



Low-frequency Brain Oscillations and Cognitive Processes

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NOT about Gamma Oscillations (~30-100Hz)

Sensory Integration

Alpha Oscillations (~8-12Hz)

Top-down control, semantic LTM, inhibition

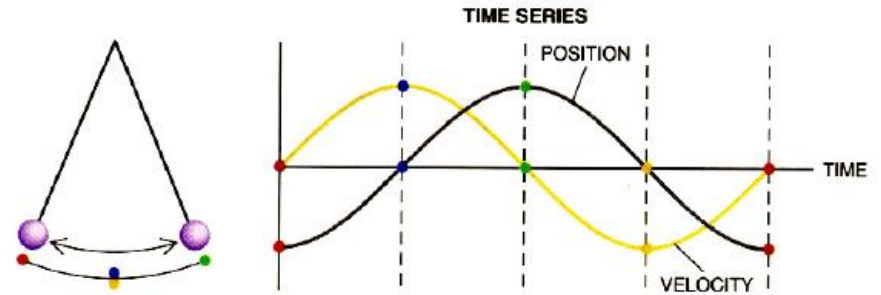
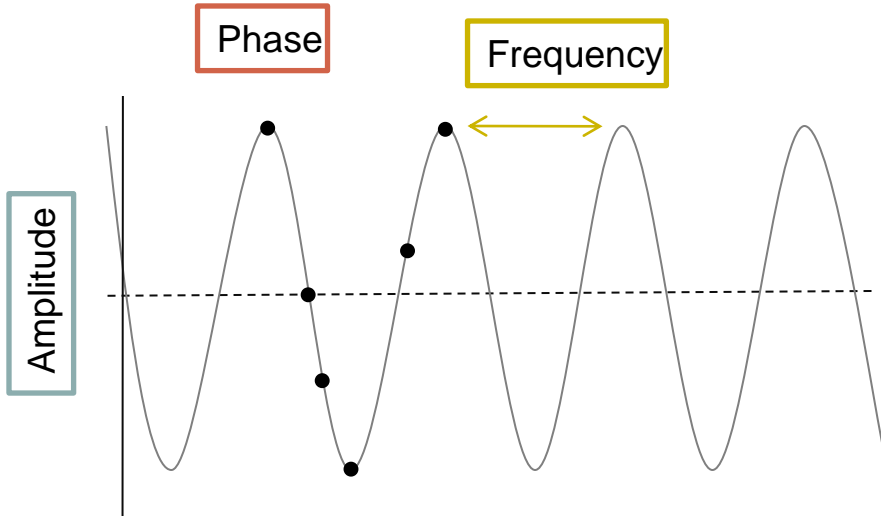
Knowledge System

Theta Oscillations (~4-6Hz)

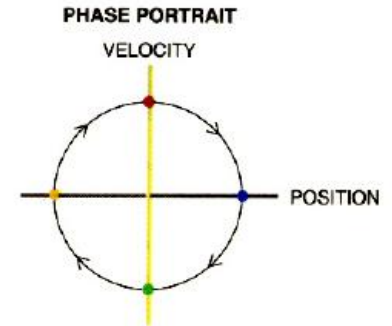
Episodic encoding/retrieval, working memory

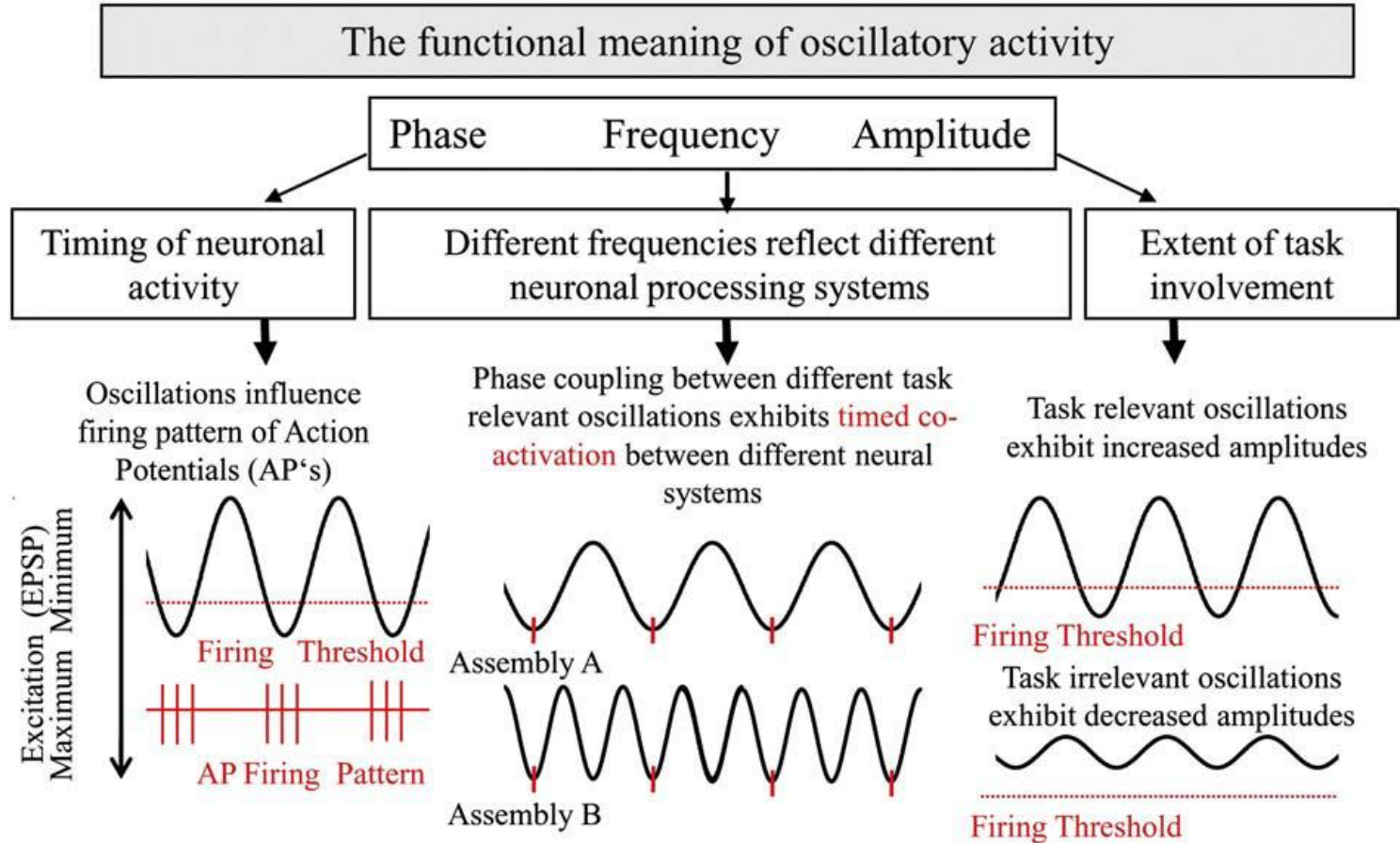
Working Memory System

Oscillations seem to be important for the coordination of information processing *within* and *between* these systems



PERIODIC MOTION can be represented in terms of a time series or a phase portrait. The phase portrait combines position and velocity, thus showing the entire range of states that a system can display. Any system that undergoes periodic behavior, no matter how complex, will eventually trace out a closed curve in phase space.





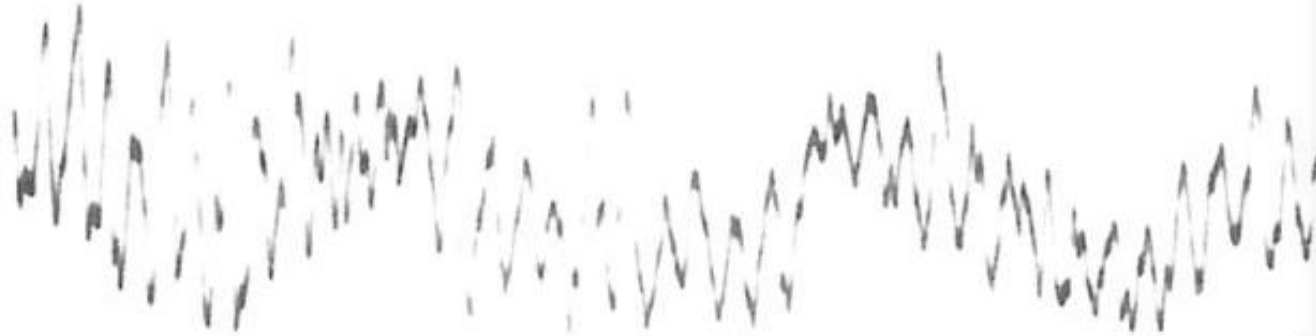


Figure 1.3. Hans Berger. (From Kollé K. 1956. Hans Berger. In *Gross Nervenärzte*, vol. 1, Ed. K. Kollé, pp. 1-6. Stuttgart: Thieme.)

- i. Alpha is the dominant rhythm during rest with a frequency between **8 and 12 Hz**.
- ii. Alpha can respond with an **increase** or a **decrease** in power
- iii. Tasks demands that involve **top-down control** of stored information (e.g. during retention) induce alpha synchronization (cf. Klimesch et al., 1999).
- iv. When retained information is retrieved alpha **desynchronizes**.





Top-Down Control

Binding (e.g. process binding)

Inhibition (e.g. of irrelevant information)

The functional meaning of oscillatory activity

Phase

Frequency

Amplitude

Timing of neuronal activity

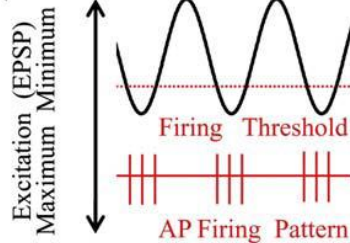
Different frequencies reflect different neuronal processing systems

Extent of task involvement

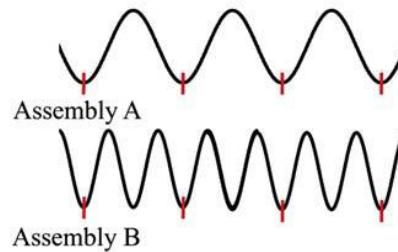
Phase-Coupling

Power/Amplitude

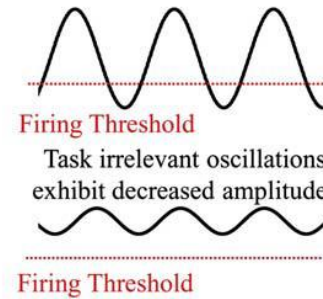
Oscillations influence firing pattern of Action Potentials (AP's)



Phase coupling between different task relevant oscillations exhibits **timed co-activation** between different neural systems

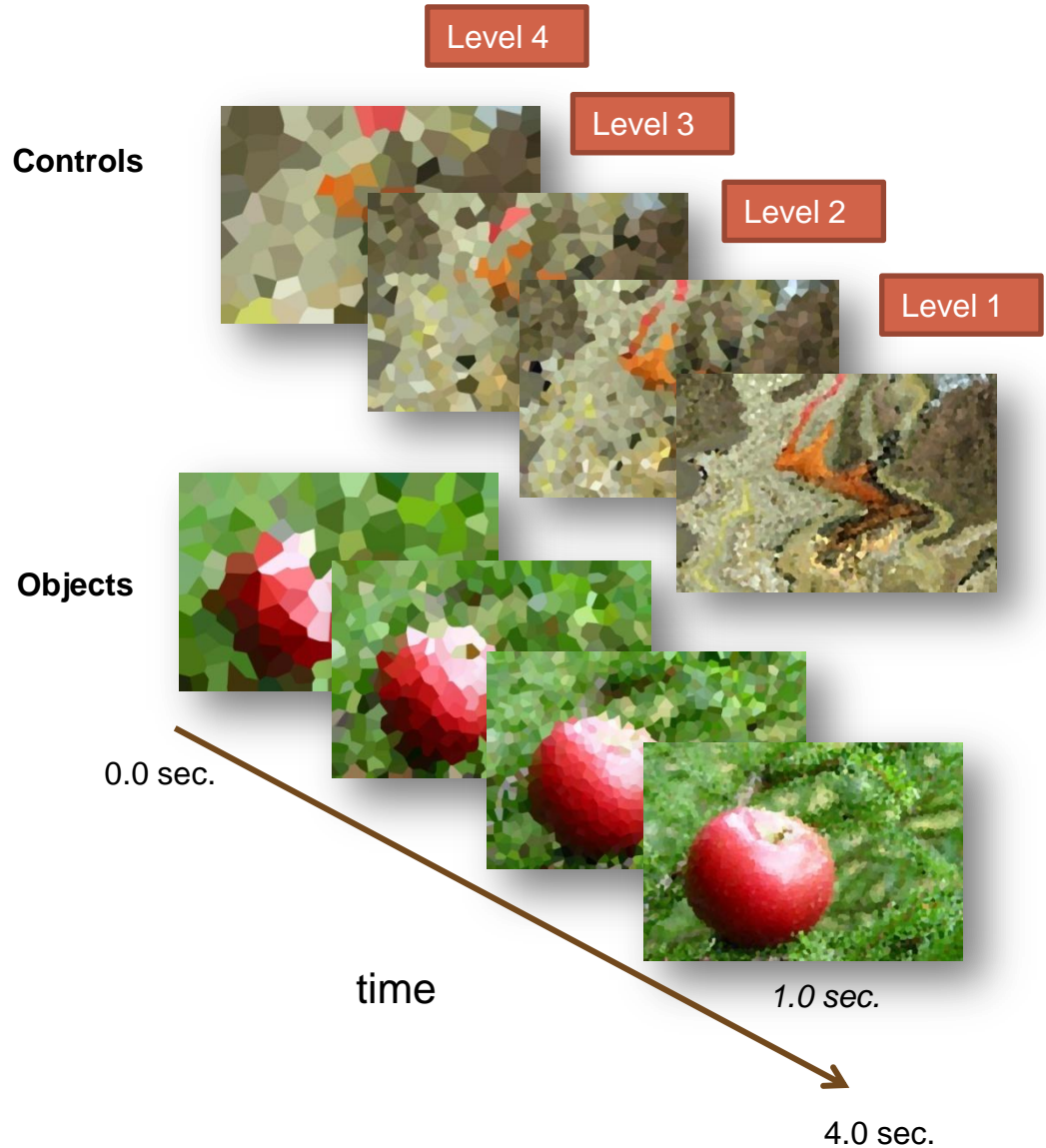


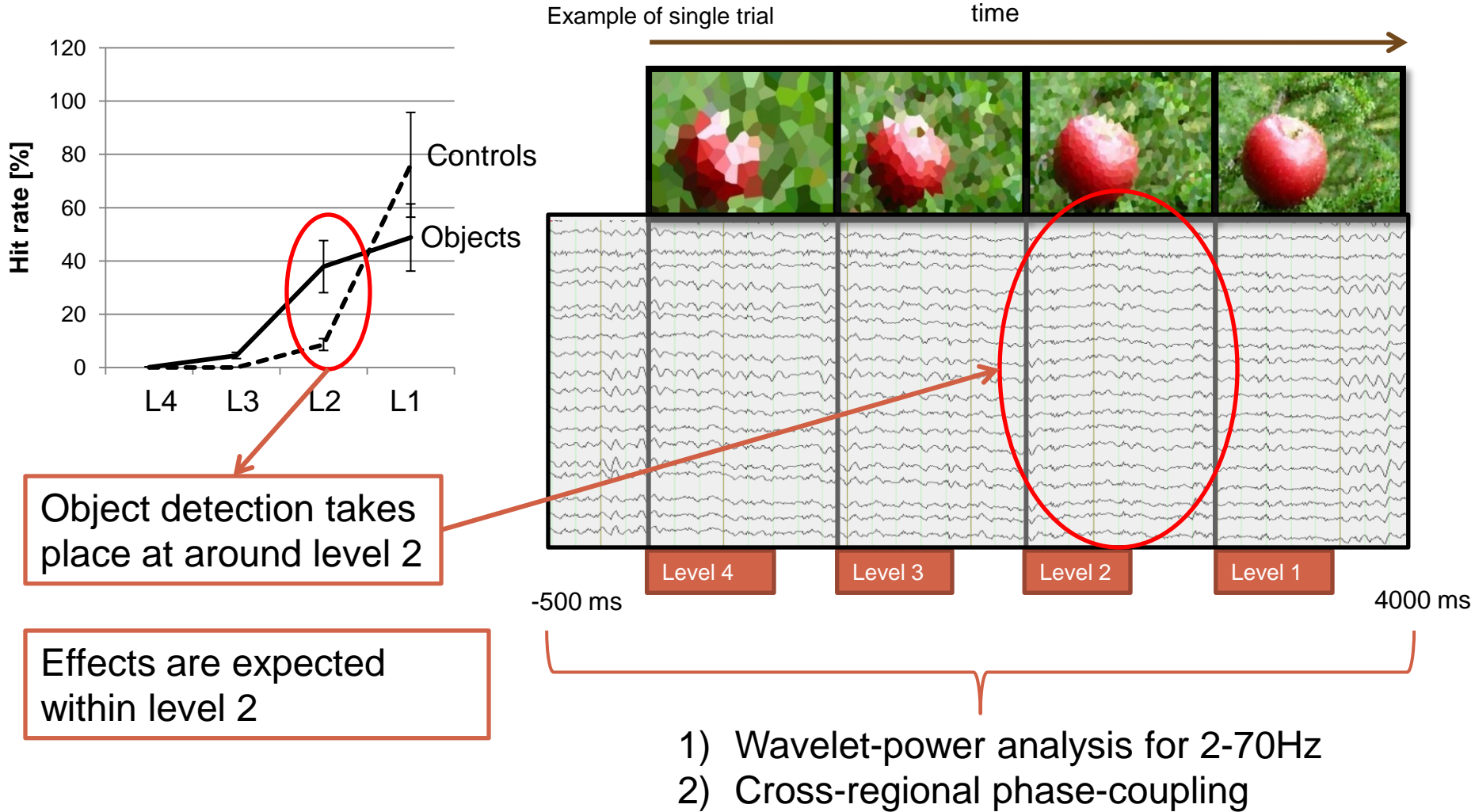
Task relevant oscillations exhibit increased amplitudes

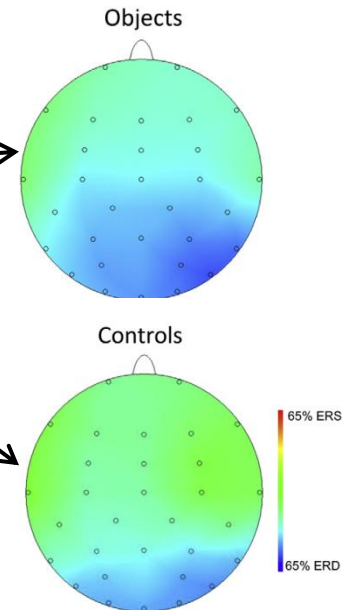
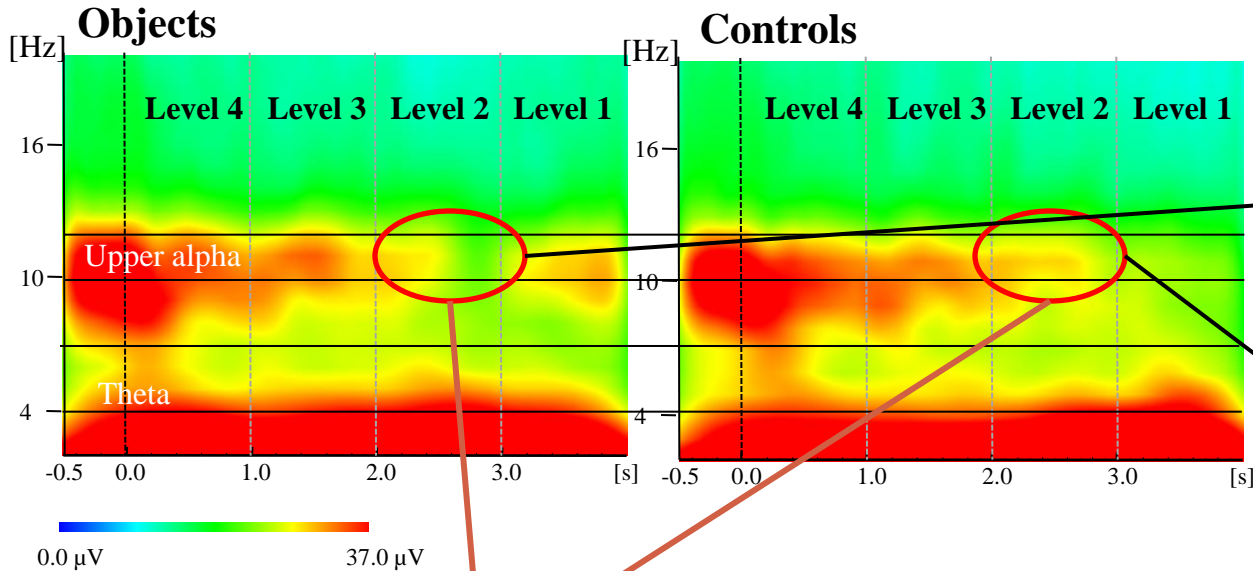




„Respond as soon as you can recognize the presented image“

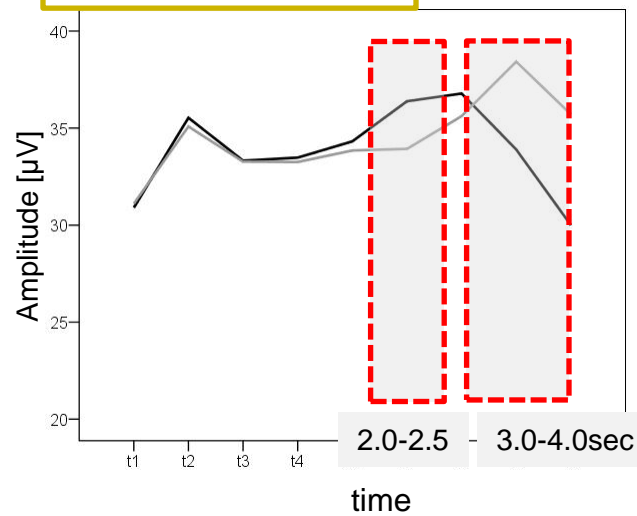
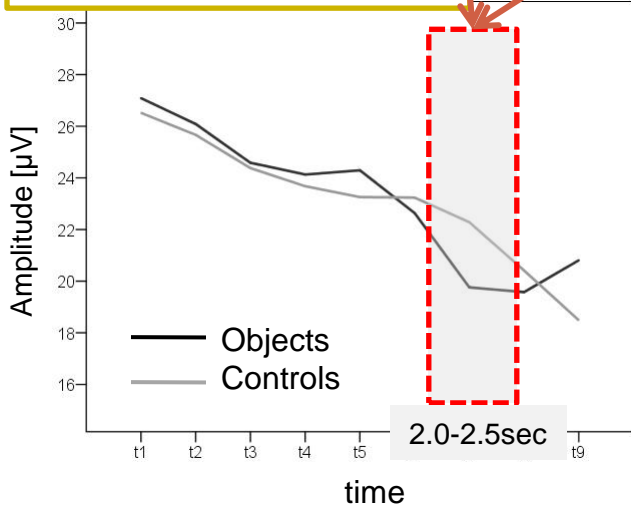






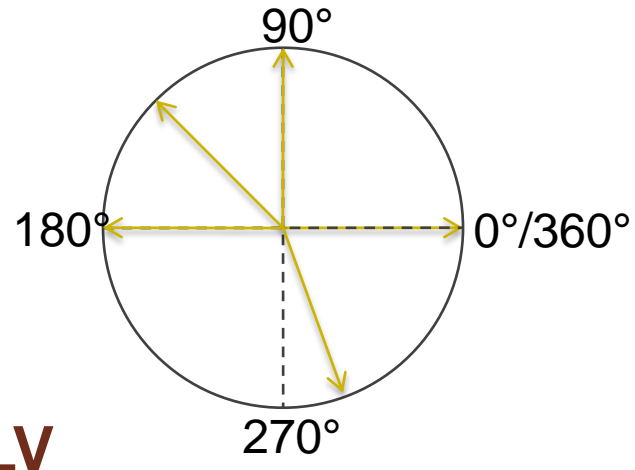
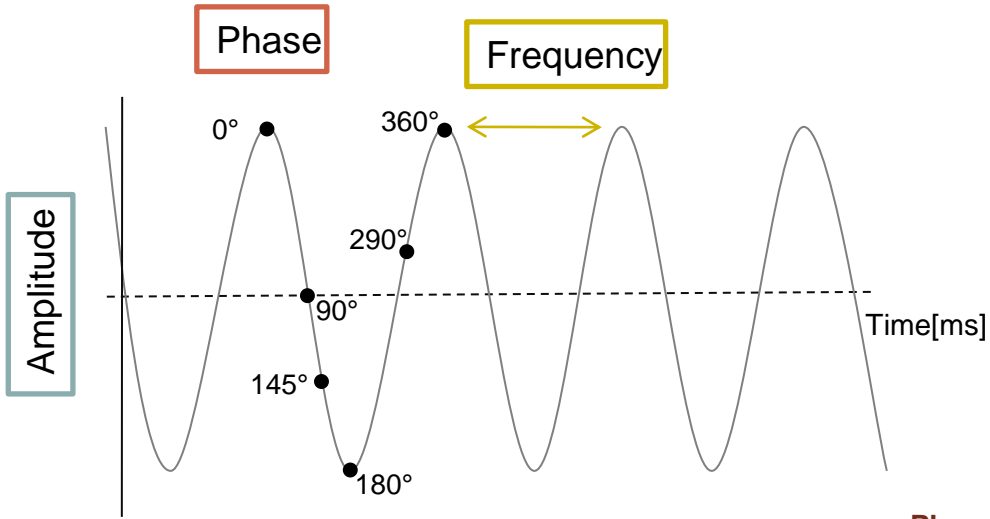
Upper alpha: right temporal

Theta: midline central



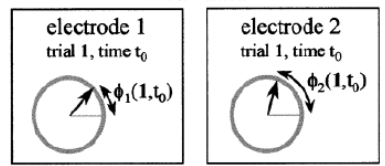
Upper alpha effect is specifically related to posterior regions.

2) Phase-Coupling Analysis



PLV

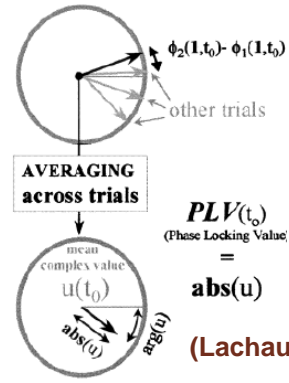
Phase-locking value



Coherence = $\frac{\text{Crossspectrum (X,Y)}}{\sqrt{\text{Autospectrum (X)} \cdot \text{Autospectrum (Y)}}$

Coherence is influenced by amplitude (power) and phase

Phase coherence (PLV) is (mathematecally) independent of amplitude (power)!

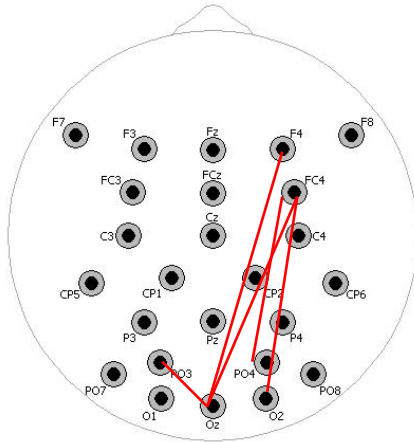


$PLV(t_0)$
(Phase Locking Value)
= $abs(u)$

(Lachaux et al., 1999)

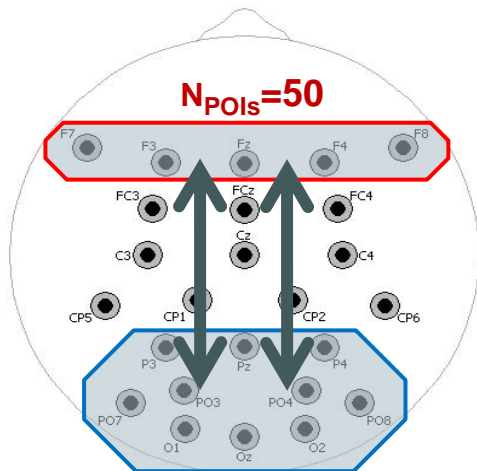


Upper Alpha

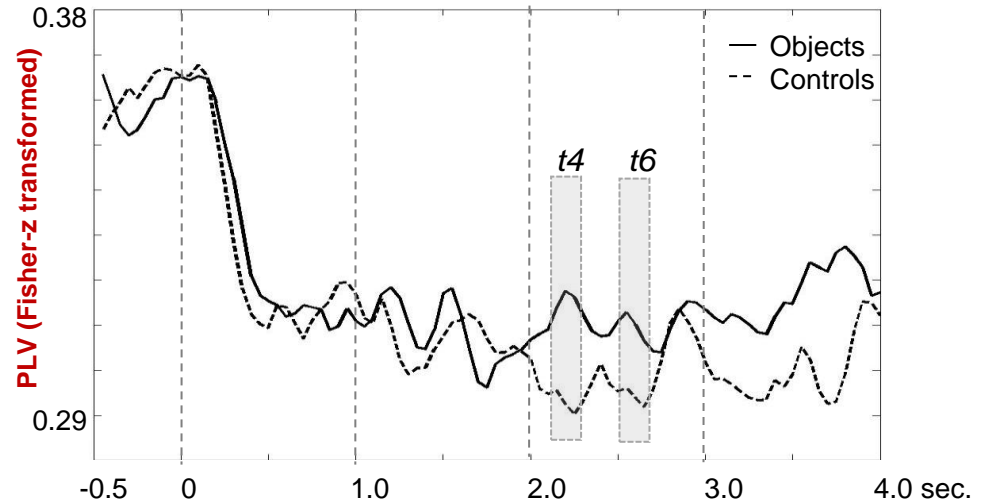


2.0-2.5 sec.

- Objects > Controls ($p < .01$)
- Controls > Objects ($p < .01$)



Upper alpha grand average PLV over 50 POIs

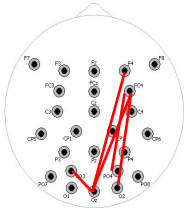




Onset of upper alpha ERD is associated with retrieval of a semantic memory trace (e.g. Klimesch et al., 2007)

Theta reflects context updating and is important for episodic encoding (e.g. Makeig et al., 2004; Sauseng et al., 2007).

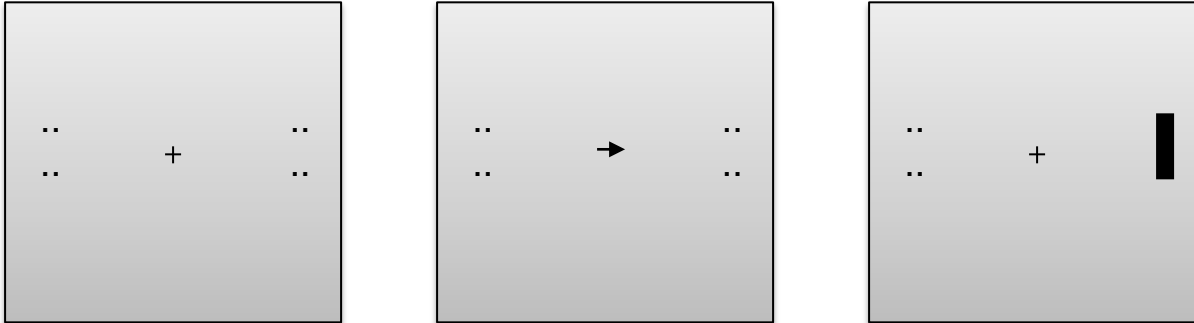
„The theta-alpha response is important for episodic and semantic encoding „ (Klimesch, 1999).



- The coupling between frontal and posterior regions reflects a top-down control process for the access to semantic information from LTM.
- Upper Alpha coupling serves as a **guiding mechanism** enabling access to a LTM trace (cf. Klimesch et al., 2007).
- **Context** is encoded in slow oscillations and **content** in high oscillations (Van Rullen & Koch, 2003, Bar, 2007).
- Slow oscillations like alpha reflect **top-down processing** over large cortical distances whereas gamma is more focal and relevant for specific sensory processing (Von Stein et al., 2001).



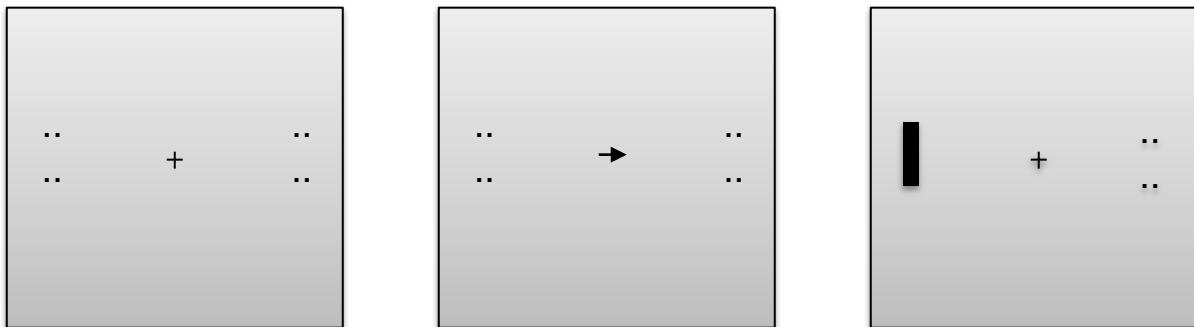
VALID Trial, Example:



Cue: Arrow, 34 ms; Random SOA (600-800 ms); Target 50 ms

The cue indicates the most likely side ($p = .75$; valid trials).

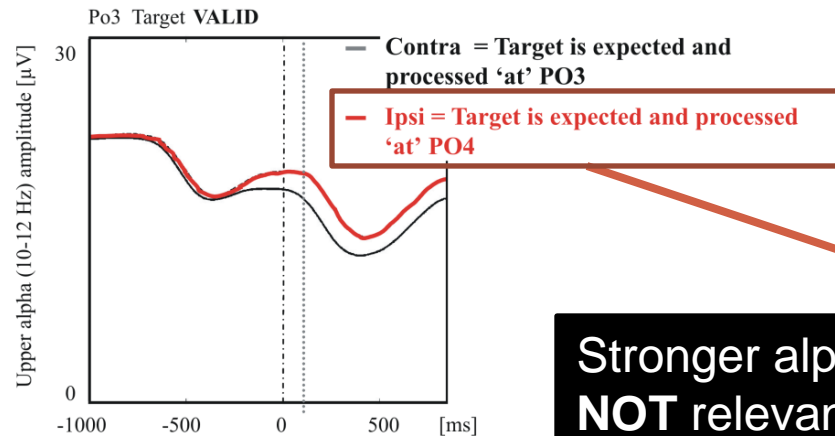
INVALID Trial, Example:



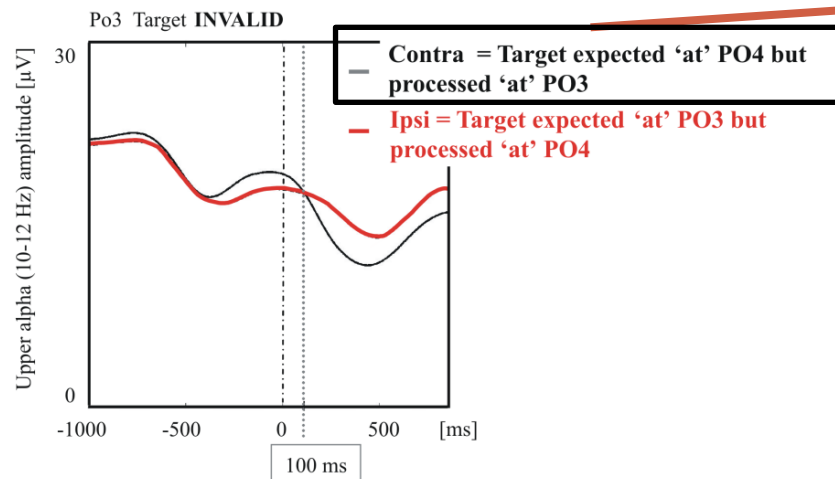
Cue: Arrow, 34 ms; Random SOA (600-800 ms); Target 50 ms

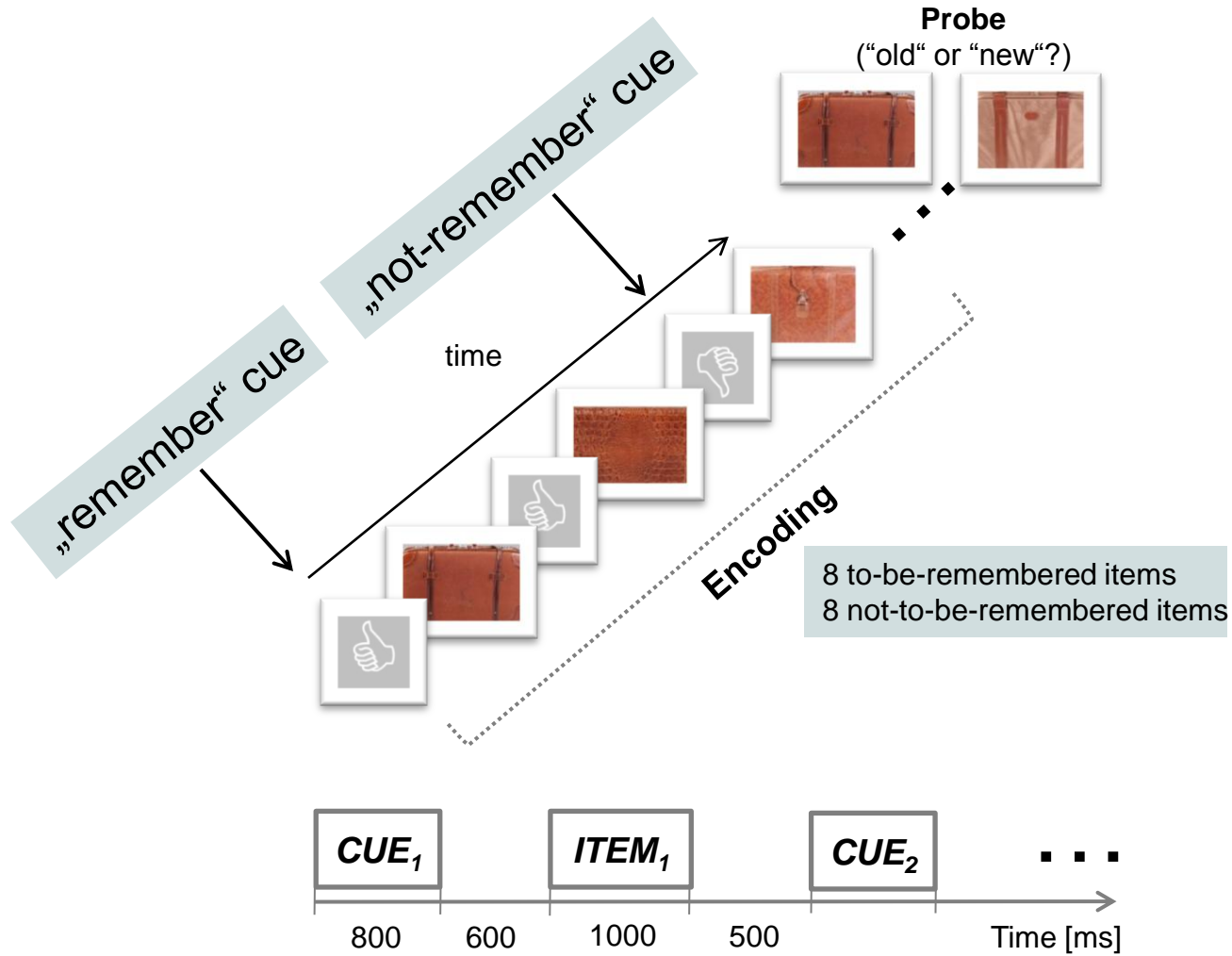


Alpha Amplitude



Stronger alpha synchronization on sites **NOT** relevant for task processing (pre-stimulus)

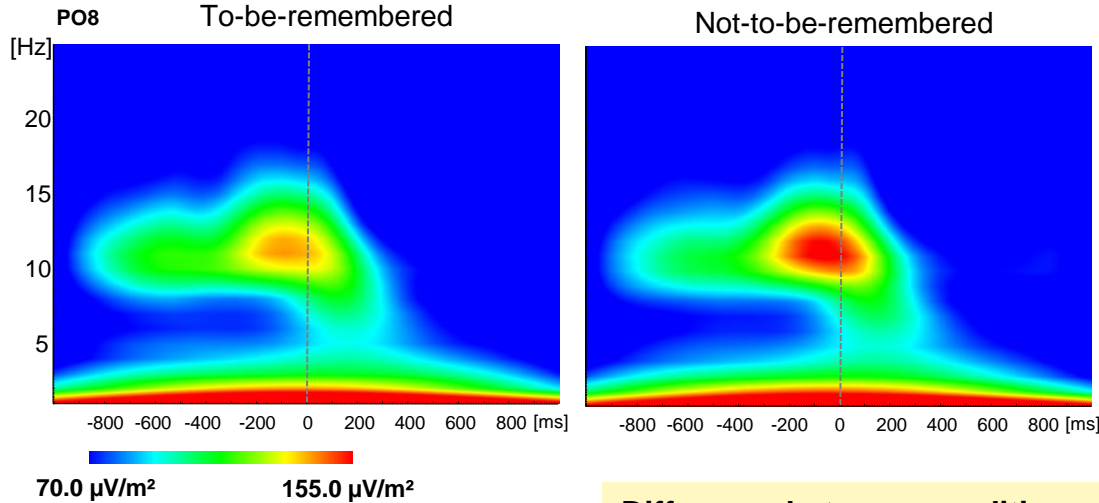




N=23

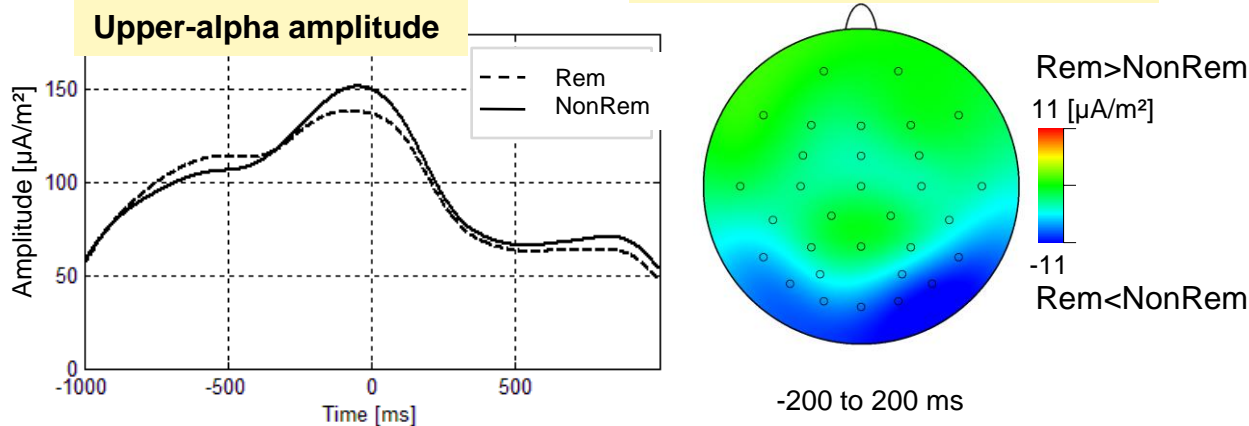


Amplitude



Upper-alpha power is stronger for **non-rem items** in a time-window from *-200 to 400ms* compared to rem-items.

Difference between conditions



Alpha synchronization reflects top-down control important for attentional and memory processing.

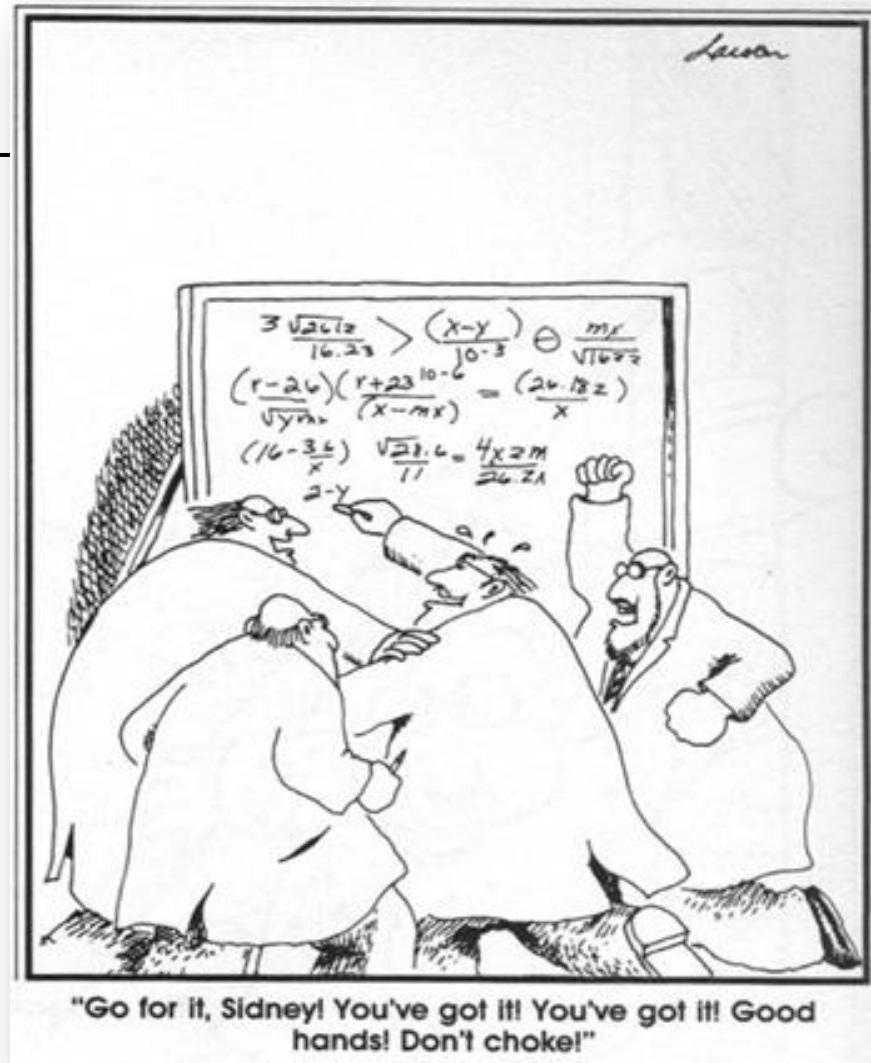
Alpha synchronization reflects inhibition of task-irrelevant items.

Alpha oscillations are not just background noise:

- **Alpha mirrors top-down control mechanisms for inhibition**
- **Alpha is important for the access to semantic LTM traces**

Previous work:

- Upper alpha is relevant for **semantic processing** (Klimesch et al., 1999)
- Alpha phase is important for the **timing** of neuronal activity (Klimesch et al., 2006)
- Correlation between alpha synchronization and **object recognition** (Mima et al., 2001)
- Alpha and **top-down processing** (Sauseng et al., 2005; Von Stein et al., 2001).
- Alpha an **inhibitory mechanism** in motor control (Hummel et al., 2002).



©Gary Larson



Salzburg



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Walter Gruber



Paul Sauseng



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