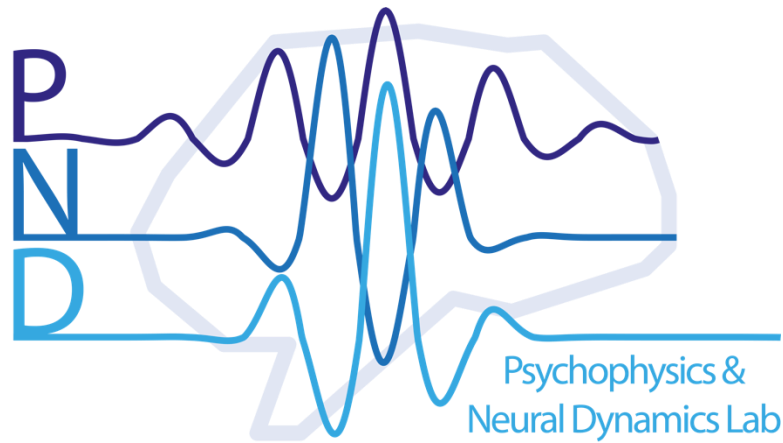

ALPHA OSCILLATIONS IN VISUAL PERCEPTION BEYOND RHYTHMIC SAMPLING



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Maëlan Menétrey

Rhythms of the brain

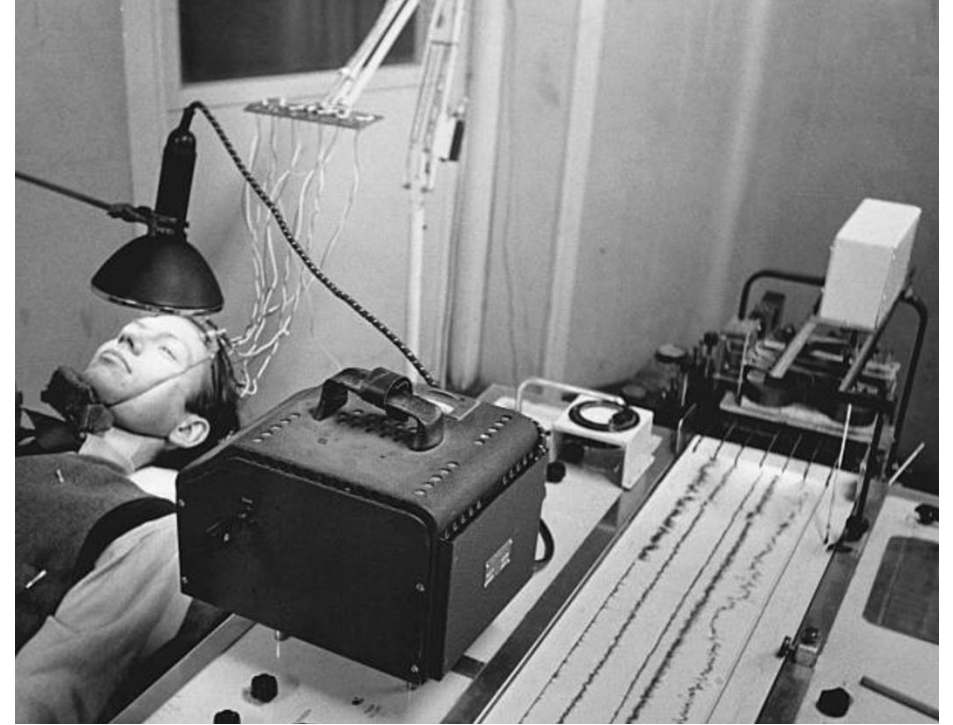
Electrical activity of the brain was measured for the first time 100 years ago.

- Prominent rhythmic waves around 10 Hz: **the alpha oscillations.**

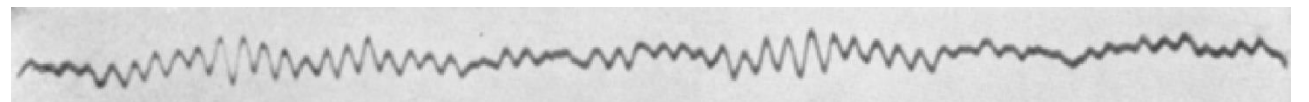
Hans Berger



Electroencephalogram (EEG)



Alpha oscillations



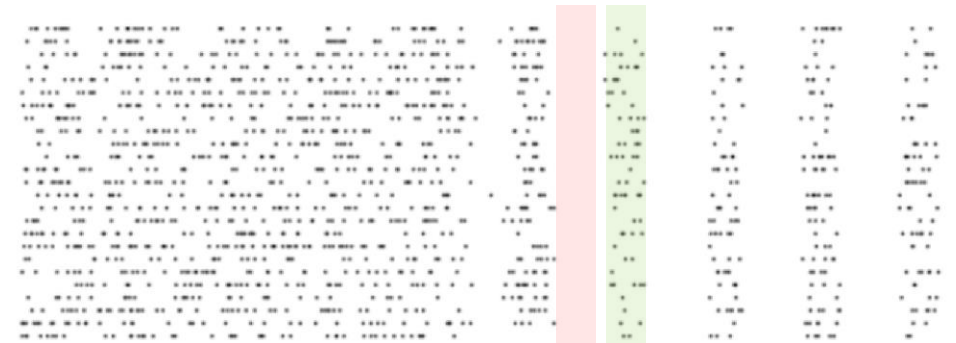
~10 cycles per second

Alpha oscillations and neural excitability

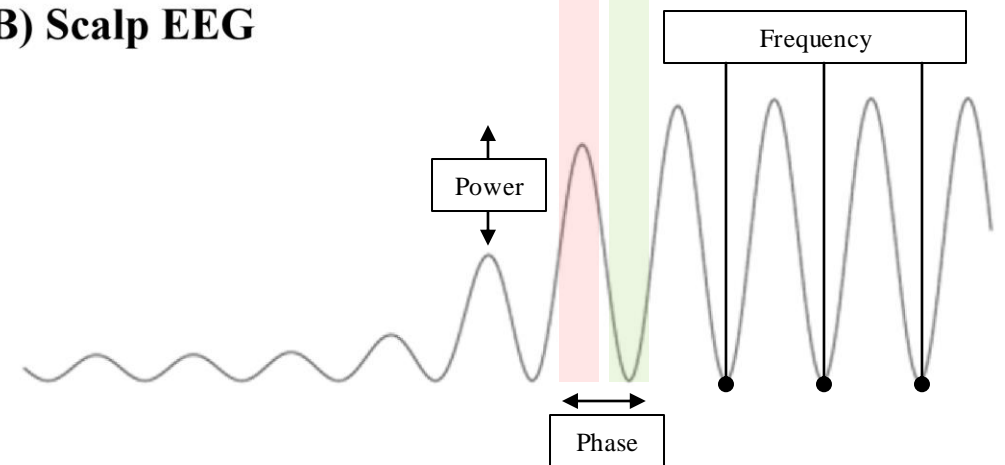
Alpha oscillations reflect neural synchronization and pulsed inhibition (Jensen, 2024).

- Power is inversely correlated with neuronal firing rate.
- One phase is associated with high excitability.
- The duration of the cycles can be determined from the frequency.

A) Firing neurons



B) Scalp EEG



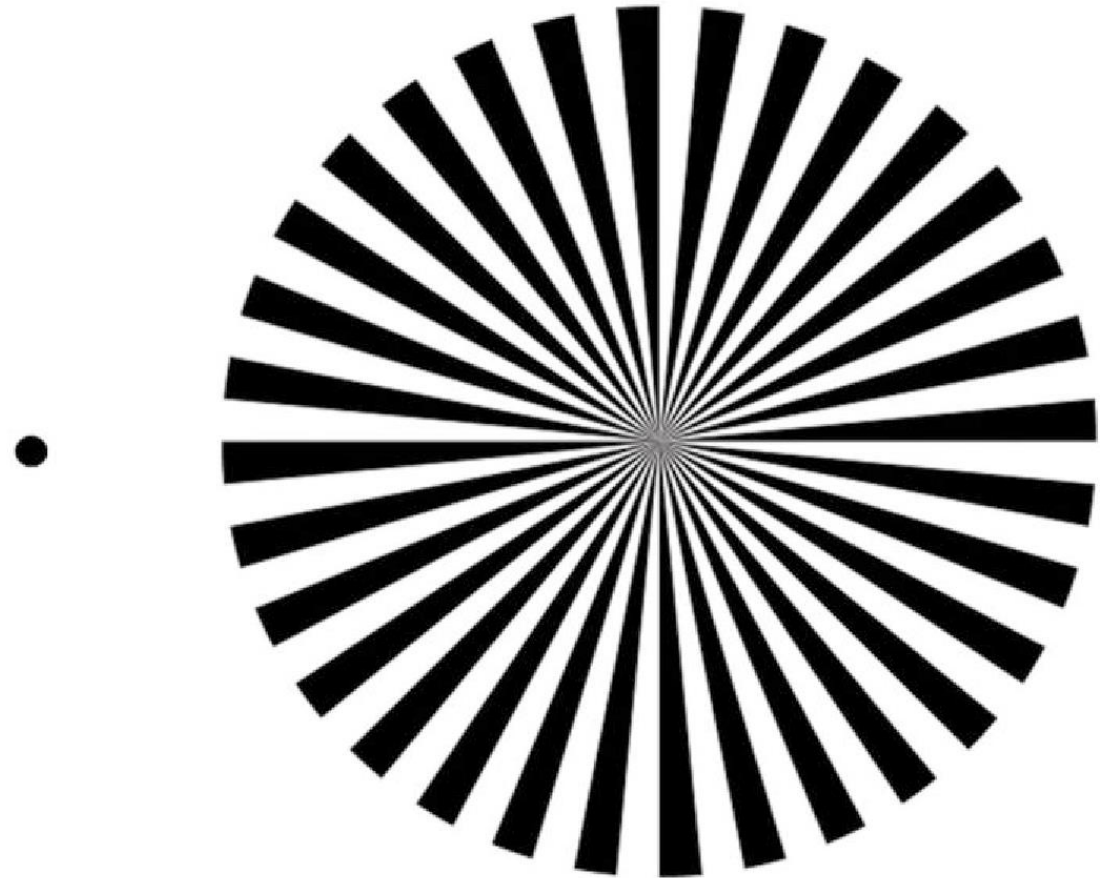
Rhythms in perception

The flickering wheel illusion

- A conscious experience of fluctuations in perception?

Illusory flicker is predicted by **occipital alpha oscillations**.

- When alpha power is strong, the probability of reporting illusory flicker increases.
- The perceived rhythm of flicker is correlated with the alpha frequency.



Rhythmic sampling via alpha oscillations

Two potential effects (e.g., Samaha & Postle, 2015; VanRullen, 2016; Ronconi et al., 2018)

Sensory modulator

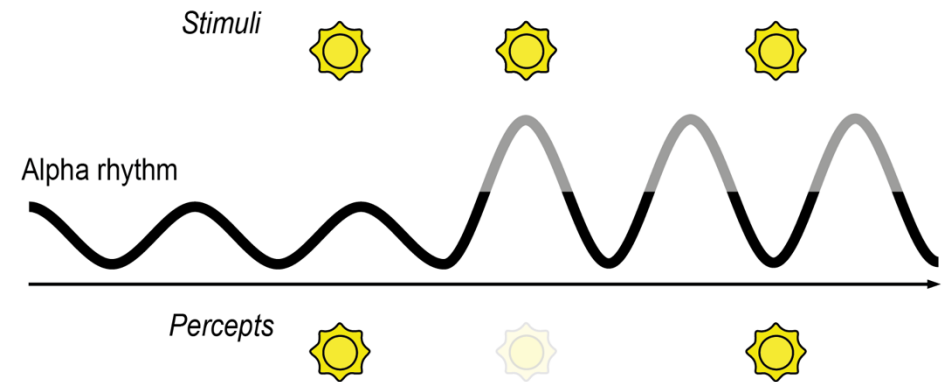


Rhythmic sampling via alpha oscillations

Two potential effects (e.g., Samaha & Postle, 2015; VanRullen, 2016; Ronconi et al., 2018)

Sensory modulator

- Perception fluctuates: the power and phase of alpha oscillations modulate sensory processing.



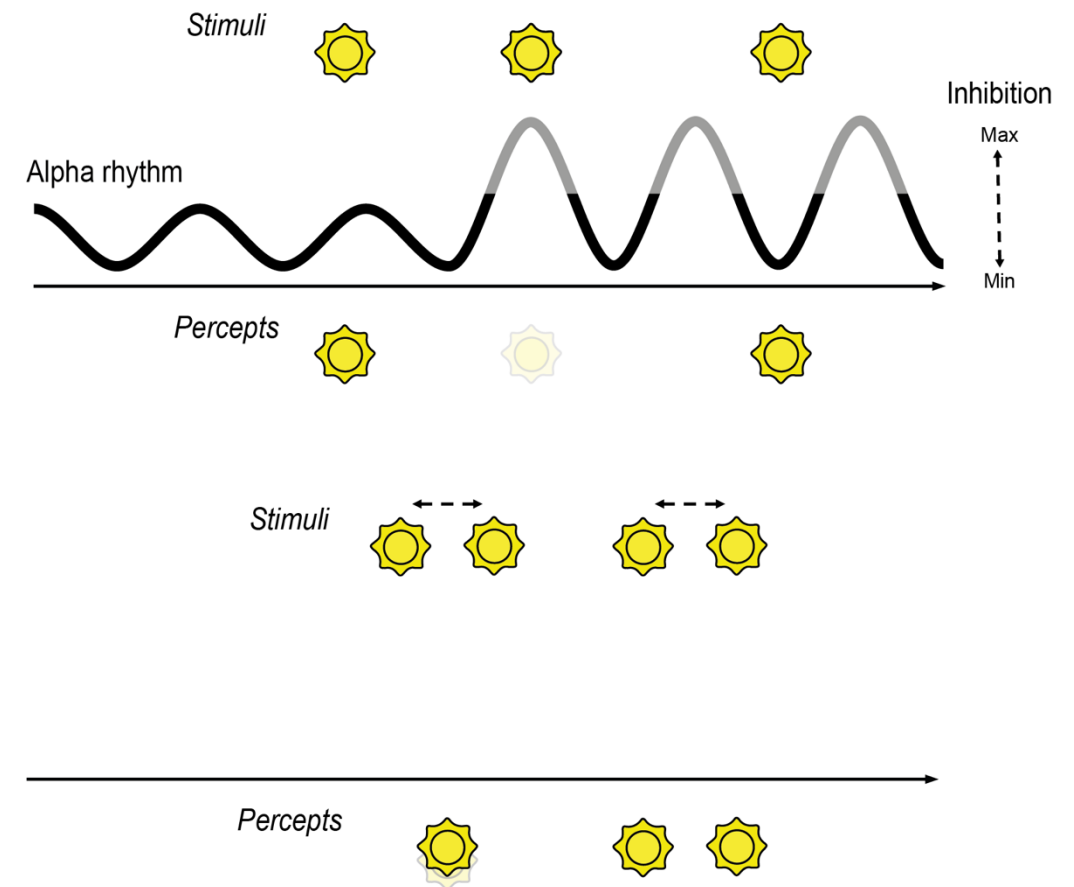
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Sensory integrator

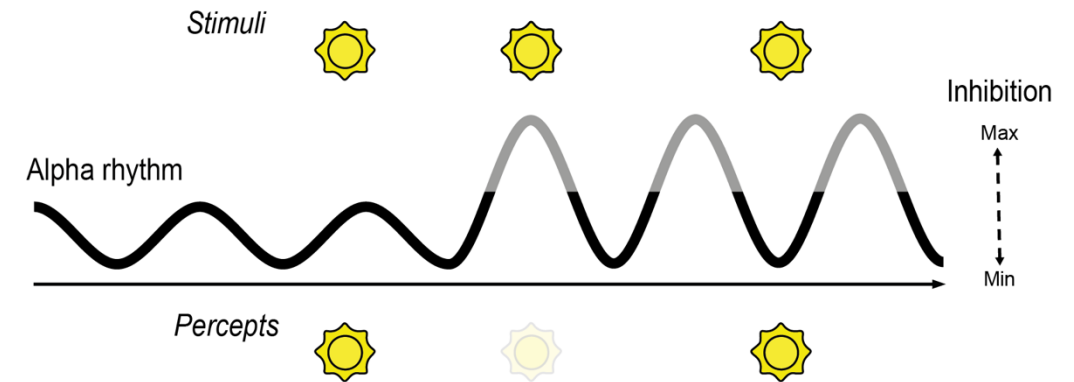


Rhythmic sampling via alpha oscillations

Two potential effects (e.g., Samaha & Postle, 2015; VanRullen, 2016; Ronconi et al., 2018)

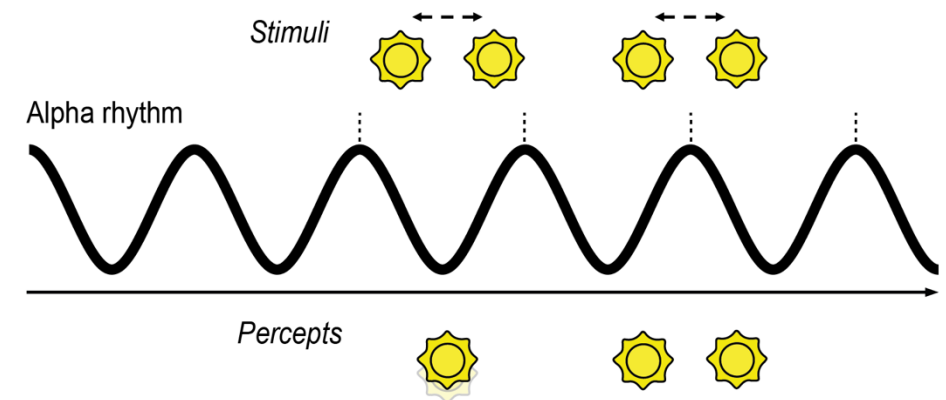
Sensory modulator

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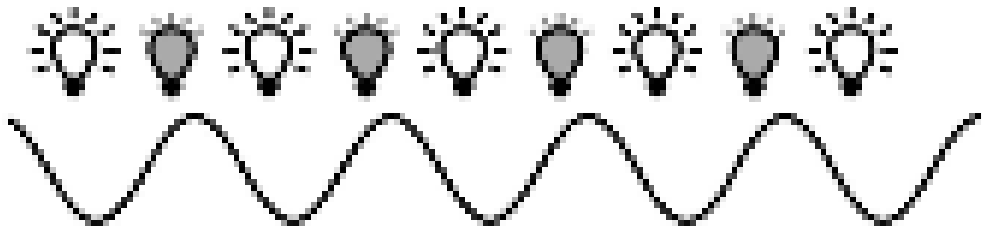
Sensory integrator

- Perception is discrete: visual information is integrated within discrete epochs defined by the alpha cycles.



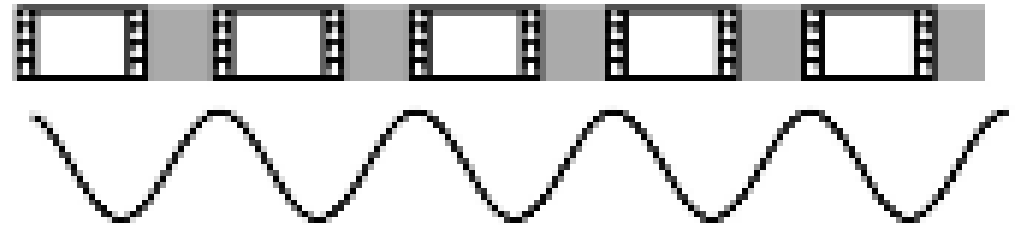
Which aspects of perception are affected?

The *content* of perception



versus

The *structure* of perception



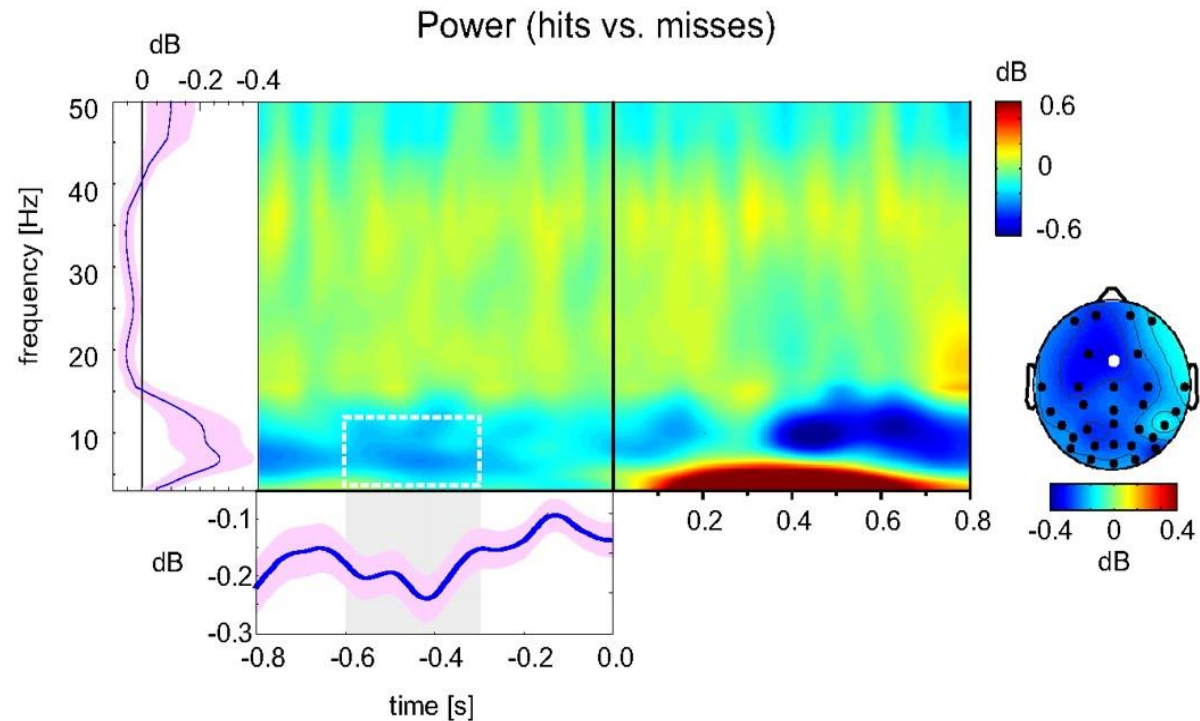
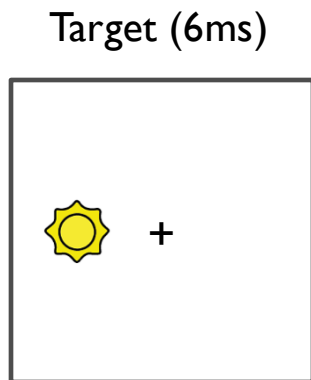
Study 1: Do alpha oscillations modulate conscious perception or unconscious sensory processing?

- Pre-stimulus alpha activity

Study 2: Do alpha oscillations determine windows of temporal integration?

Pre-stimulus activity

- Numerous studies have shown that pre-stimulus alpha activity modulates the detection of visual stimuli (for reviews, see Ruzoli et al., 2019; Keitel et al., 2022).

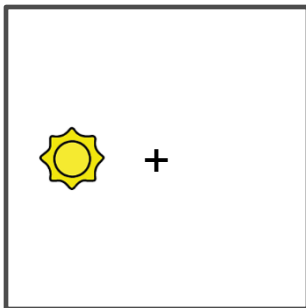


Limitations

However, these studies only focus on short-lived effects, in which alpha activity influences the perception

- of brief, static and near-threshold stimuli

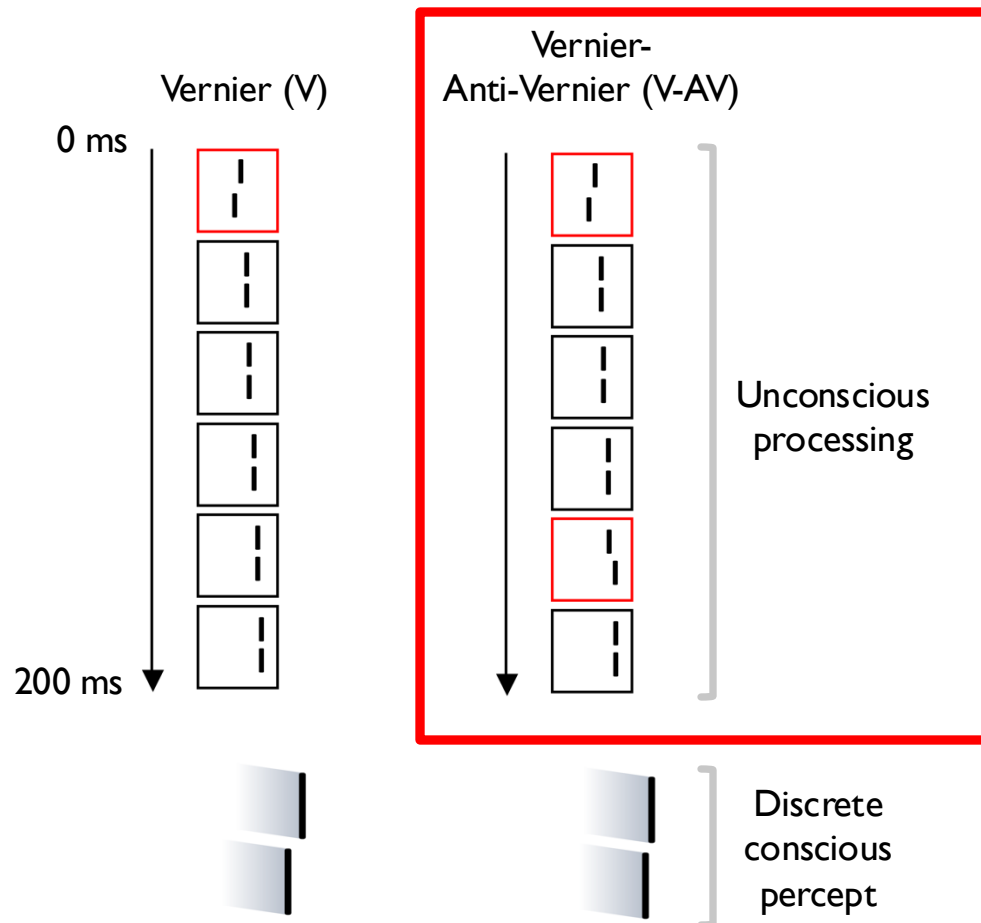
Target (6ms)



- These studies ignore the dynamic nature of perception and the integration of visual information over time.
- ❖ **Do pre-stimulus effects generalize to paradigms that involve long-lasting integration?**

Long-lasting feature integration

- The Sequential Metacontrast Paradigm (SQM).



- Pre-stimulus analysis using EEG recordings during the V-AV condition.

- 2AFC 

1st vernier offset dominates

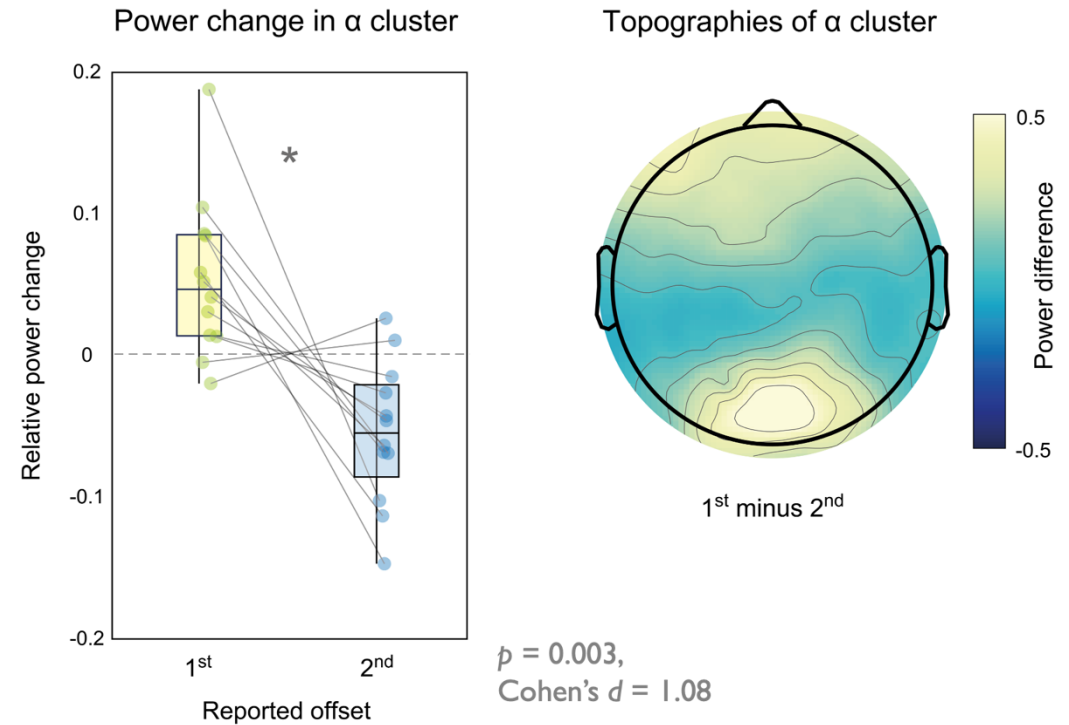
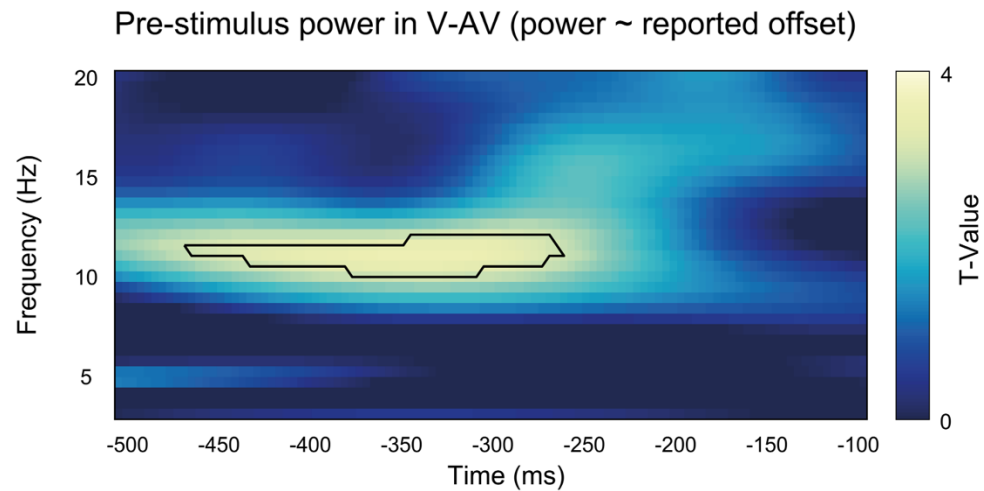


2nd vernier offset dominates



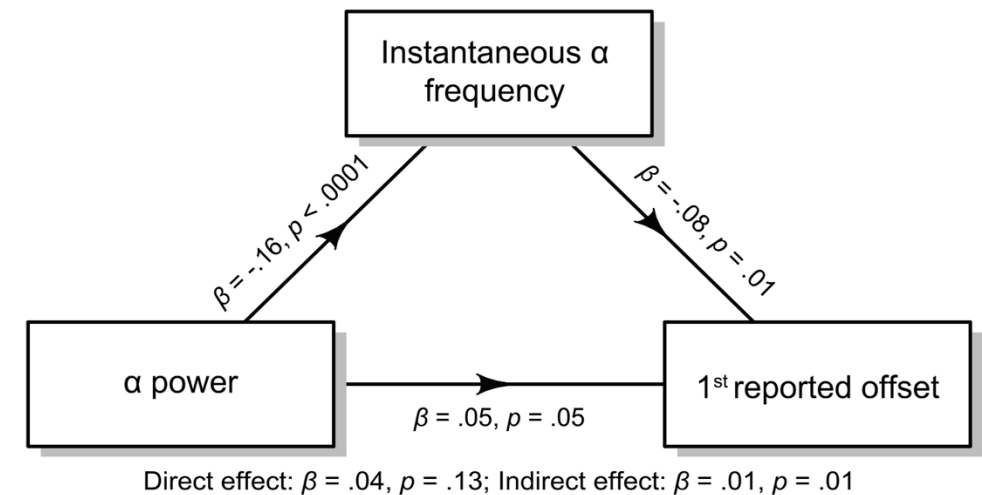
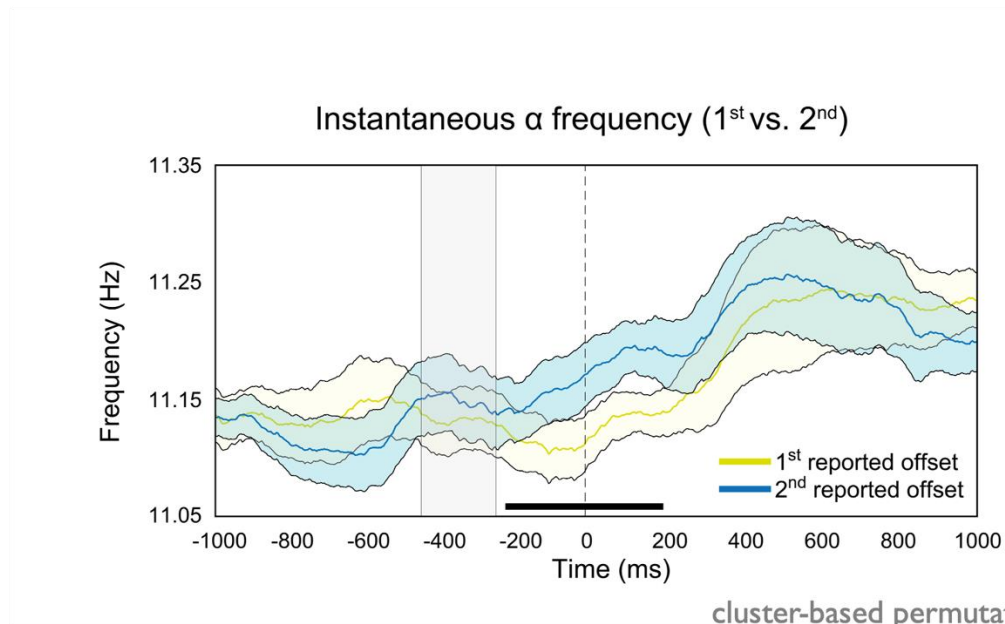
Pre-stimulus analysis

- Pre-stimulus alpha power affects whether the 1st or 2nd vernier offset dominates.



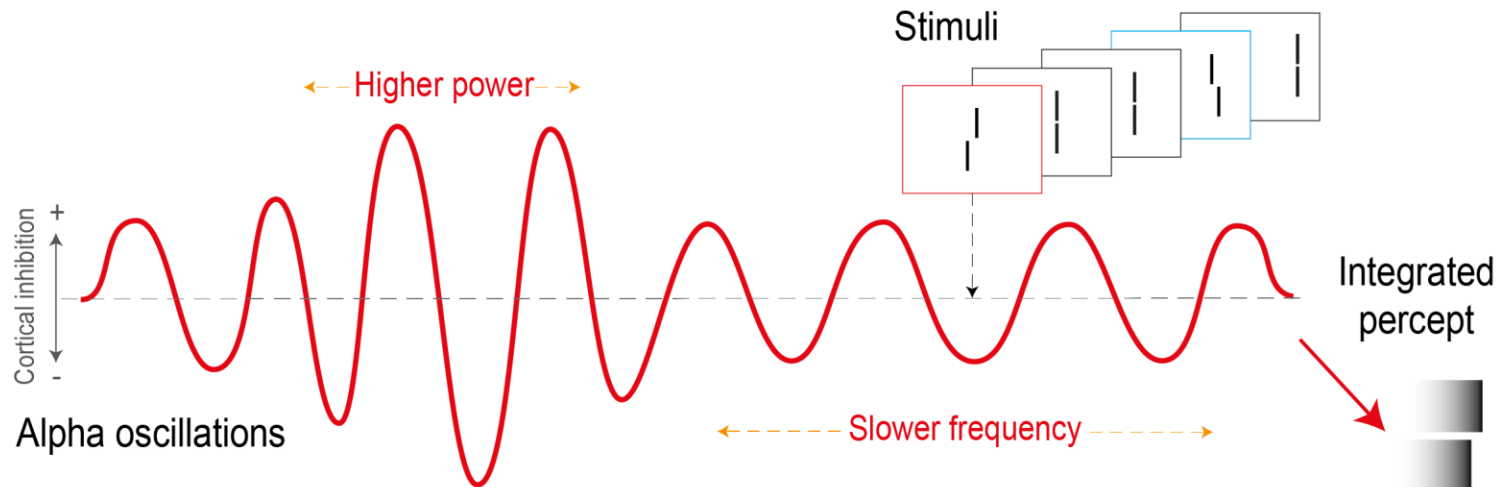
Frequency sliding analysis

- Pre-stimulus alpha power effects are mediated by a decrease in the instantaneous alpha frequency.



Alpha oscillations modulate unconscious processing

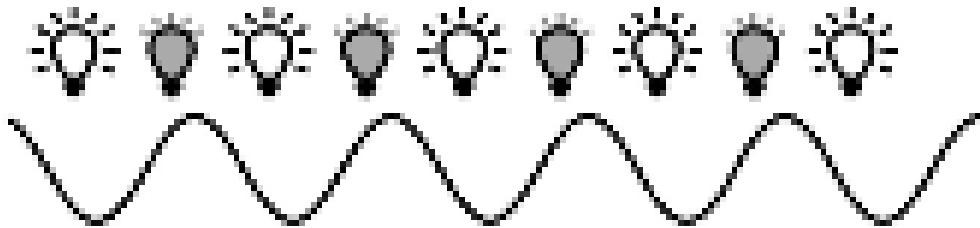
- Alpha activity affects the relative weighting of individual features during unconscious integration.
 - Feature integration in the SQM occurs before conscious perception.
- The effects of alpha activity are not limited to single points in time.
 - Alpha bursts are followed by long-lasting slowing of the alpha frequency.



- Slower alpha rhythms increase the representation of the 1st vernier in the integrated percept.

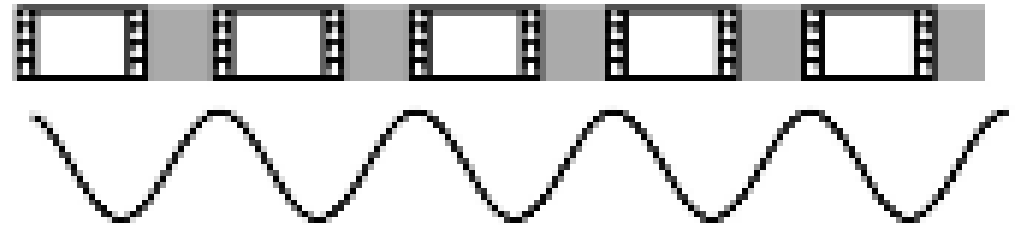
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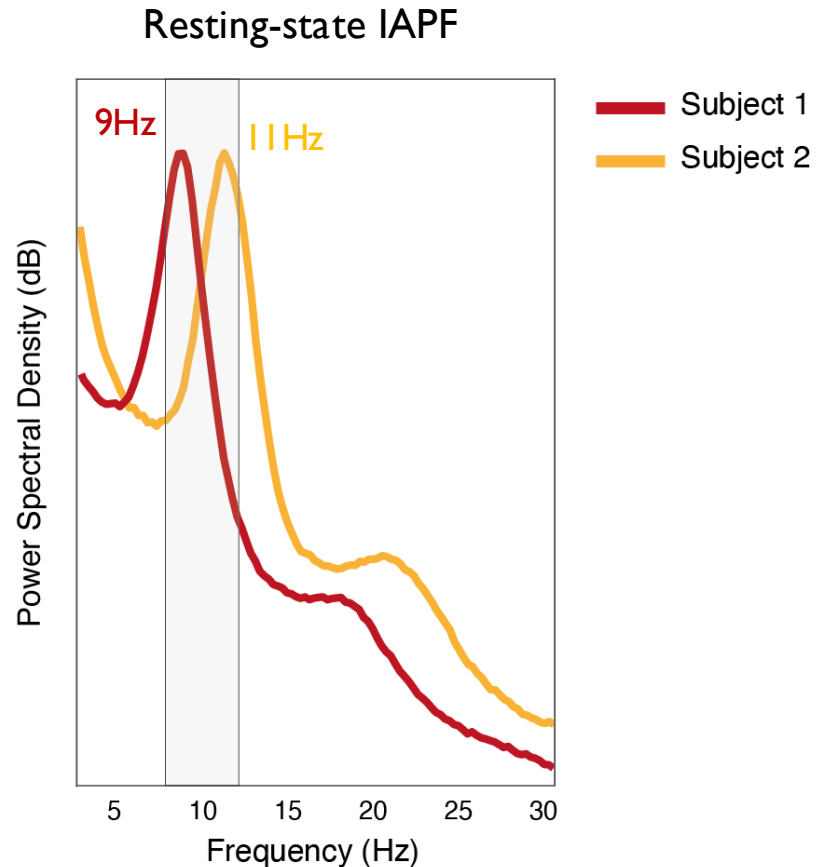
Study 1: Do alpha oscillations modulate conscious perception or unconscious sensory processing?

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Study 2: Do alpha oscillations determine windows of temporal integration?

- Individual alpha peak frequency

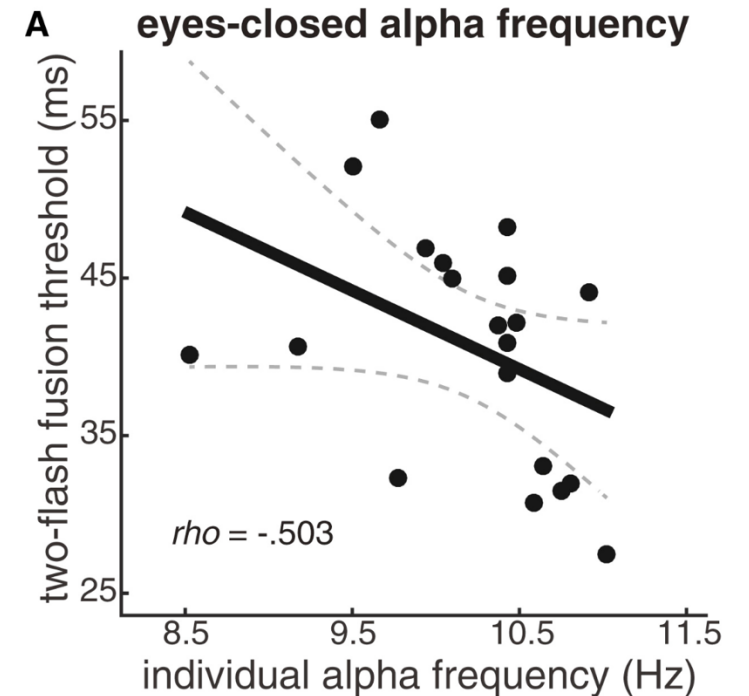
Individual alpha peak frequency (IAPF)



Two-flash fusion task



What is the minimum delay between two flashes to perceive them separately?

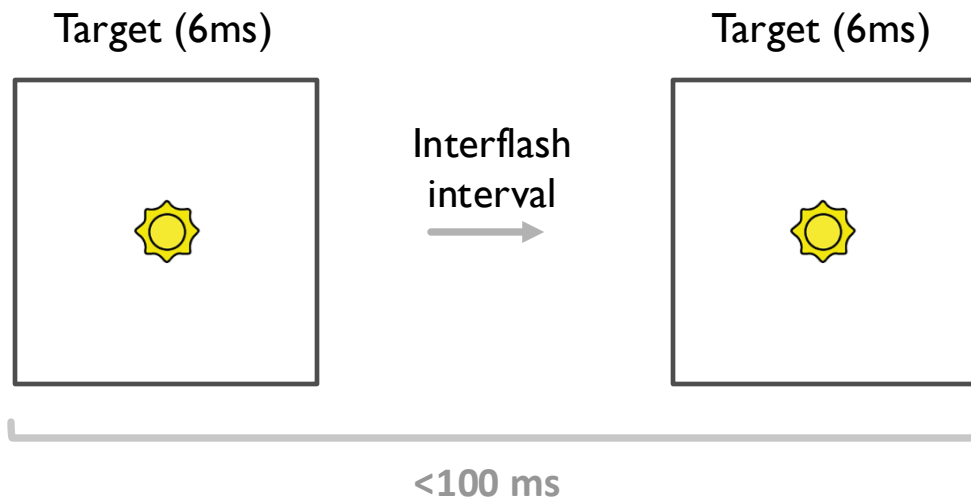


- Faster alpha rhythms are often associated with finer temporal resolution in visual perception.

Limitations

However, these studies only focus on short-lived effects, in which alpha activity influences the perception

- of brief, static and near-threshold stimuli
- of successive stimuli presented within a single alpha cycle.

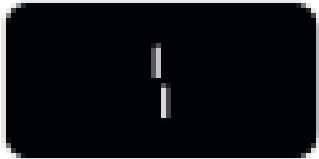


- ❖ **Do IAPF effects generalize to paradigms with stimuli separated by more than 100 ms?**

Visual backward masking (VBM)

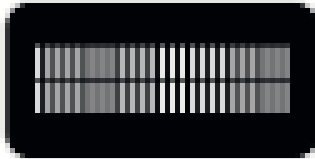
Verrier Only

30ms

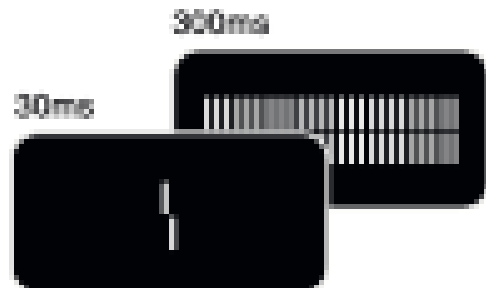


Mask Only

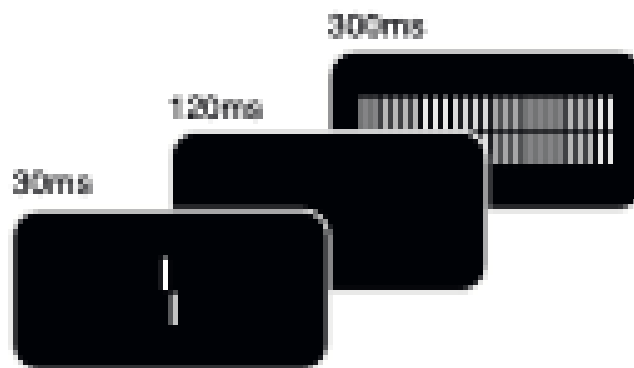
300ms



Short SOA (30ms)

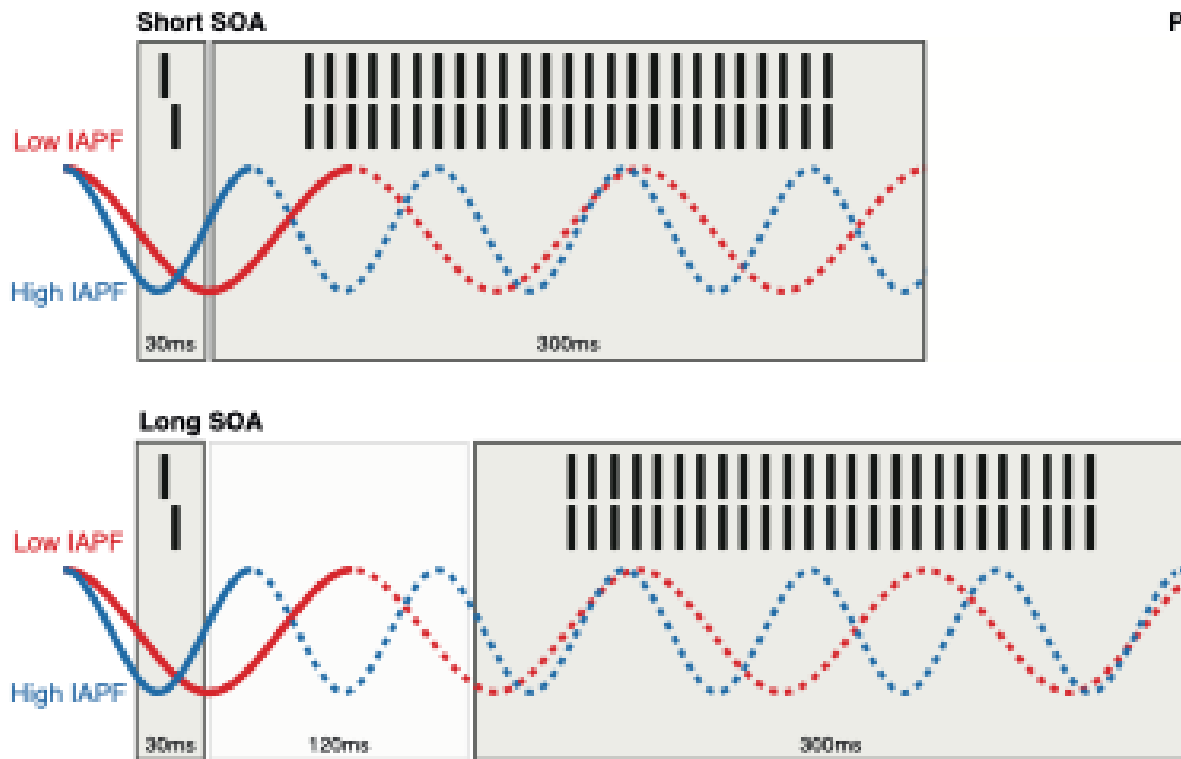


Long SOA (150ms)



- Target discrimination depends on the ability to segregate the target from the mask.

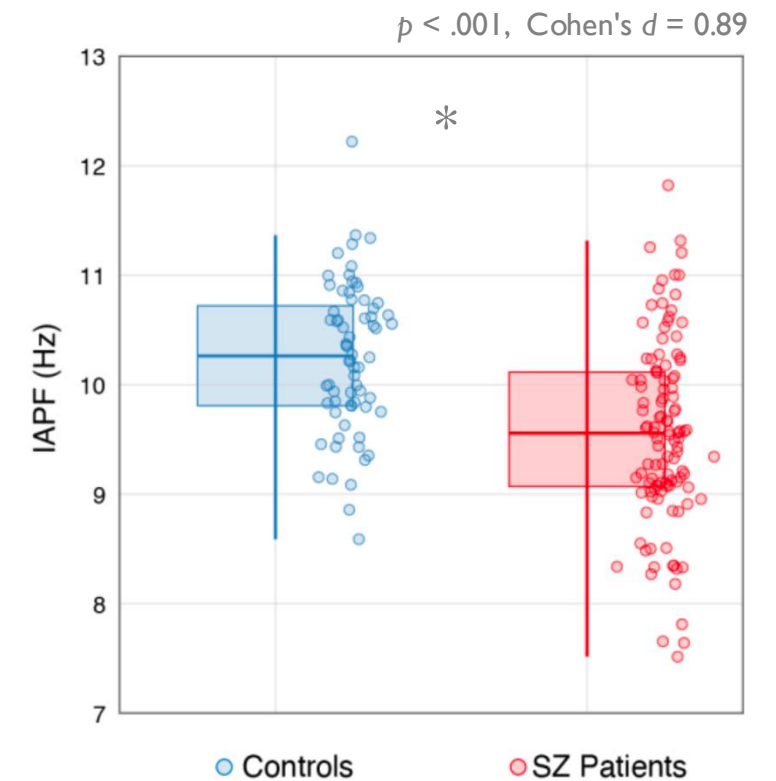
Relationship between IAPF and VBM performance



Percept:



Resting-state IAPF



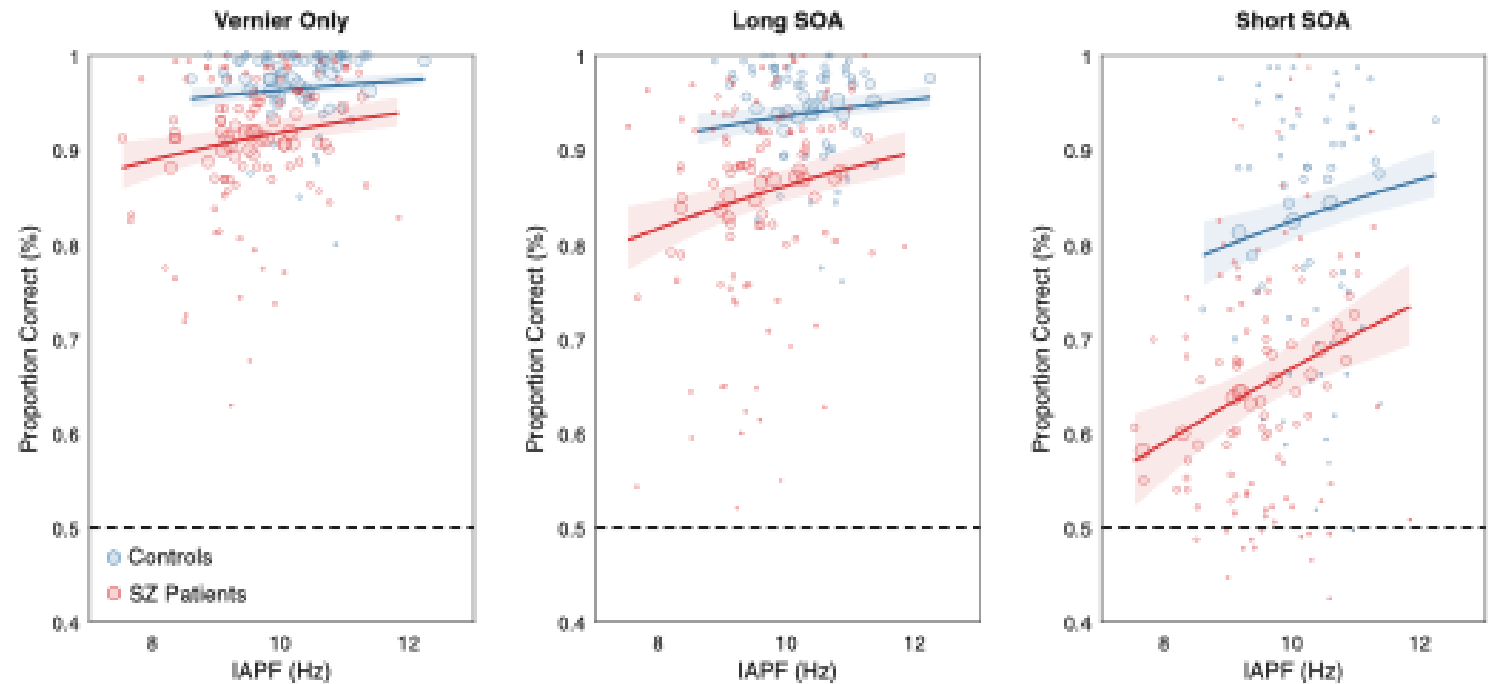
Generalized linear model

- IAPF predicts performance in all conditions and for both groups

VBM performance \sim IAPF + Group + Condition

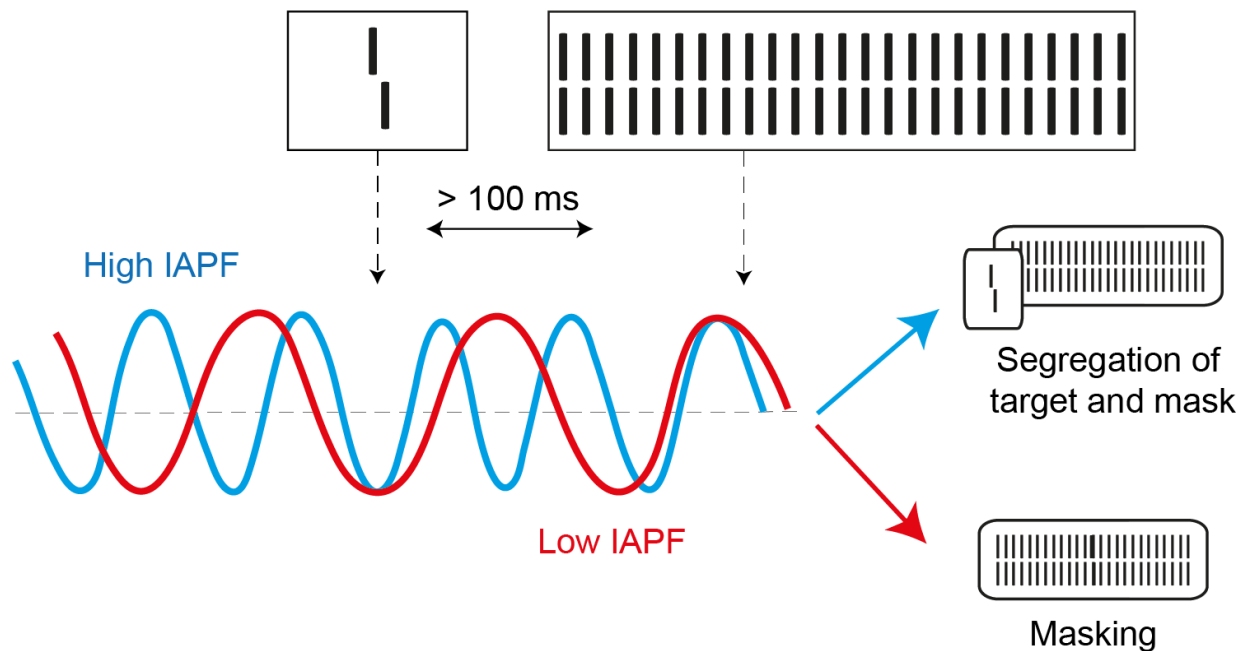
Predictors	Performance in VBM			
	Est.	SE	<i>t</i>	<i>p</i>
(Intercept)	1.57	0.45	3.45	< .001
IAPF	0.17	0.04	3.87	< .001
Group	-0.84	0.08	-9.75	< .001
Condition_LongSOA	-0.58	0.1	-5.54	< .001
Condition_ShortSOA	-1.72	0.09	-17.91	< .001

Note: Est. = Estimates (β), SE = Standard Error, *t* = *t*-statistic, *p* = *p*-value.



IAPF modulates general visual performance

- IAPF is not exclusively related to temporal resolution and processes constrained within a single alpha cycle.
- Alpha frequency might affect processing duration.



- Faster alpha rhythms shield the target representation from subsequent stimuli.
- Slower alpha rhythms increase interactions between successive stimuli.

Key findings

- Alpha oscillations modulate unconscious processing over extended time windows, beyond the duration of a single alpha cycle.
- Alpha frequency does not dictate a fixed window of temporal integration.

Together, these findings challenge the suggestion that alpha cycles define discrete frames in the structure of consciousness.

- **Alpha oscillations influence sensory processing, ultimately affecting the content of perception.**

Implications

Alpha power is suggested to modulate the duration of the ‘duty cycle’, the phase associated with increased neuronal firing (Jensen et al., 2014; Peylo et al., 2021).

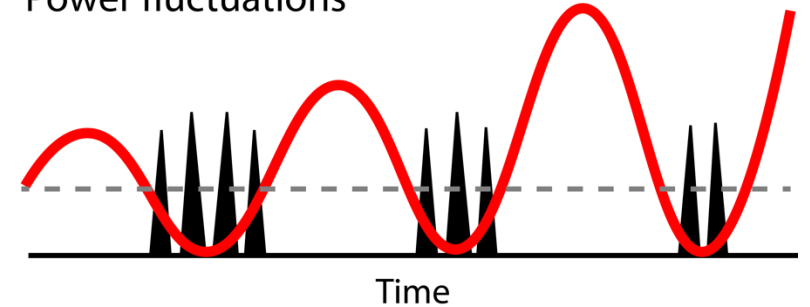
Similarly, slower alpha frequency might lead to longer excitatory phases.

- This could enhance neuron responsiveness and prolong the persistence of sensory traces, increasing interactions between successive sensory signals.

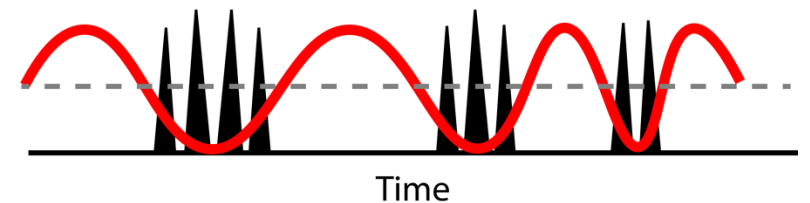
Alpha frequency might therefore reflect the efficiency of visual processing,

- characterized by stable individual traits (IAPF),
- or modulated dynamically (instantaneous frequency) through a mechanism governed by alpha power.

Power fluctuations



Frequency fluctuations



Thank you for your attention !



David Pascucci



Michael Herzog

EPFL

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