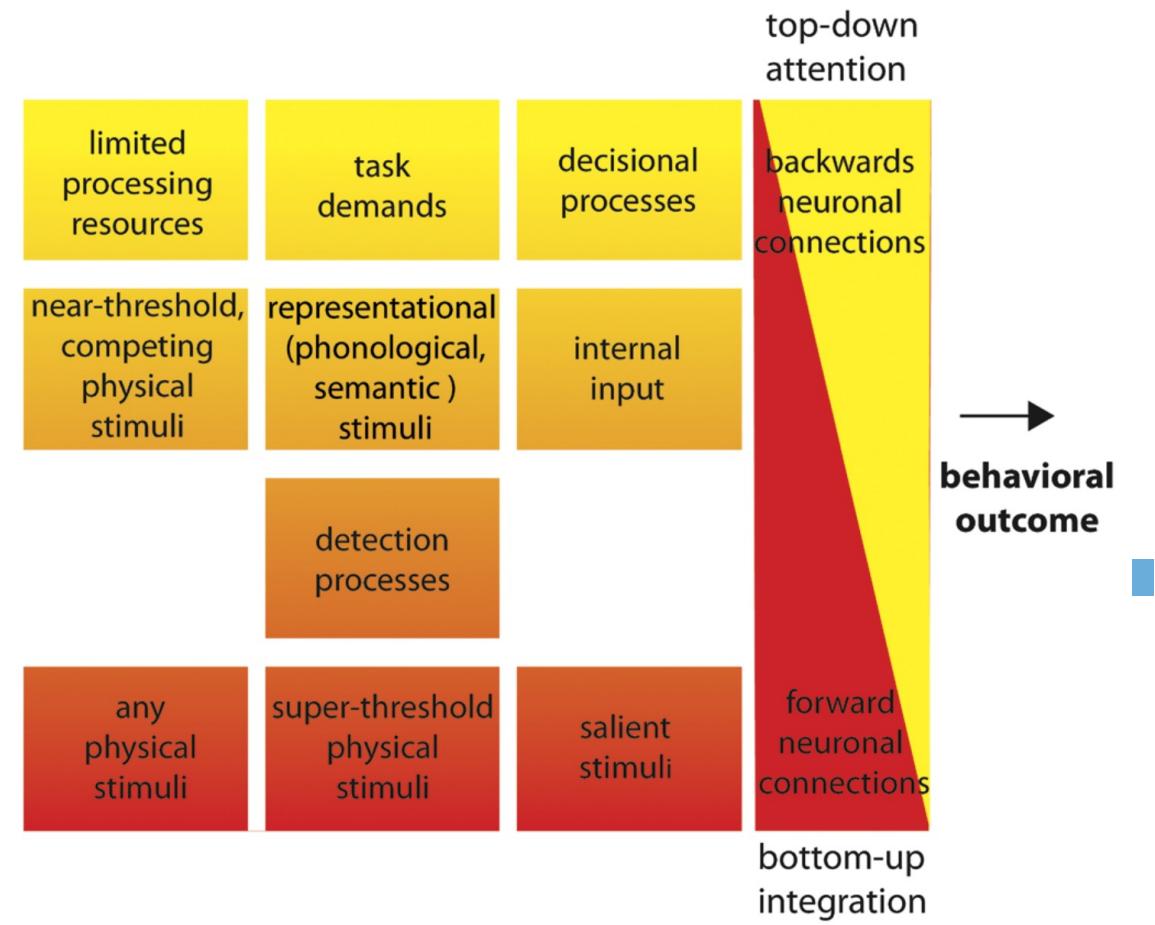


Hirst et al., 2020

Bizley et al., 2016

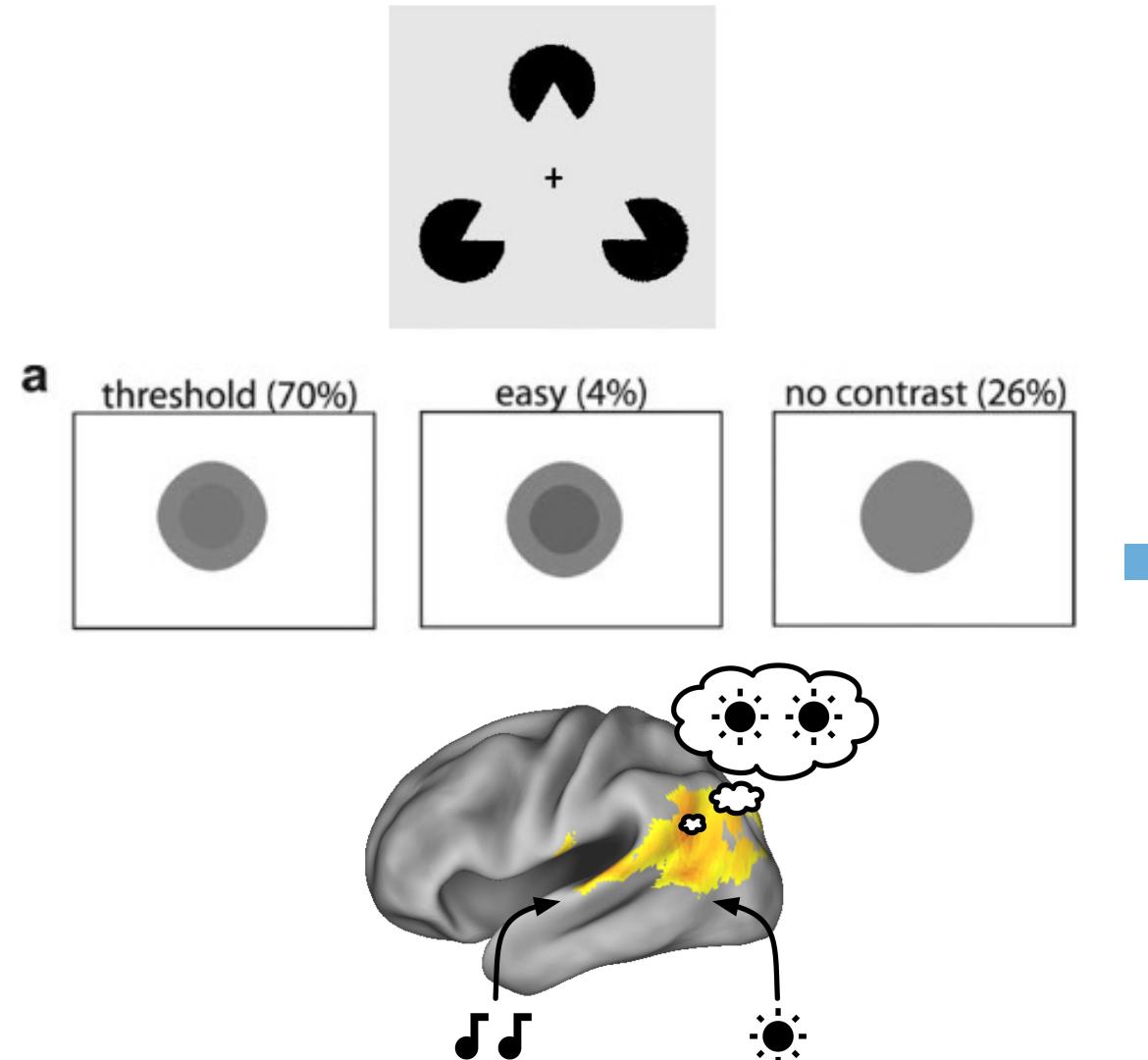
Starting Point

- (Multisensory) perception involves multiple steps
 - Encoding, evaluation, integration
- Neural activity reflects different steps
 - Bottom-up vs. top-down processes
- Brain state influences stimulus processing and perceptual decision making

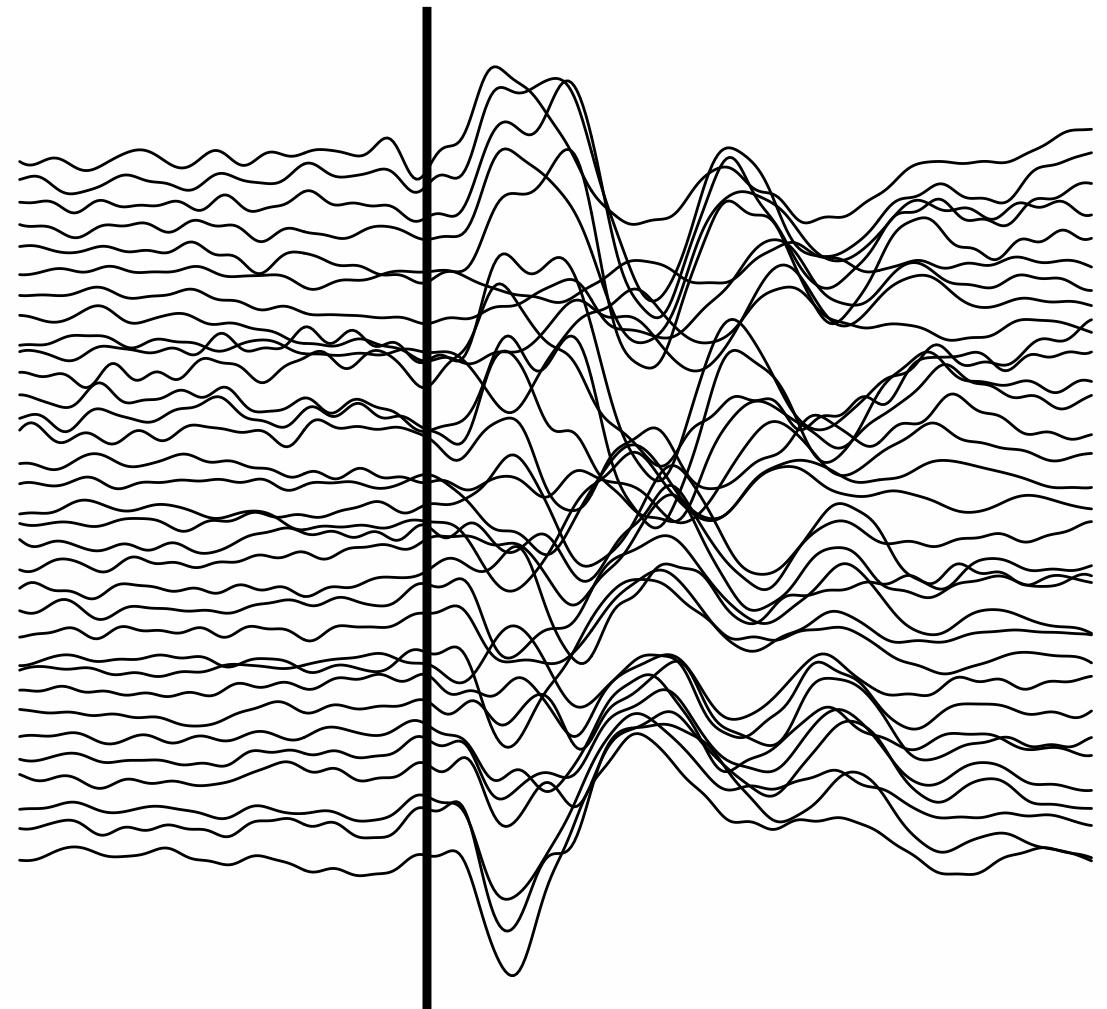
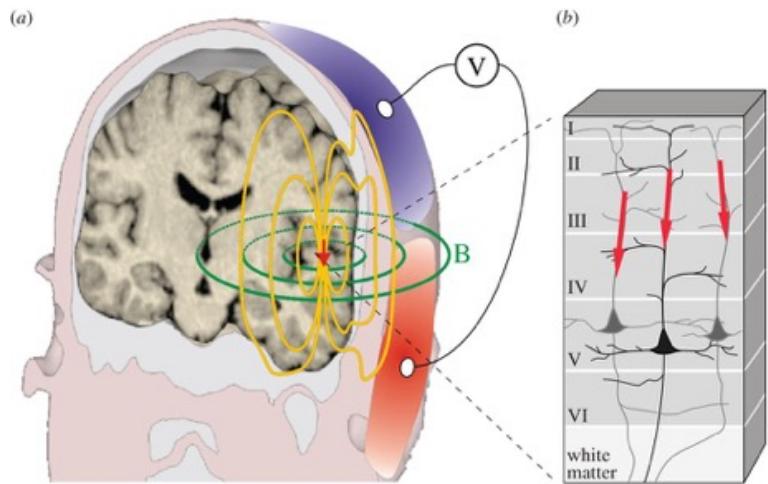


Testing the Brain State: Bistable Perception

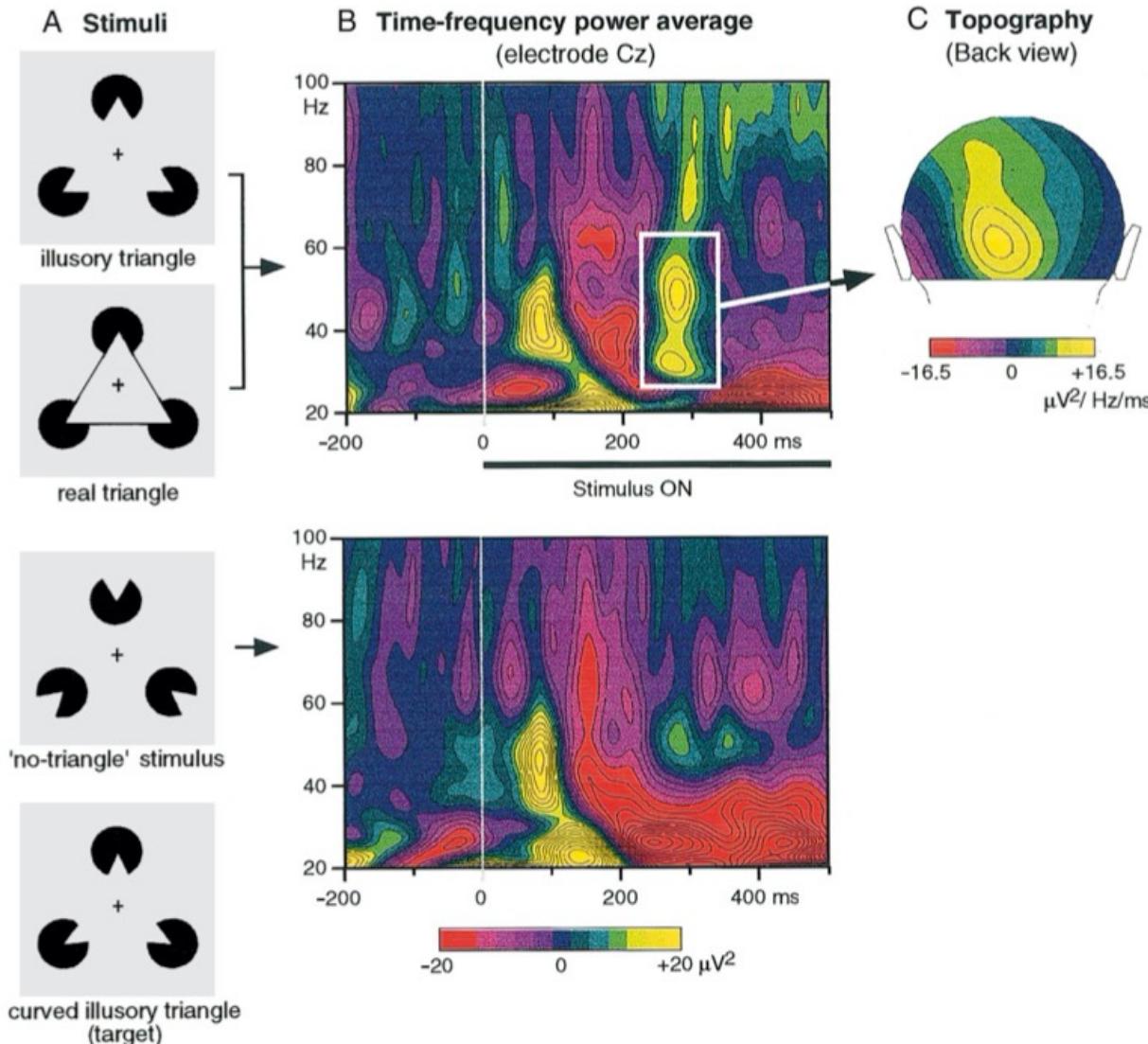
- Unisensory perception:
 - Illusory contours
 - Near-threshold stimuli
- Multisensory perception:
 - Crossmodal illusions



Recording the Brain State: EEG

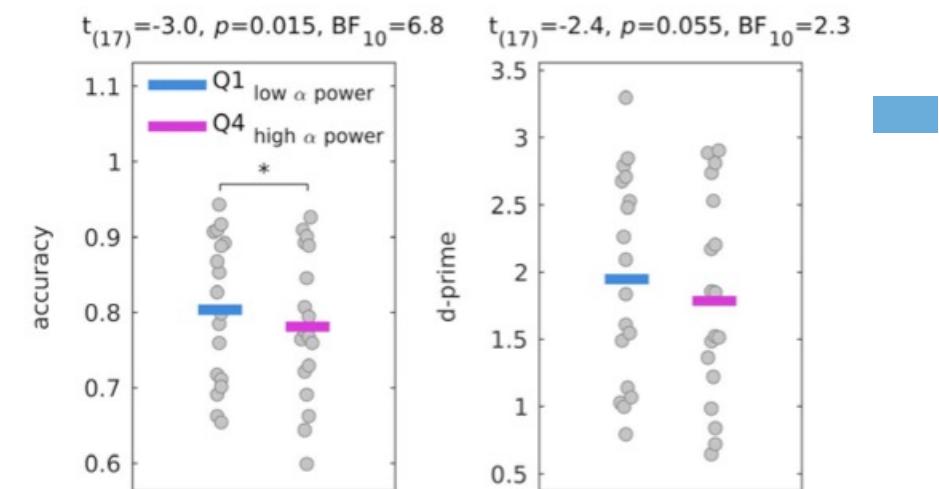
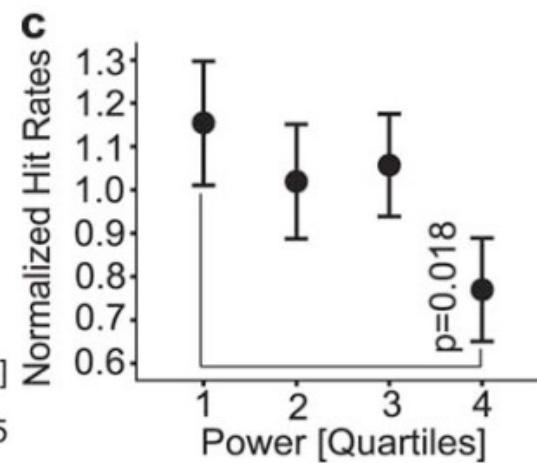
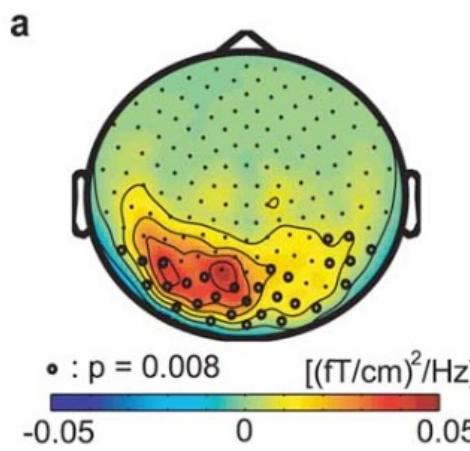
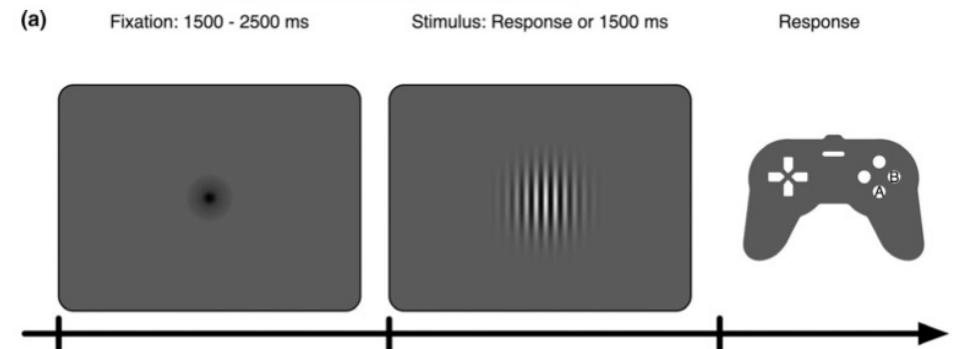
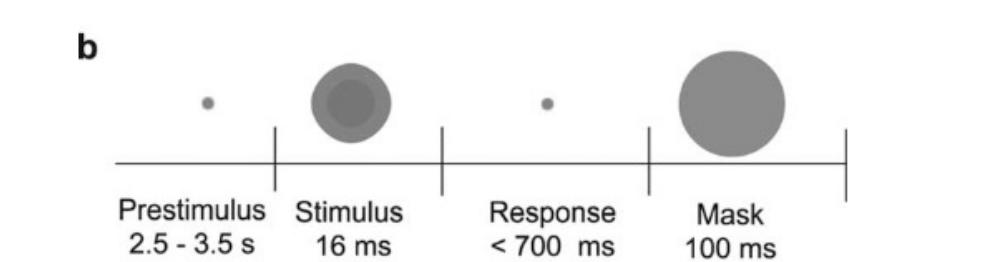


Part 1: Illusory Contours



Tallon-Baudry & Bertrand, 1999

Part 1: Near-Threshold Stimuli



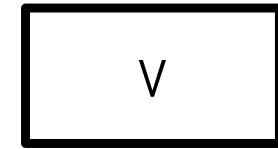
Van Dijk et al., 2008; Michail et al., 2021

Interim Summary 1

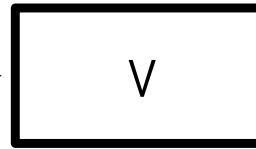
Stimulation



Encoding



Evaluation



Integration



Encoding: Local states influence stimulus processing

- Alpha power as an index of excitability

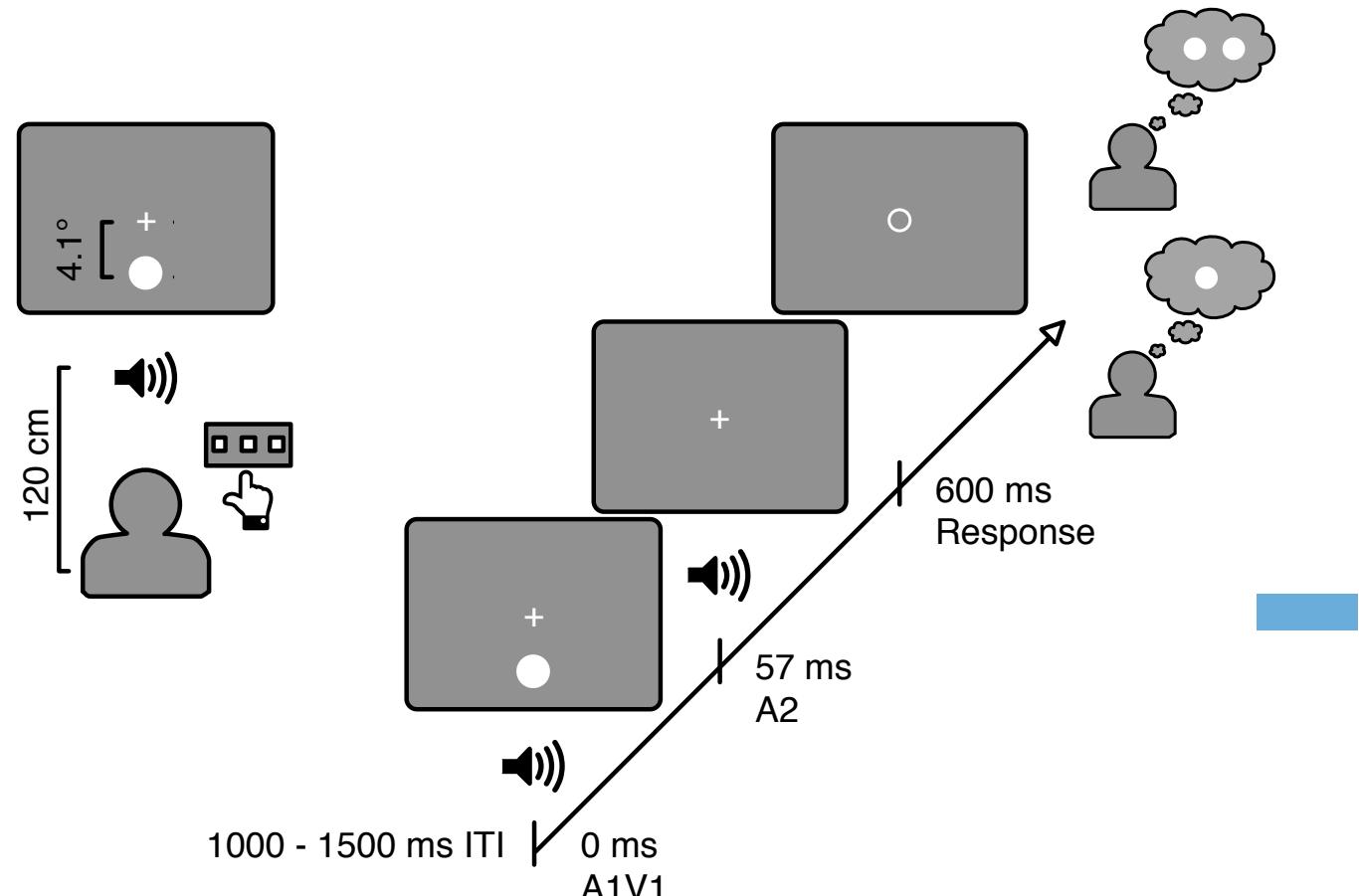
Evaluation and Integration: Local power reflects sensory binding

- Gamma power signals perceptual binding
- Processing “bottlenecks” at multiple stages
 - Available resources influence stimulus processing

Part 2: Multisensory Perception

Sound induced flash illusion

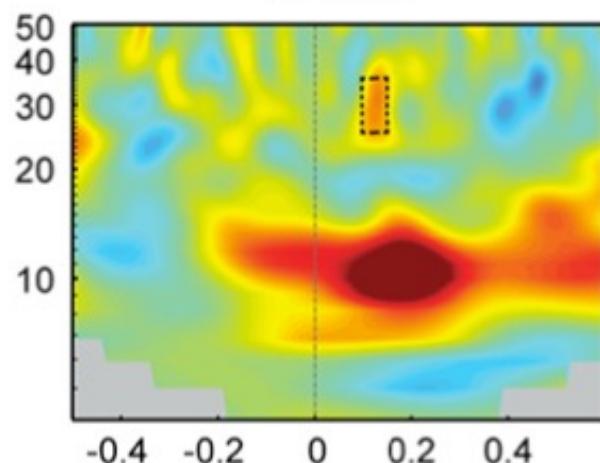
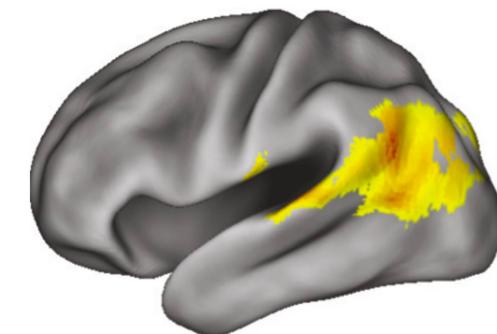
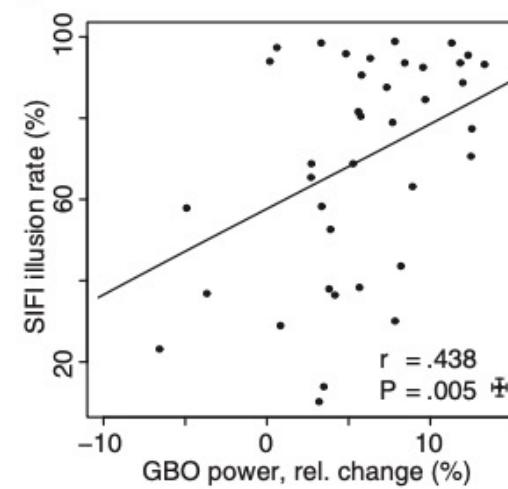
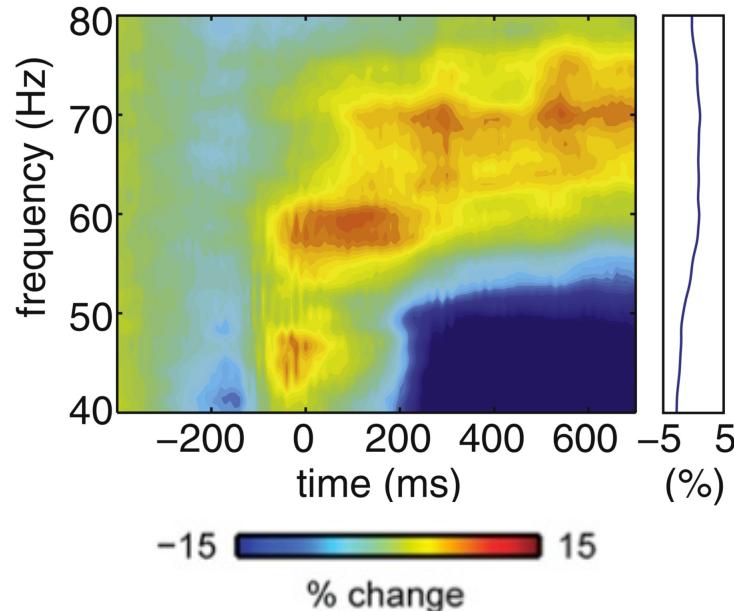
- Combination of short auditory and visual stimuli
 - Simple visual discrimination task
 - Stimuli salient in isolation
 - Controls for response biases



Shams et al., 2000

Keil, 2020

Bistable perception: Illusion vs. No-Illusion



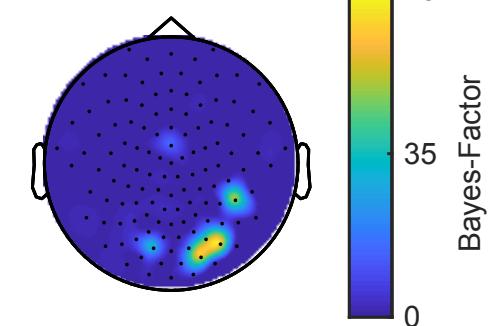
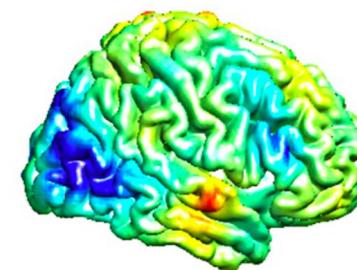
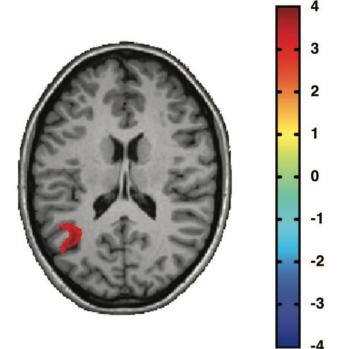
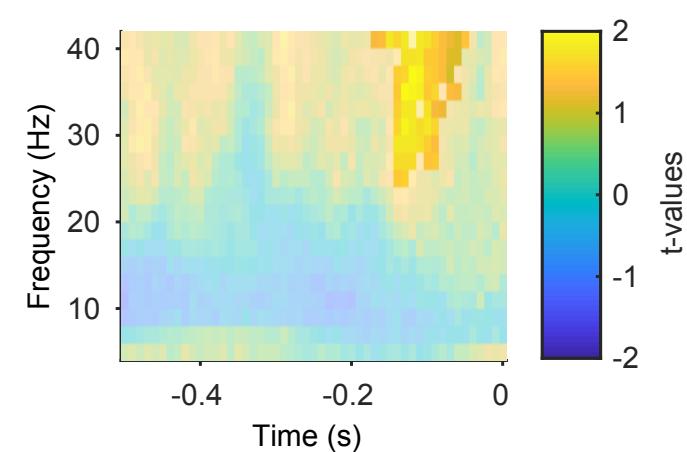
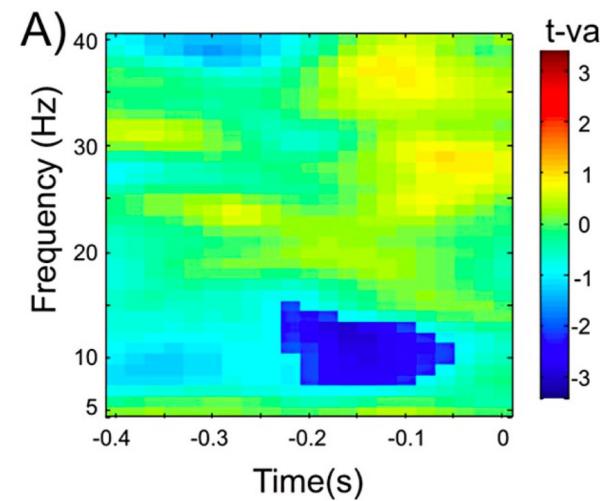
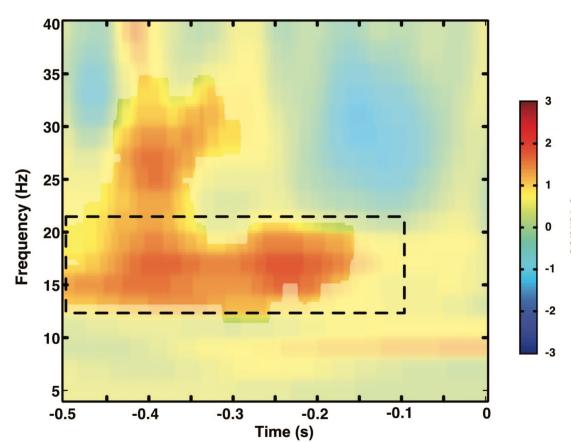
Integration of incongruent input: Illusion

- Increased gamma band power correlates with fission illusion
- Higher gamma band power for illusion vs. no-illusion perception

Bistable perception: Illusion vs. No-Illusion

Brain state influences upcoming perception

- Low-frequency power in sensory and association areas

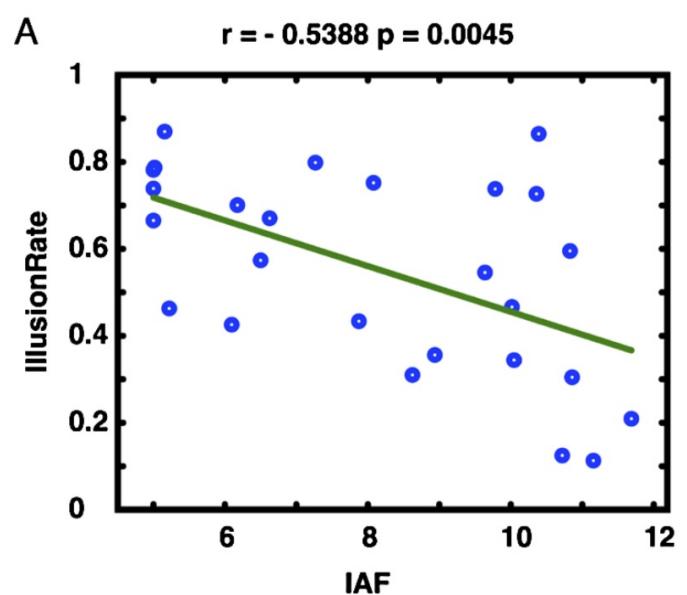


Keil et al., 2014; Lange et al., 2013; Kaiser et al., 2019

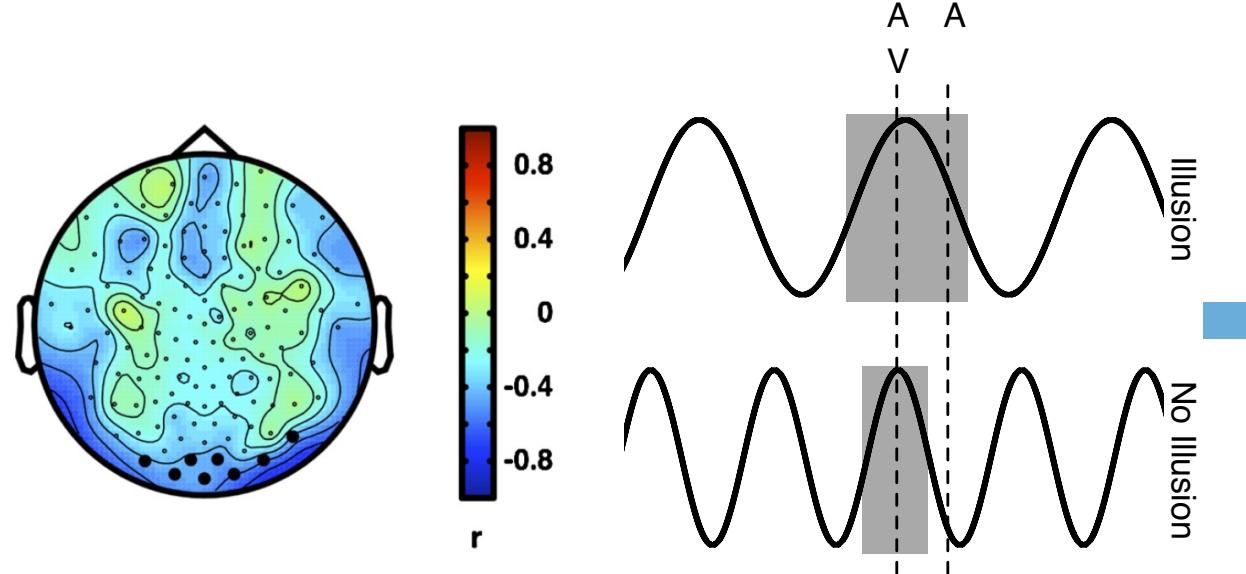
Bistable perception: Illusion vs. No-Illusion

Brain state influences upcoming perception

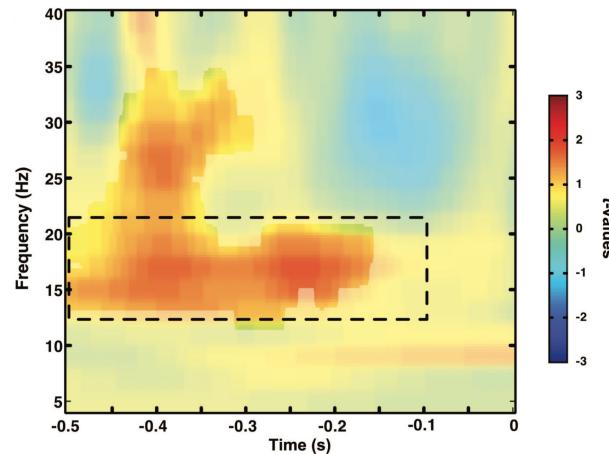
- Low-frequency phase duration in sensory areas



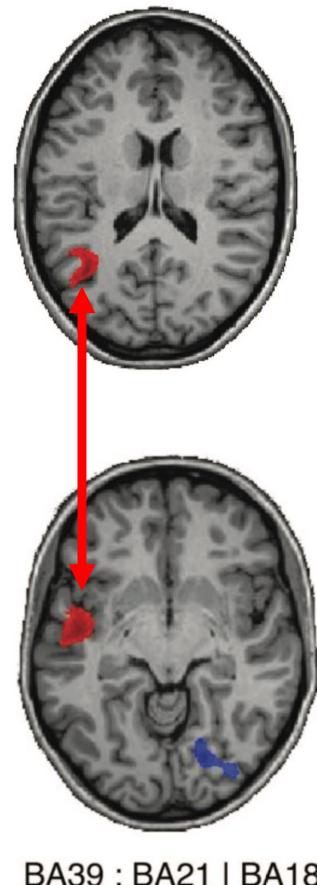
B



Bistable perception: Illusion vs. No-Illusion

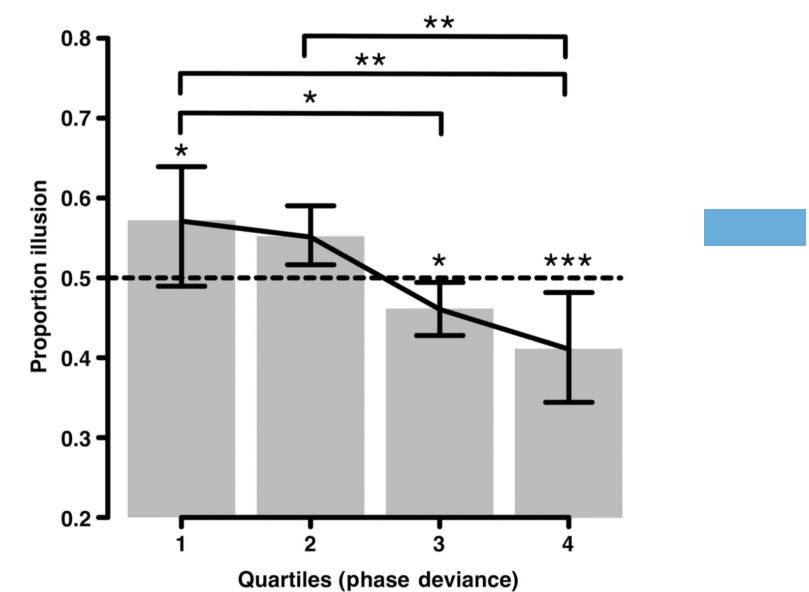


Beta connectivity reflects crossmodal influences: Similar phase angle supports integration

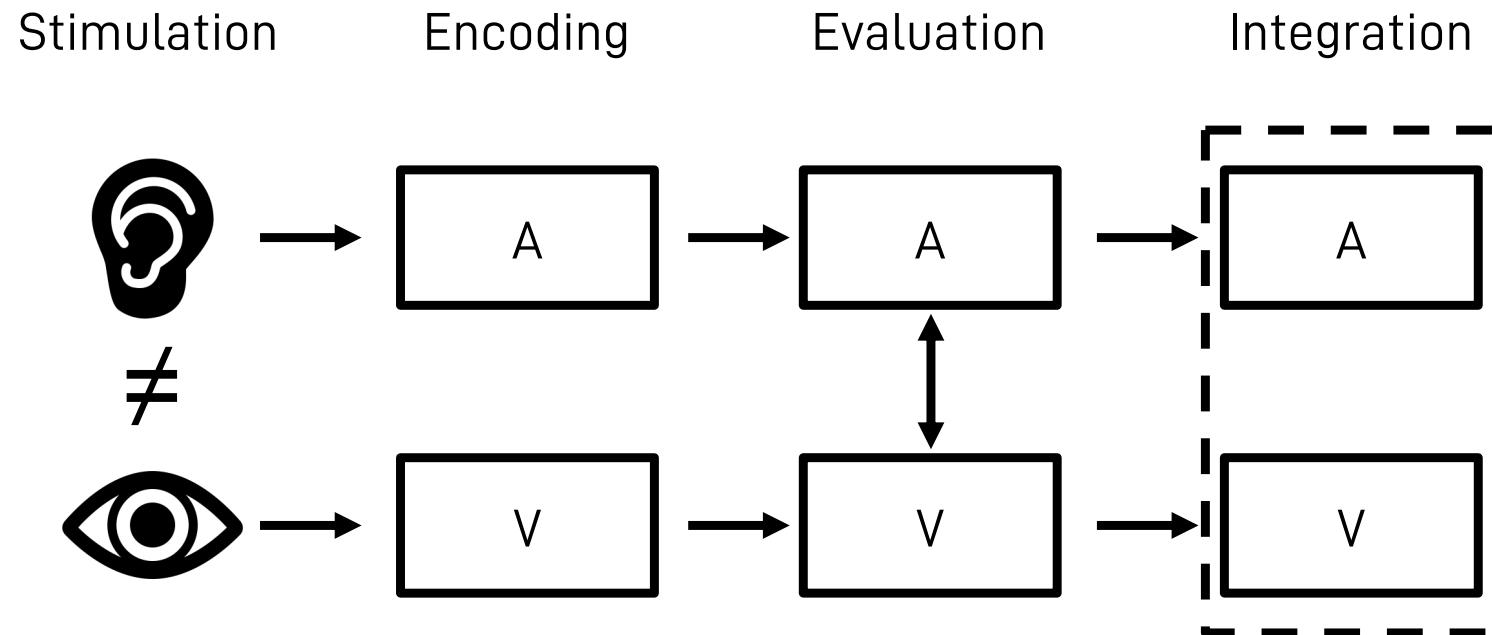


BA39 : BA21 | BA18

Beta power reflects state of integration areas: High power supports integration



Interim Summary 2



Encoding: Local and network states influence stimulus processing

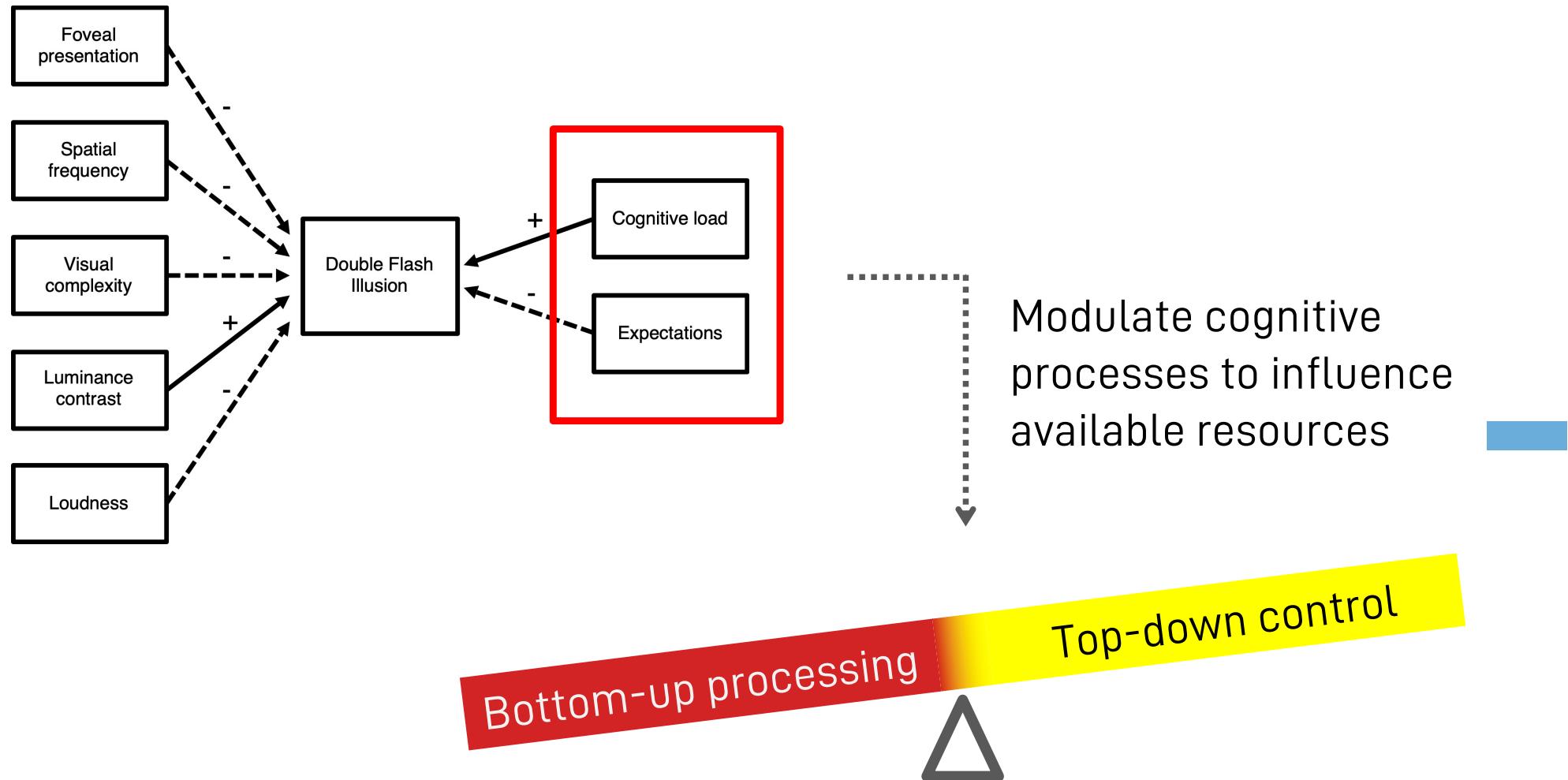
- Alpha frequency as temporal binding window
- Alpha & Beta power, beta connectivity as state of crossmodal communication

Evaluation and Integration: Local power reflects multisensory integration

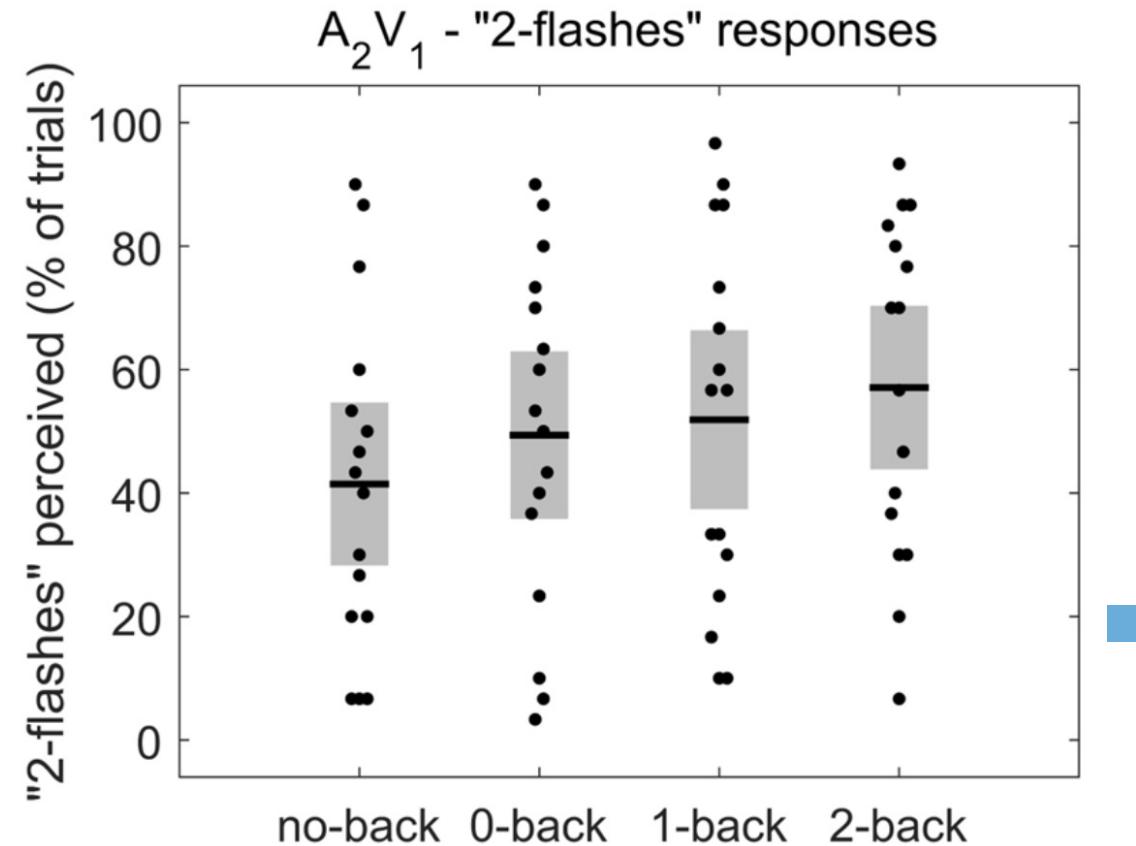
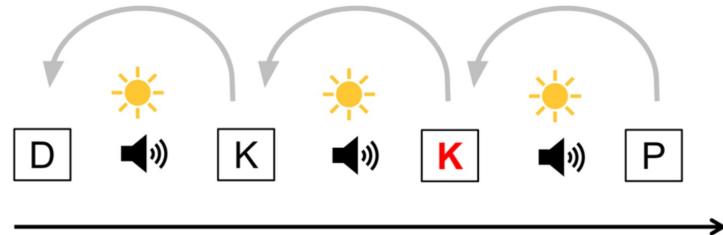
- Gamma power in multisensory integration areas correlates with illusion perception

Part 3: Change the State

Stimulus properties Cognitive Influences



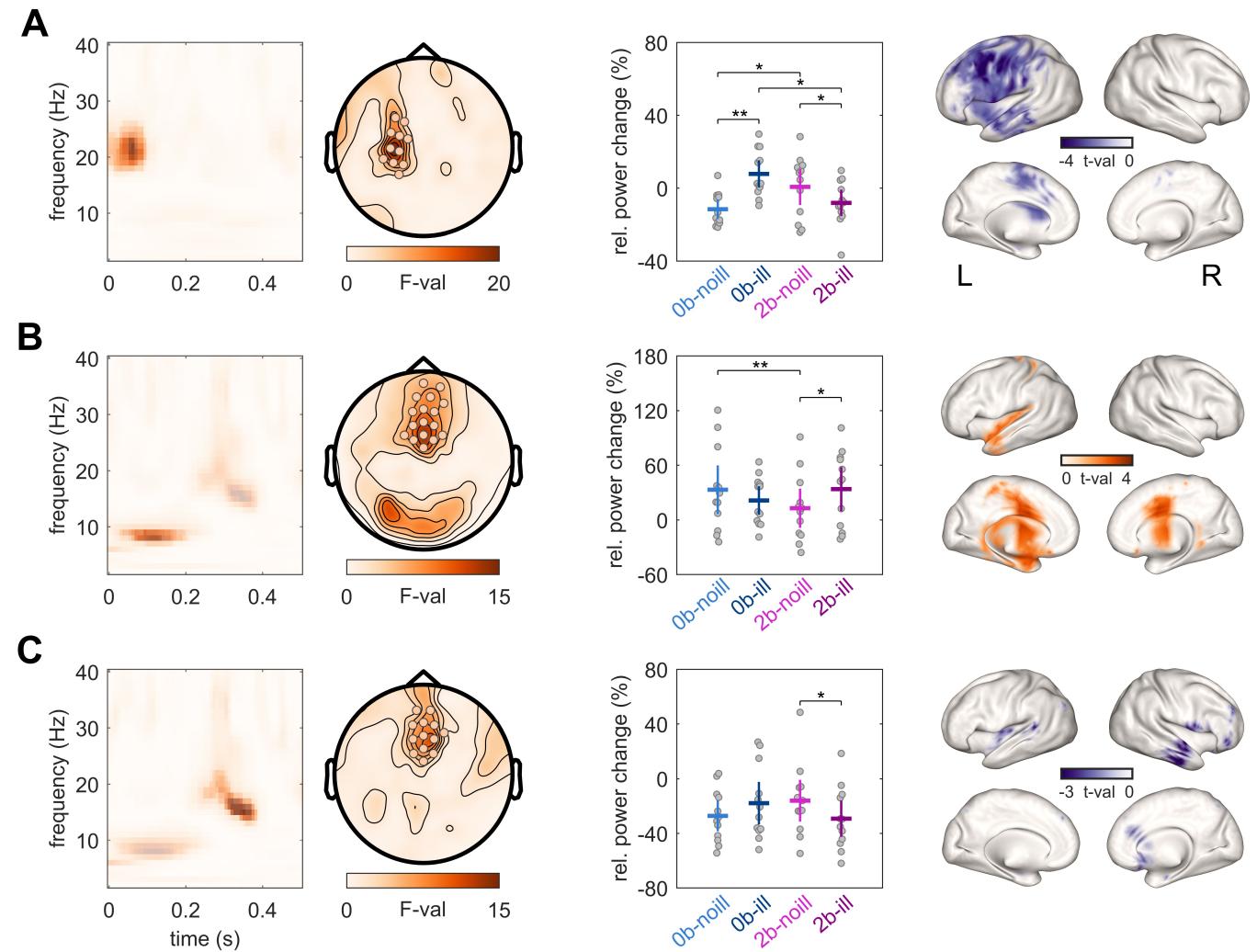
Change the State: Cognitive Load



- N-back task increased cognitive load and depletes resources
- Cognitive load increases the SIFI

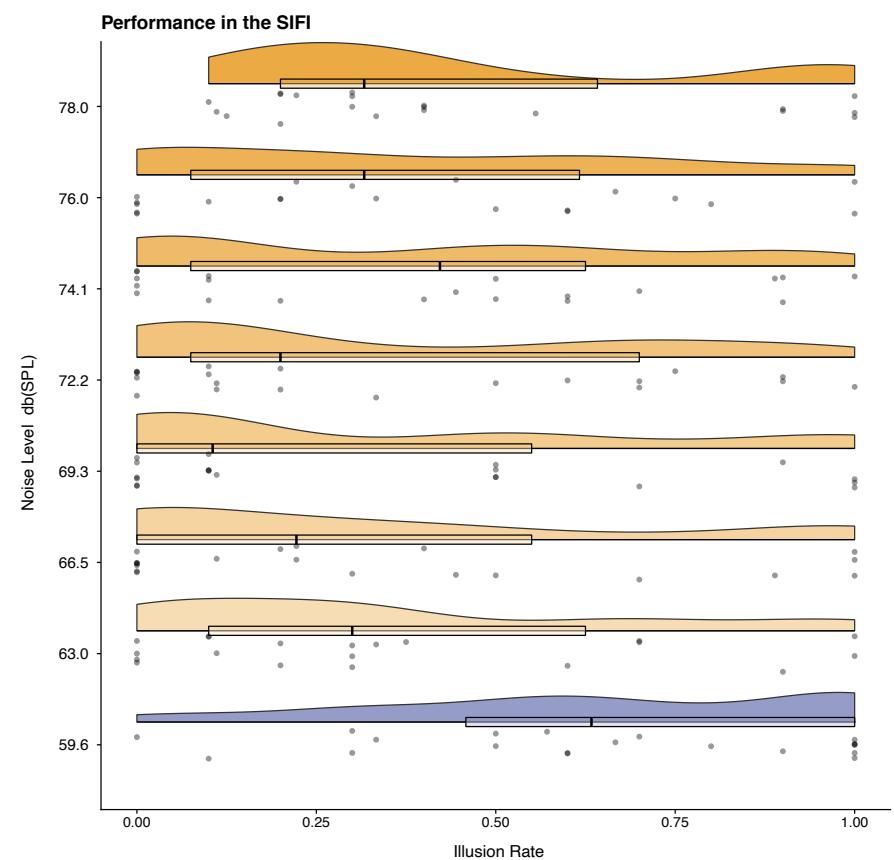
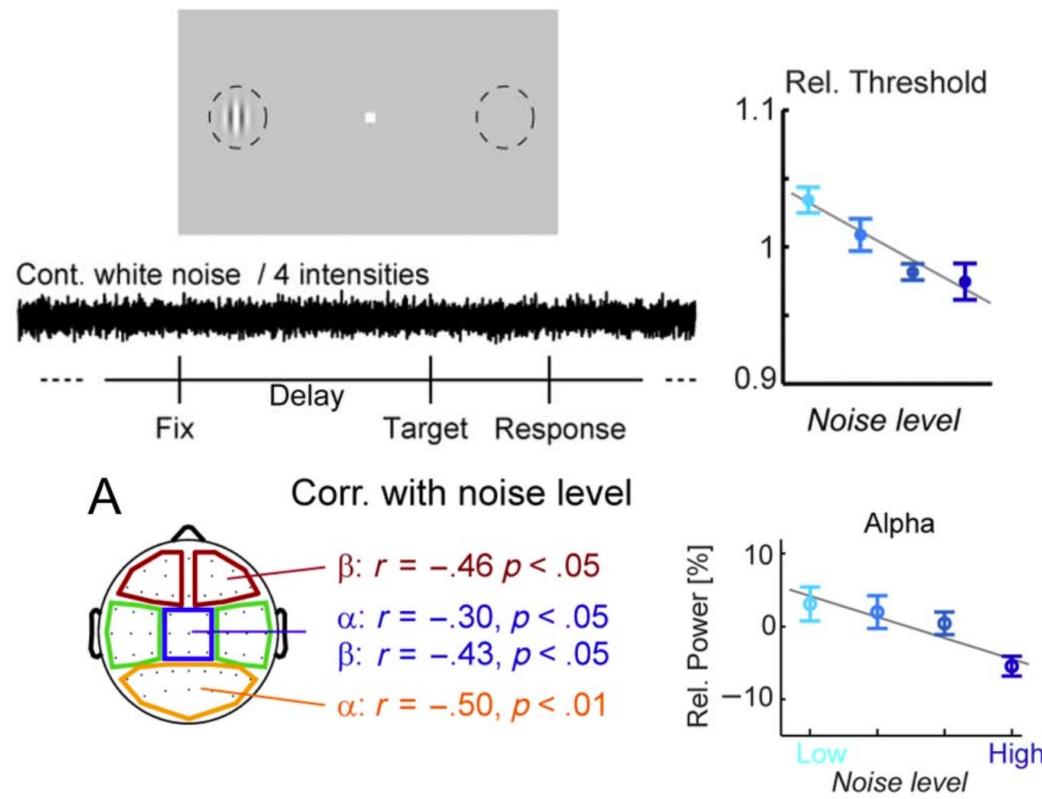
Neural Mechanisms of Cognitive Load

- Replication:
Cognitive load
increases the SIFI
 - Impaired
sensory
encoding
- Theta and beta
power reflect
interaction
between load and
perception
 - Resolve
competition



Change the State: Stochastic Resonance

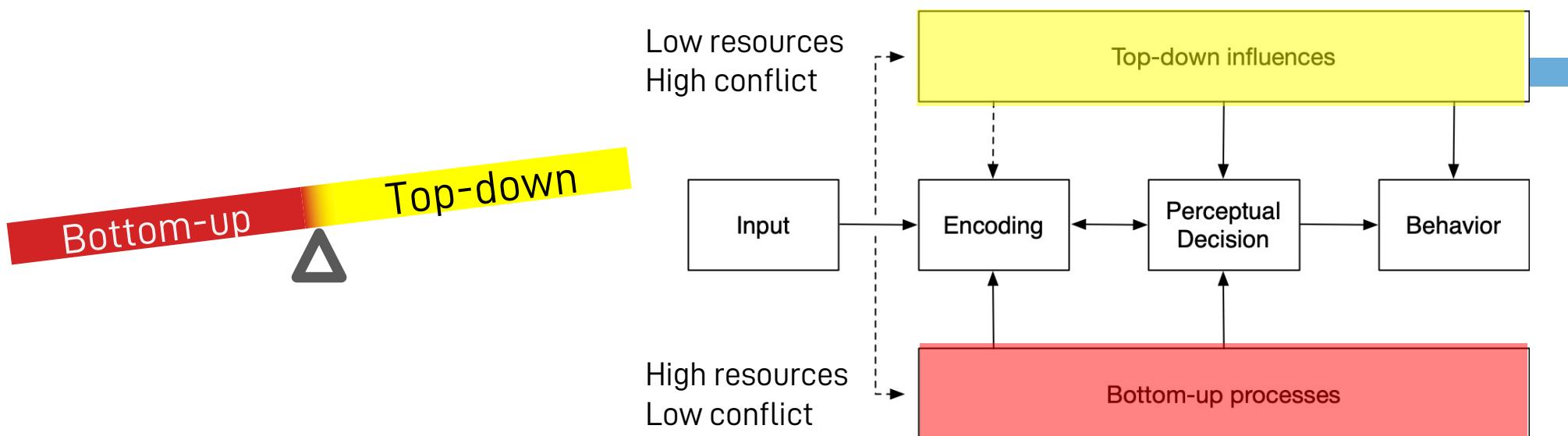
- Intermediate noise improves information transfer in complex systems (Moss et al., 2004)
 - Improve sensory encoding



Gleiss & Kayser, 2014; Keil et al., in prep.

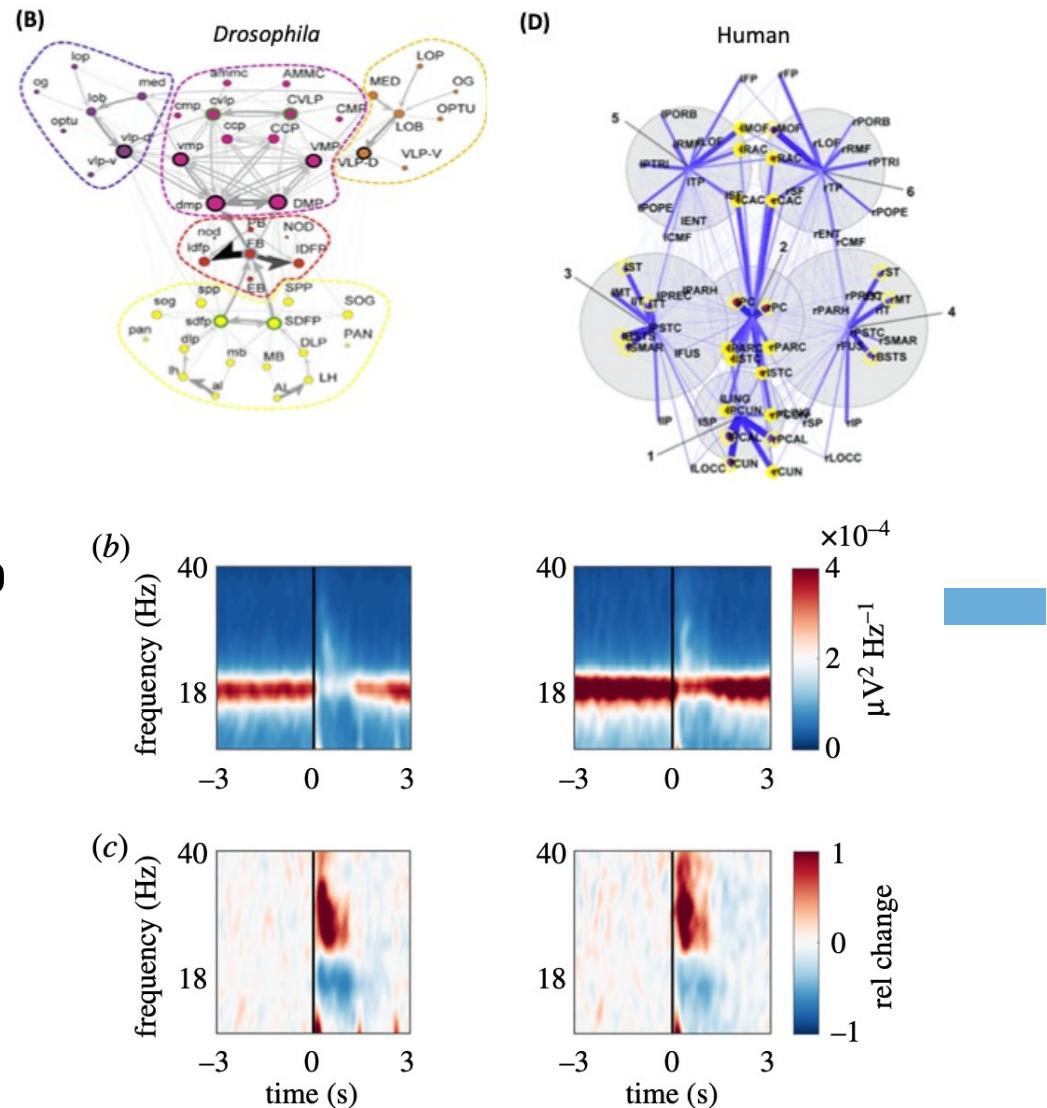
Interim Summary 3

- Multisensory perception depends on the brain state
 - Neural oscillations reflect crossmodal interactions and influence stimulus processing
 - Changing the brain state influences sensory encoding and integration
 - Cognitive processes influence available resources: varying demand of (late) top-down resources to resolve intersensory conflict



Part 4: Non-Human Animals

- Comparisons across species reveal structural similarities:
 - Community structure
 - Short communication paths
 - Hubs and functional clusters
- Do these similarities translate to similar functional neural mechanisms?
 - Spontaneous alpha and evoked gamma oscillations in honeybees



Van der Heuvel et al., 2016
Popov & Szyszka, 2020

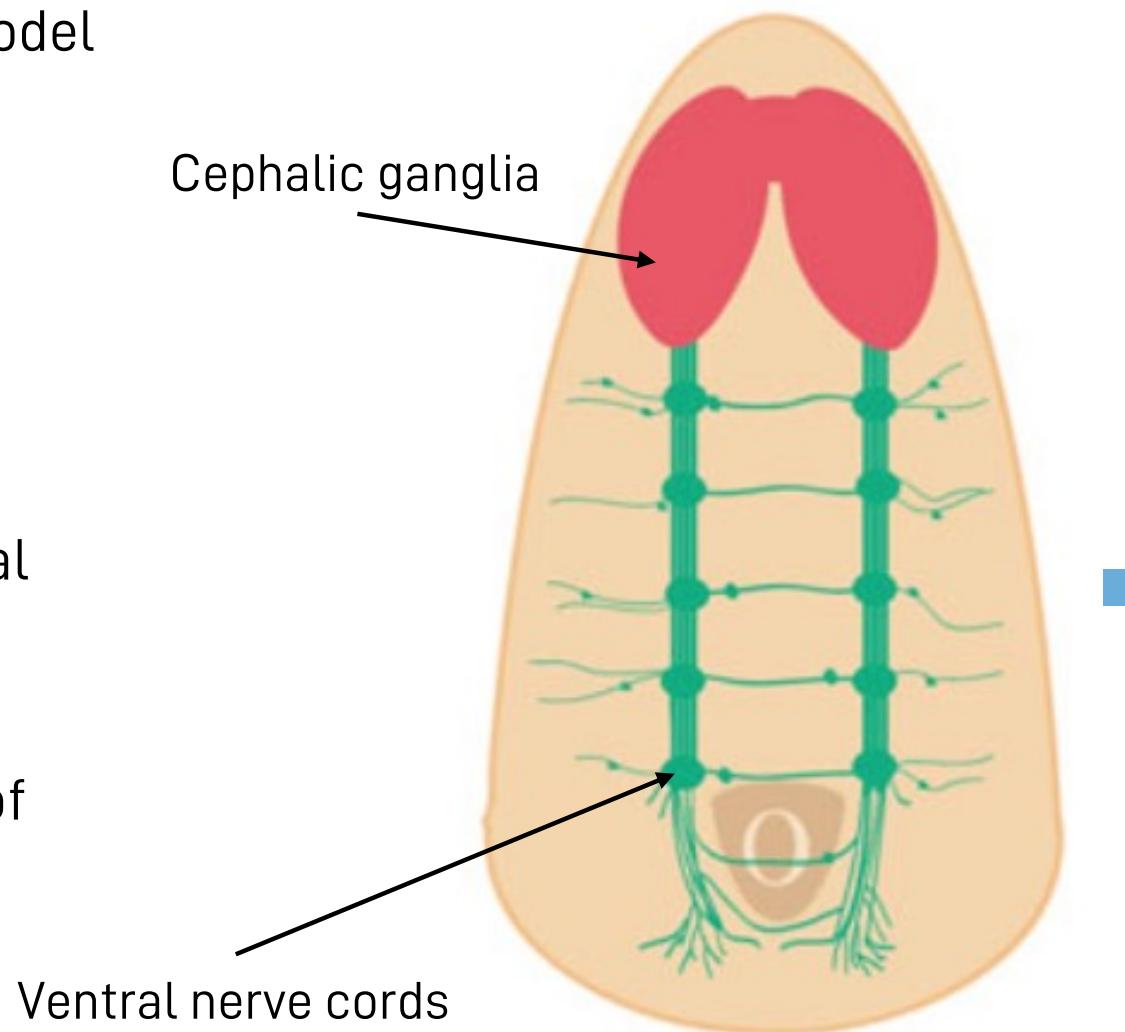
Keep it simple!

What is the simplest possible model system?

- Bilateral organization
- Visual processing
- Cognitive processes

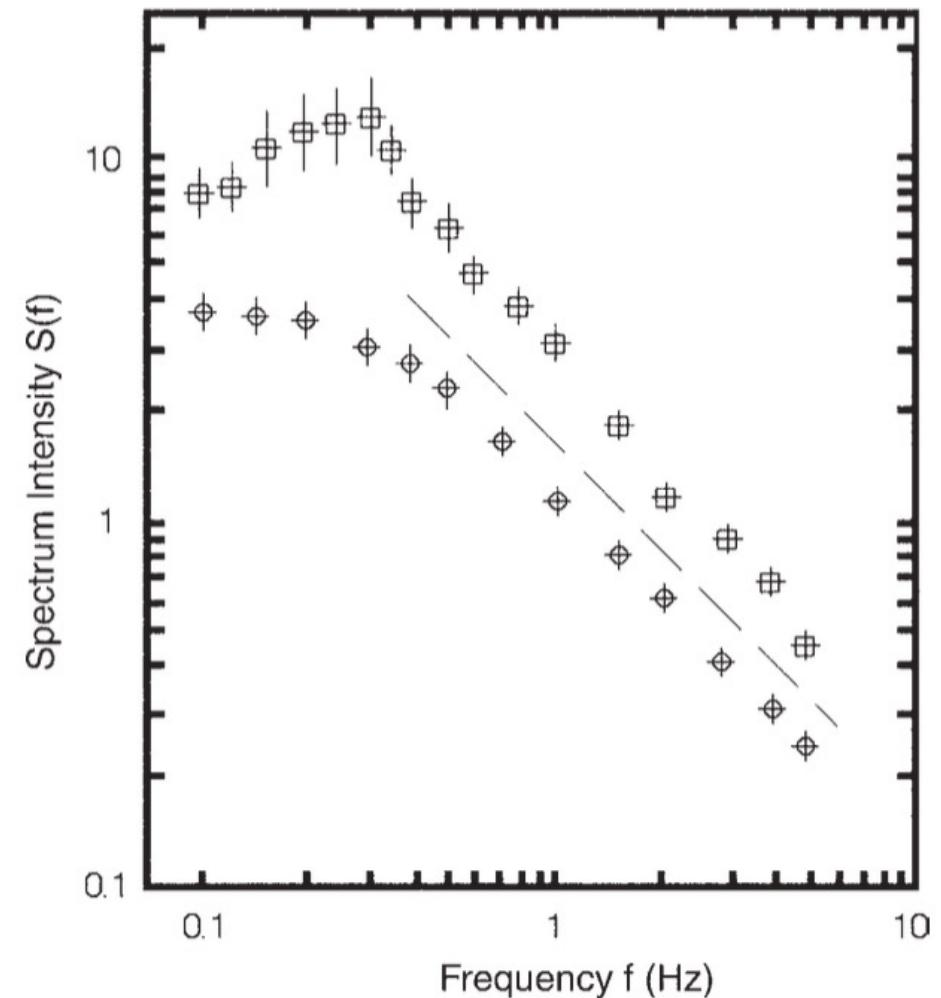
Schmidtea mediterranea as an animal model, to study functional neural mechanisms in simple nervous systems

Close to the common ancestor of bees and humans



Ongoing oscillations?

- 2 animals
 - Warmed to $\sim 10^\circ \text{ C}$
- No separation of ongoing activity and muscle potentials
- FFT analysis
 - 0.1 – 10 Hz
 - 1/f-characteristic above 0.5 Hz



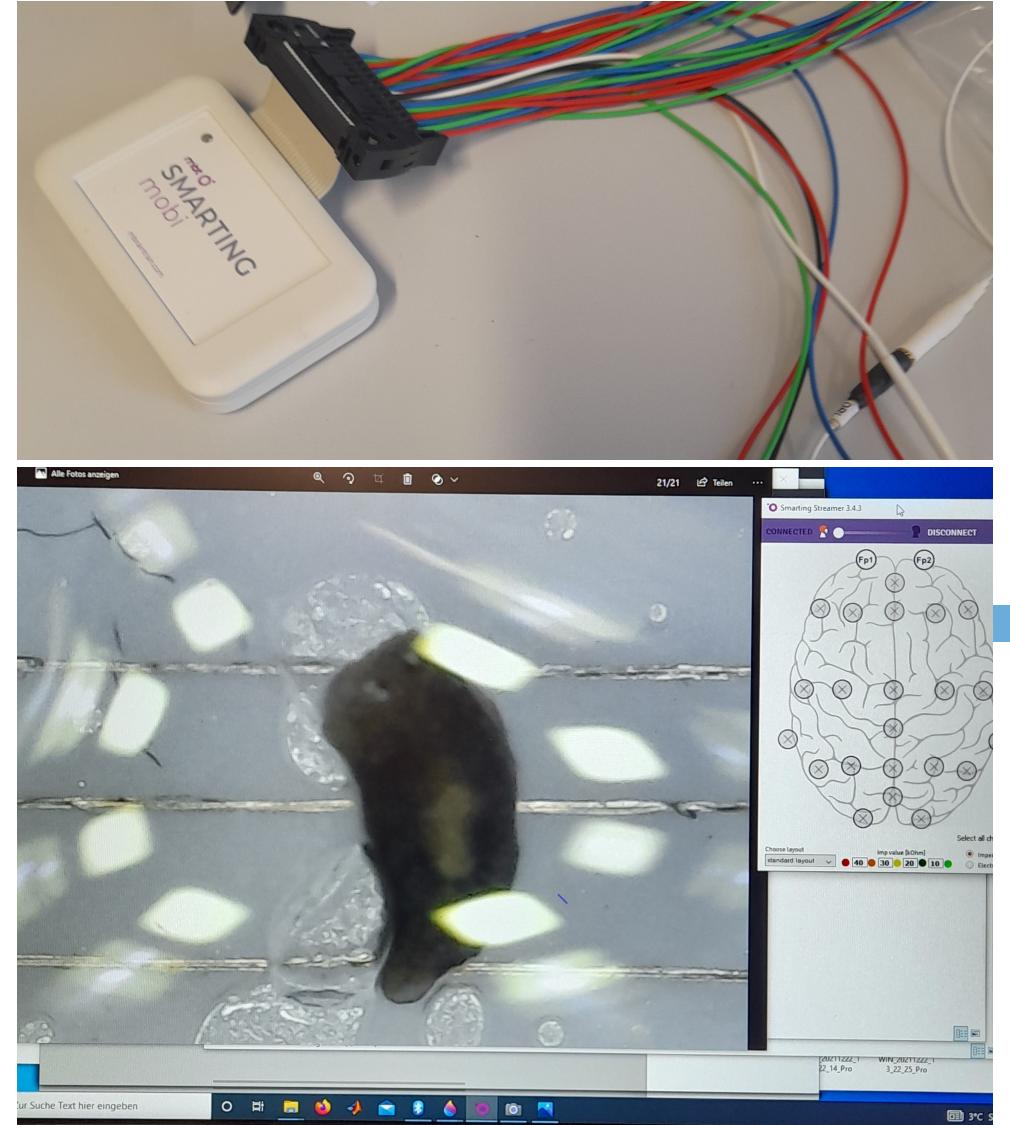
Optimize recordings

Goals:

- Less cooling
- No harming
- Simple setup

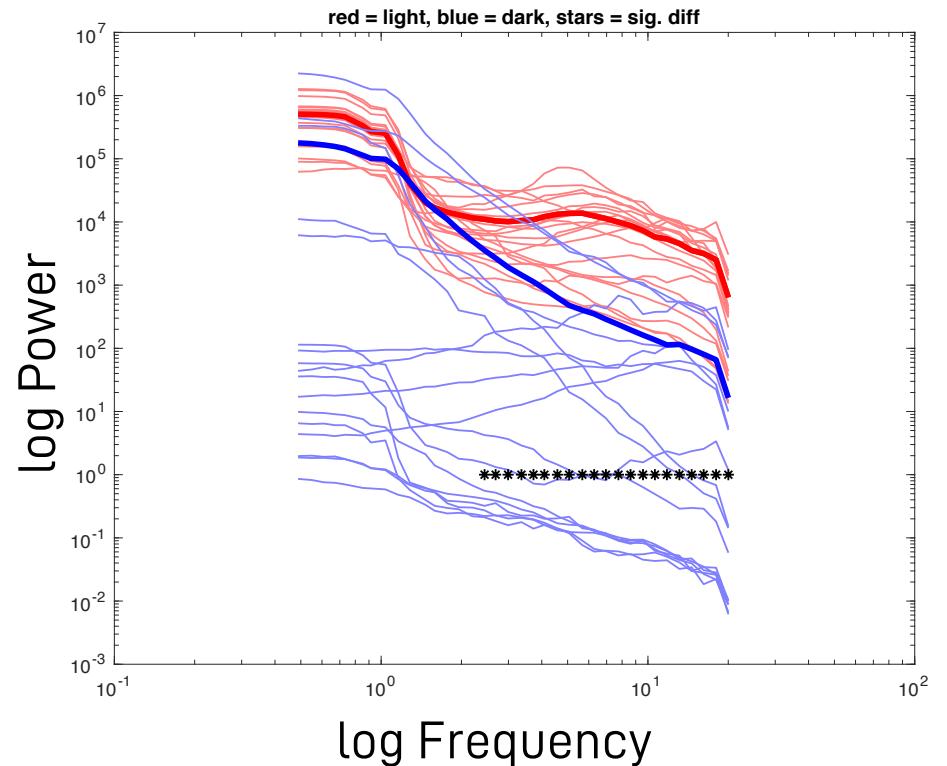
Approach:

- Human EEG amplifier
- Electroretinography wire electrodes
- Fixate the animal in agarose gel
- State-dependent recordings



First results

- N = 17 darkness, N = 20 light
- 10 minutes ongoing recording
 - 0.1 – 20 Hz FIR filter
 - 10s segments, exclude muscle activity
 - 0.5 – 20 Hz FFT
- Between-animals independent-samples t-test with cluster correction for multiple comparisons
 - 1/f-characteristic during **darkness**
 - Broadband increase in power between 3 and 20 Hz during **light** stimulation



Mean light

Individual light

Mean darkness

Individual darkness

Interim Summary 4

Current state:

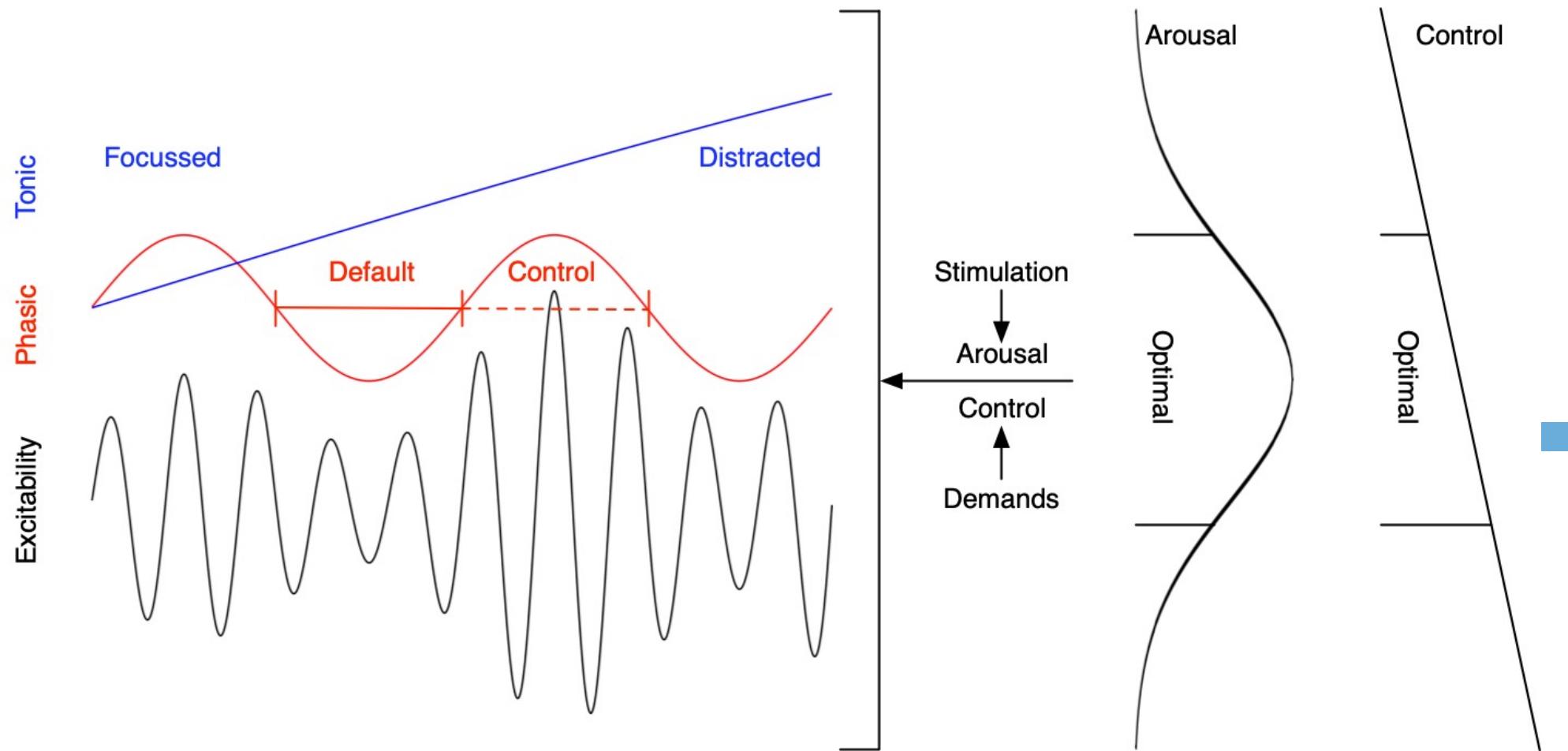
- Successful recording of ongoing neural activity without harming or killing the animal
- First evidence of functional changes of ongoing neural activity due to light stimulation

Next step:

- Optimize recording environment to exclude noise
- Introduce event-based experiments



Proposal: Interplay between excitability, arousal, and cognitive control



Thank you!



Christian-Albrechts-Universität zu Kiel

Prof. Dr. Christian Kaernbach,
Joshua Lorenzen, Jannes Freiberg,
Lukas Lang, Maren Eberle, Merle
Schuckart and many others...



Prof. Dr. Daniel Senkowski,
Dr. Mathis Kaiser, Dr. James Moran,
Dr. Georgios Michail



KE1828/2-1 (2014-2016)
KE1828/4-1 (2016-2021)

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