Pre-stimulus alpha frequency shapes sensory precision

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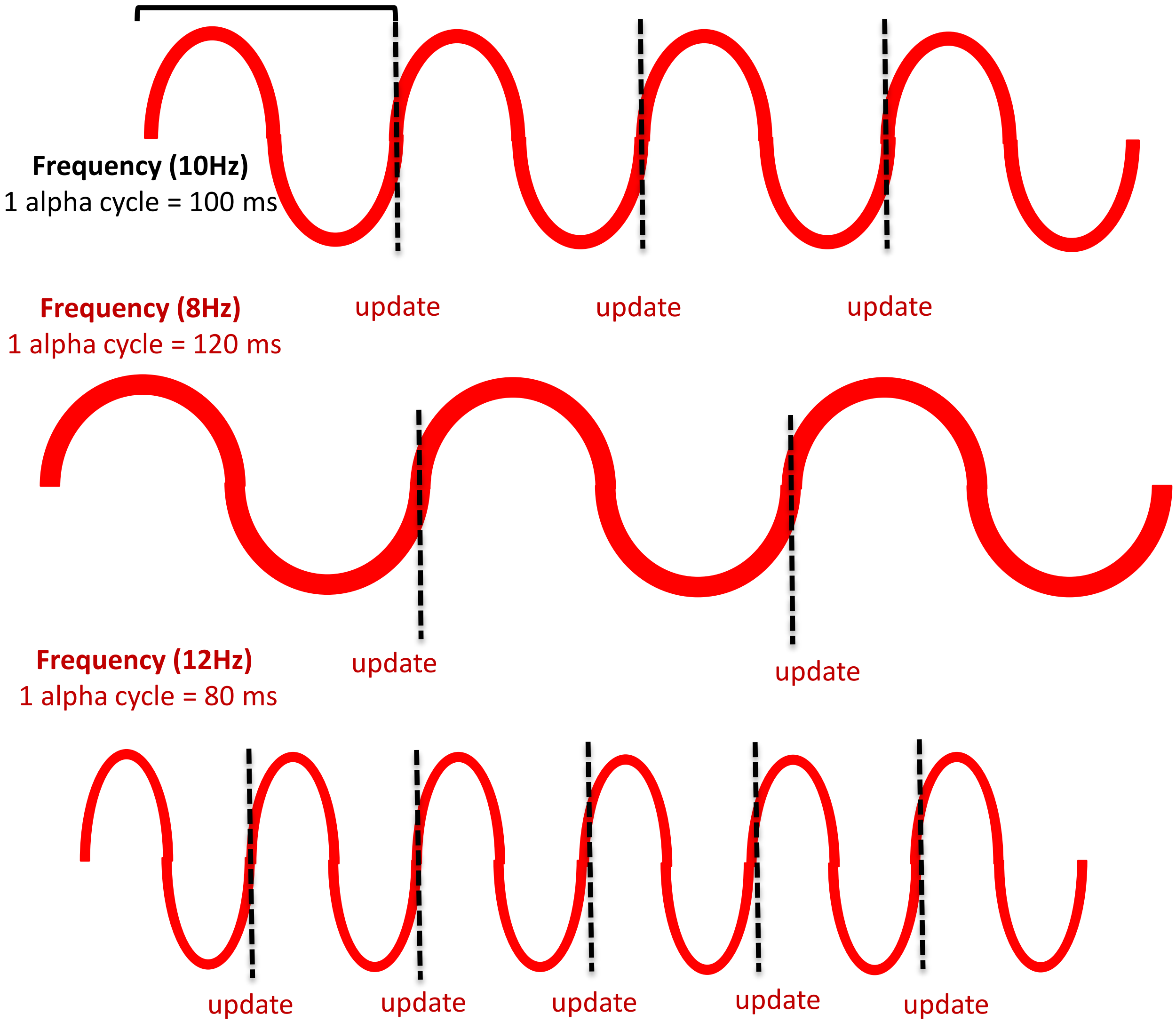
What determines the precision of our visual perception?

SAMPLING RATE Hypothesis

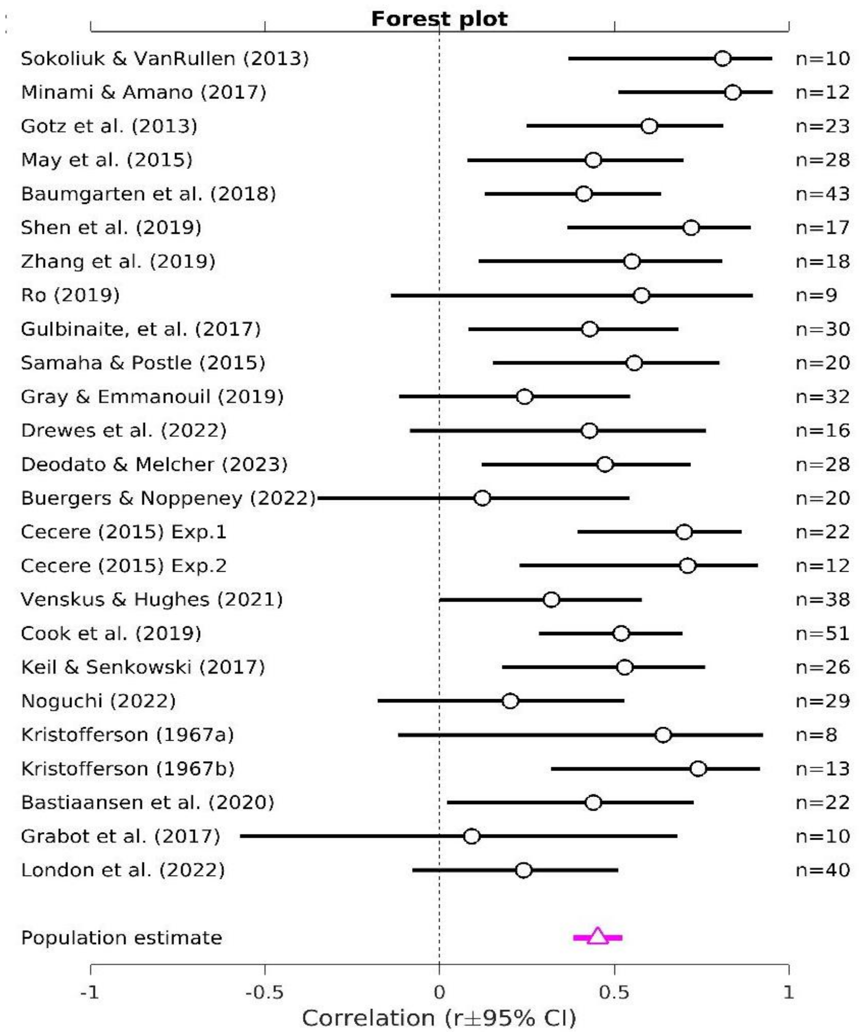


Alpha rhythm (10 Hz)
Alpha Frequency and the Sampling rate hypothesis

Slower Alpha Rhythm (8 Hz)
Slower real time info update
Lower temporal resolution
Less accumulating evidence
→ lower accuracy?

Faster Alpha rhythm (12 Hz)
Faster real time info update
Higher temporal resolution
More accumulating evidence
→ higher accuracy?

Meta-analysis of 27 experiments: Supporting the SAMPLING RATE Hypothesis



The role of alpha oscillations in temporal binding within and across the senses

Steffen Buergers & Uta Noppeney

Nature Human Behaviour **6**, 732–742 (2022)

"These results challenge the notion that alpha oscillations have a profound impact on how observers parse sensory inputs into discrete perceptual events."

The role of alpha oscillations in temporal binding within and across the senses

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Limitations of current literature supporting the sampling rate hypothesis :

1) "*previous studies did not use experimental designs or analyses that enabled the dissociation of accuracy and bias."*

2) "*Extensive variability of analysis choices across and even within studies to calculate alpha peak frequency*"

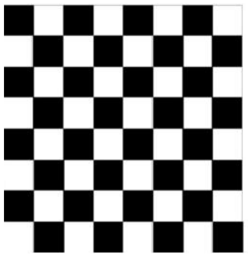
3) Both between and within subject effects reported but **trial by trial analysis lacking**?

4) The effect has been tested on **limited samples** (Buerges & Noppeney N = 20)

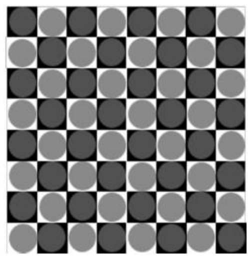
Methods: Experimental paradigm

Detection task (n = 124):

«were the targets (grey circles) present or absent?»



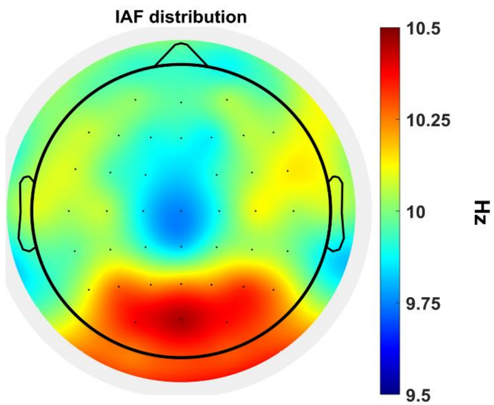
Target **absent** (50% trials)

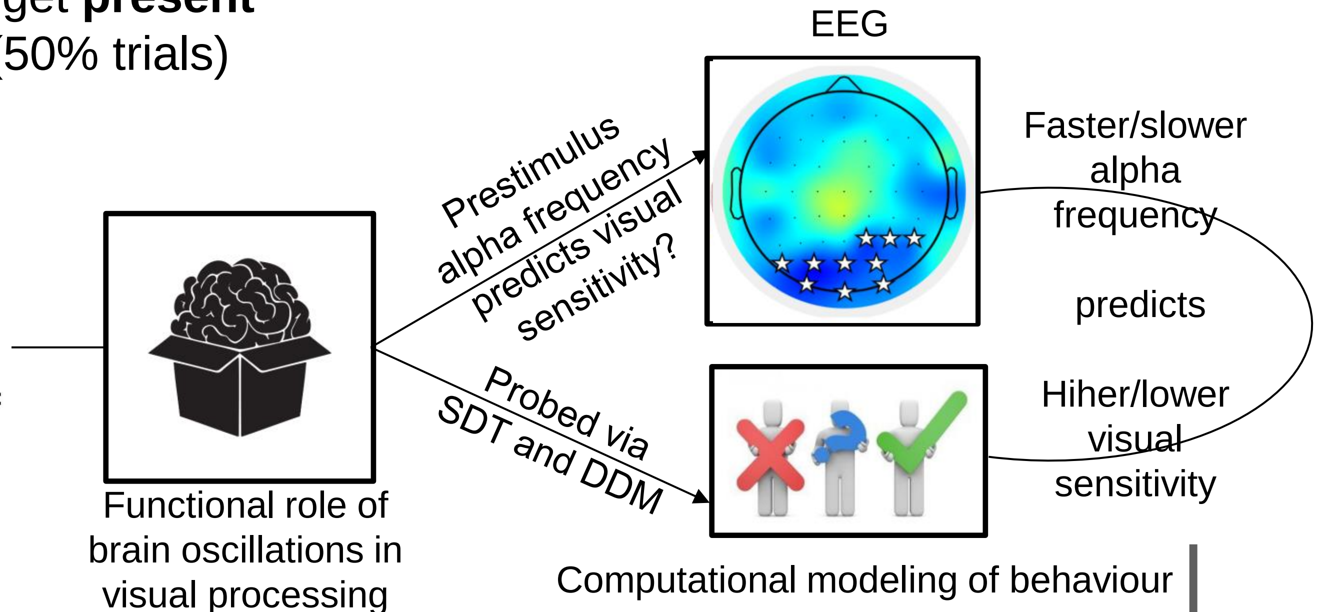


Target **present** (50% trials)

Analysis Methods:

1. **Bin analysis for IAF (Prestimulus time collapsed)**
2. **Bin analysis for IAF time by time**
3. **Bin Analysis for response accuracy**
4. **Single trial regressions**
5. **Drift Diffusion Analysis**

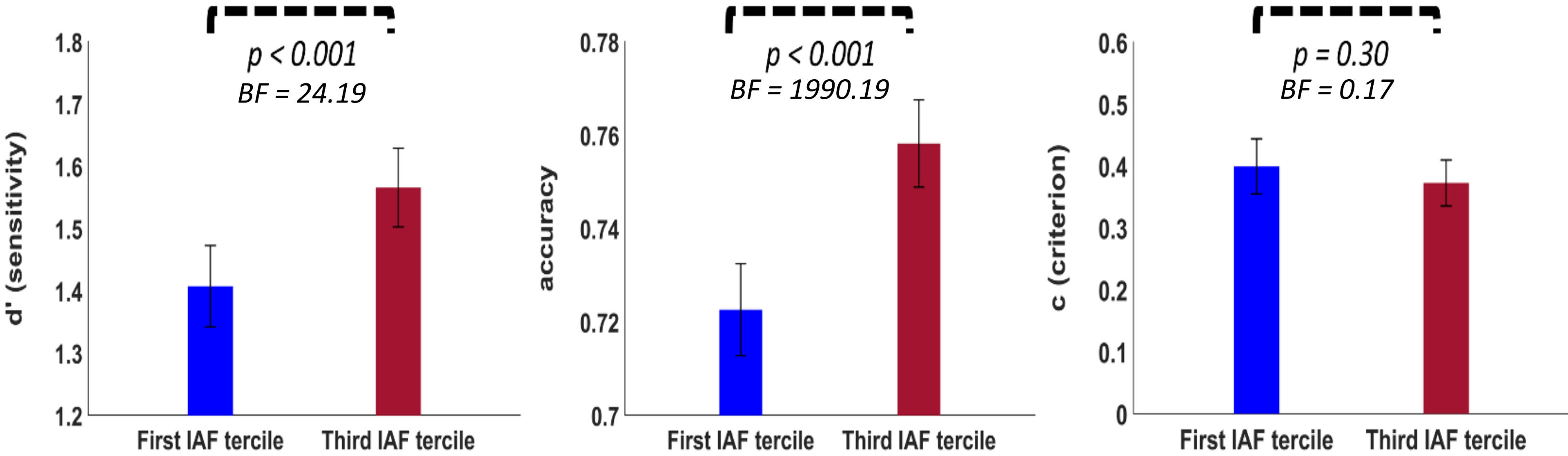




1) Bin analysis for IAF across pre-stimulus time (800 ms)

(Similar to Buergers and Noppeney 2022 -> reporting null results)

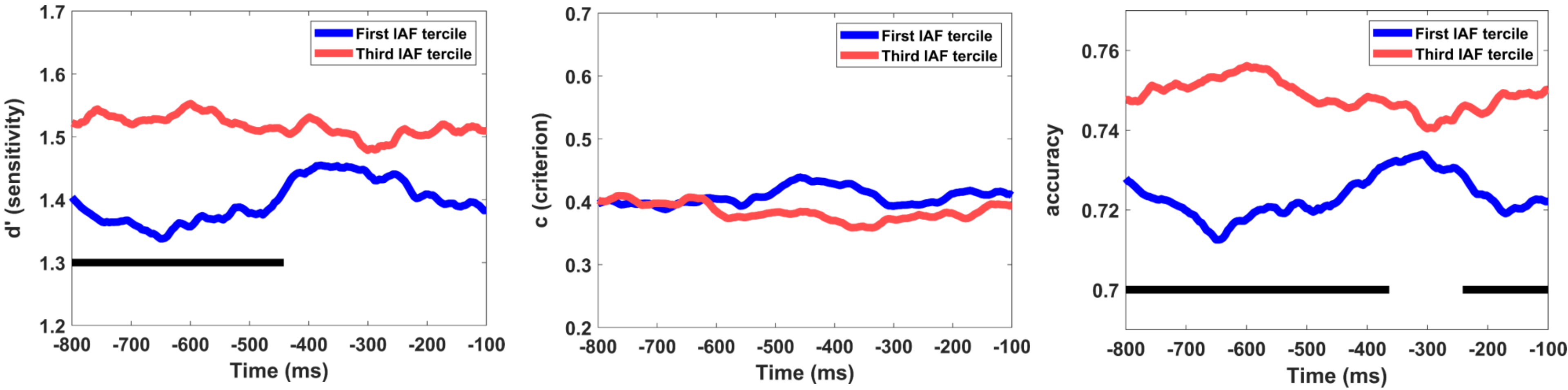
Paired t-test (slow IAF trials) vs (fast IAF trials)



Result 1 : Faster vs Slower IAF trials are characterized by higher accuracy and higher sensitivity BUT NOT CRITERION.

2) Bin analysis time-by-time points

(Similar to Buergers and Noppeney 2022 -> reporting null results)

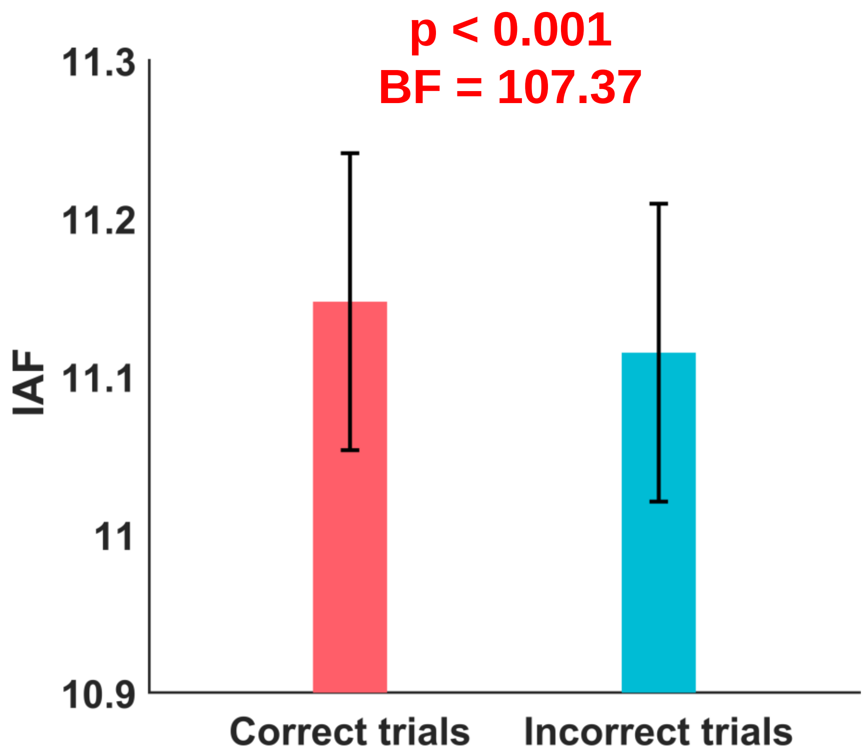


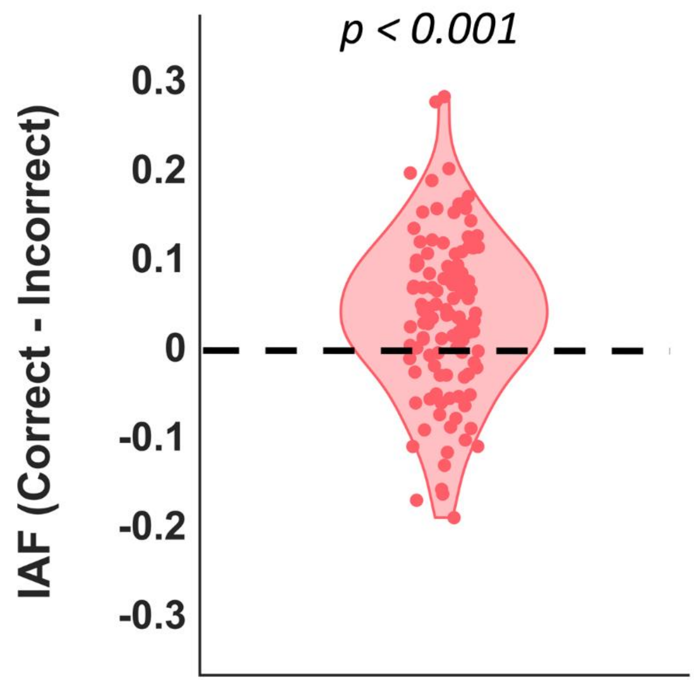
Result 2 : This effect holds true in extended pre-stimulus time windows.

Tarasi and Romei, in preparation

3) Bin analysis for response accuracy

Paired t-test IAF (Correct trials) vs IAF (Incorrect trials)





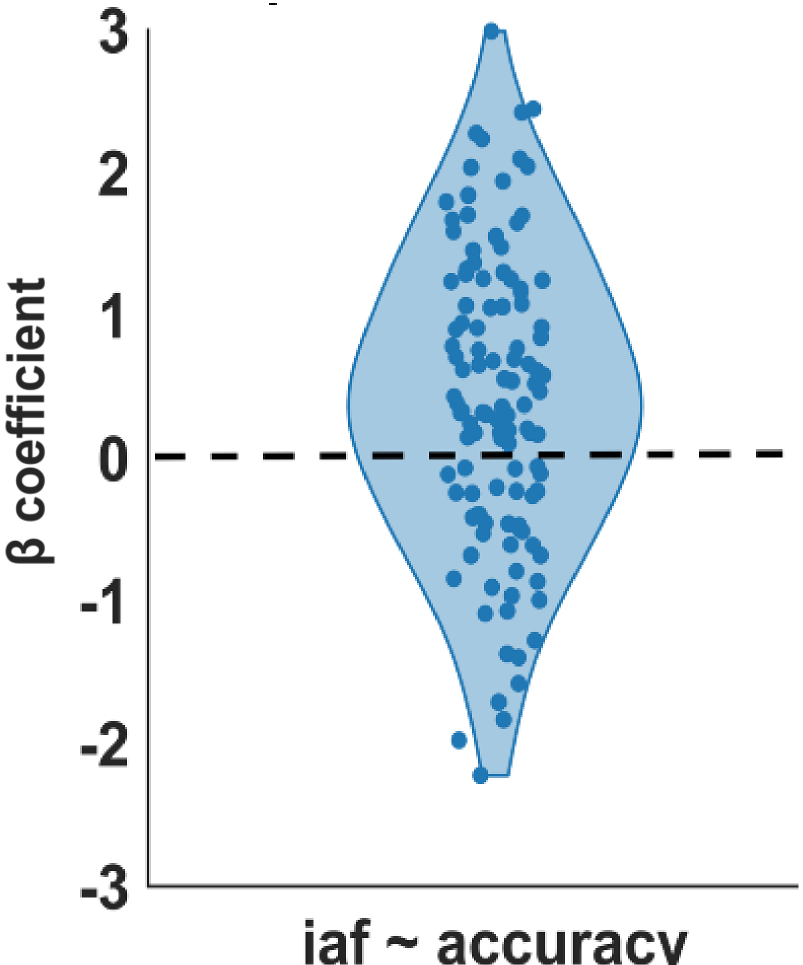
Result 3 : Correct trials are characterized by a faster alpha speed.

Tarasi and Romei, in preparation

4) Single-trials regression analysis

- Calculate the beta coefficient for each participant (predictor: prestimulus IAF, dependent variable: accuracy).
- Transform the beta coefficients in *z point* by permutation-based statistic (2000).
- t-test against zero of the z-transformed beta coefficients.

Mean slope = 0.38
p < 0.01; BF = 212



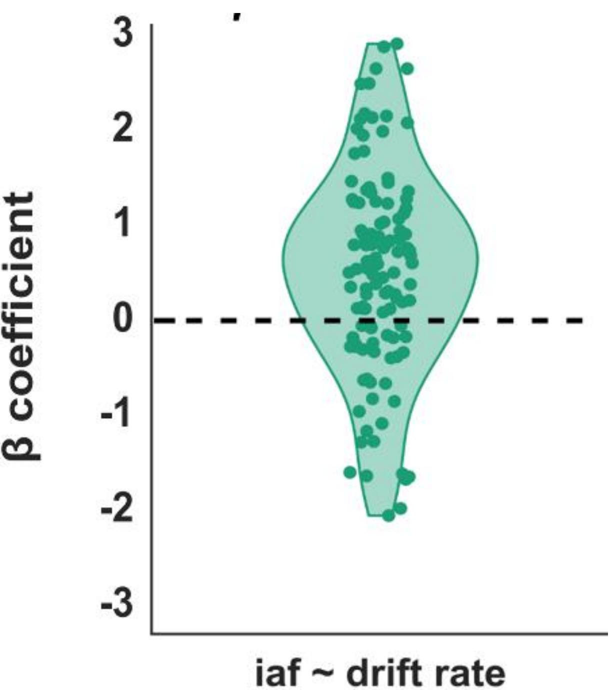
RESULTS 4: In trials with faster IAF there is a higher probability of more accurate responses

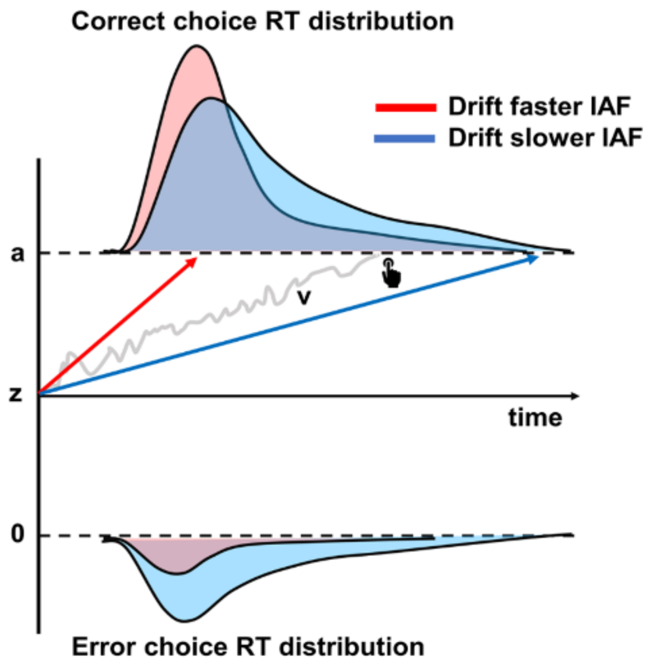
5) Drift Diffusion Model Analysis (first time used with prestimulus IAF)

- Calculate the beta coefficient for each participant

(predictor: prestimulus IAF; dependent variable: drift rate & starting point).

Mean slope = 0.39
$p < 0.01$; BF = 267.14





RESULTS 5:

Trials with faster IAF are associated with improved evidence accumulation but not with perceptual bias.

CONCLUSIONS - 1

There is increasing converging evidence in support of the sampling rate hypothesis:

1) Seminal works in the sixties

2) Many years later, new evidence in support

3) Several replications but also a few null results reported

4) Most studies underpowered (meta-analysis suggests an n = 50)

5) Confounding factors such as perceptual bias yet to be controlled for (computational models of behaviour such as SDT and DDM to be implemented)

CONCLUSIONS - 2

1) We show here in a large sample of participants (n>100) using several analysis methods, including a trial-by trial approach, that **«the faster the IAF the higher the accuracy and sensitivity (d’ and drift rate), with no impact on perceptual bias (criterion and starting point)».**

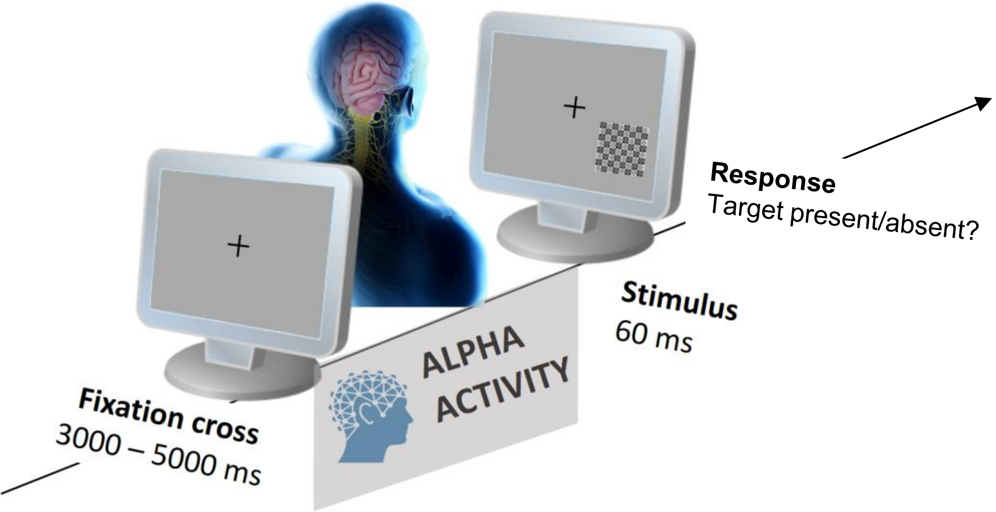
2) Prestimulus individual alpha frequency (IAF) provides a robust and reliable neural marker of temporal resolution able to point to visual efficiency levels in the general population.

Thanks for your attention!

Acknowledgment

Prof. Vincenzo Romei

«were the targets (grey circles) present or absent?»



General Experimental question:

Does **alpha frequency** account for **perceptual sensitivity?**

- when **controlling for** factors such as **spatial attention** and **perceptual bias**,

- Using **state-of-the-art** methods to extract alpha peaks,

- on a **trial-by-trial** basis,

- in a representative sample (**n>100**)?

Tarasi and Romei, in preparation

But what may determine null results?

Underpowered studies (and thus chance):

Buergers and Noppeney: N=20
Grabot et al.,: N=10

According to Samaha & Romei meta-analysis, an N of around 50 is required.

1: Titration

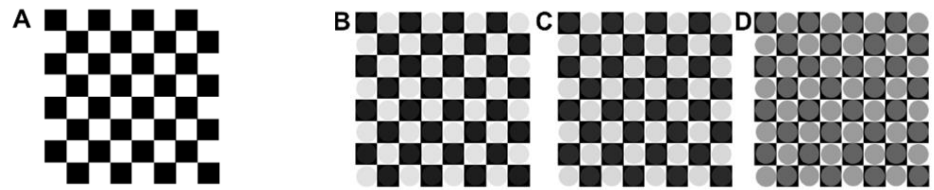
Experimental question 1: If alpha frequency accounts for visual precision, people with faster alpha should need less evidence to identify the target, hence grey circles with less contrast.

Methods:

1) Titration:

Staircase to reach **70% accuracy**

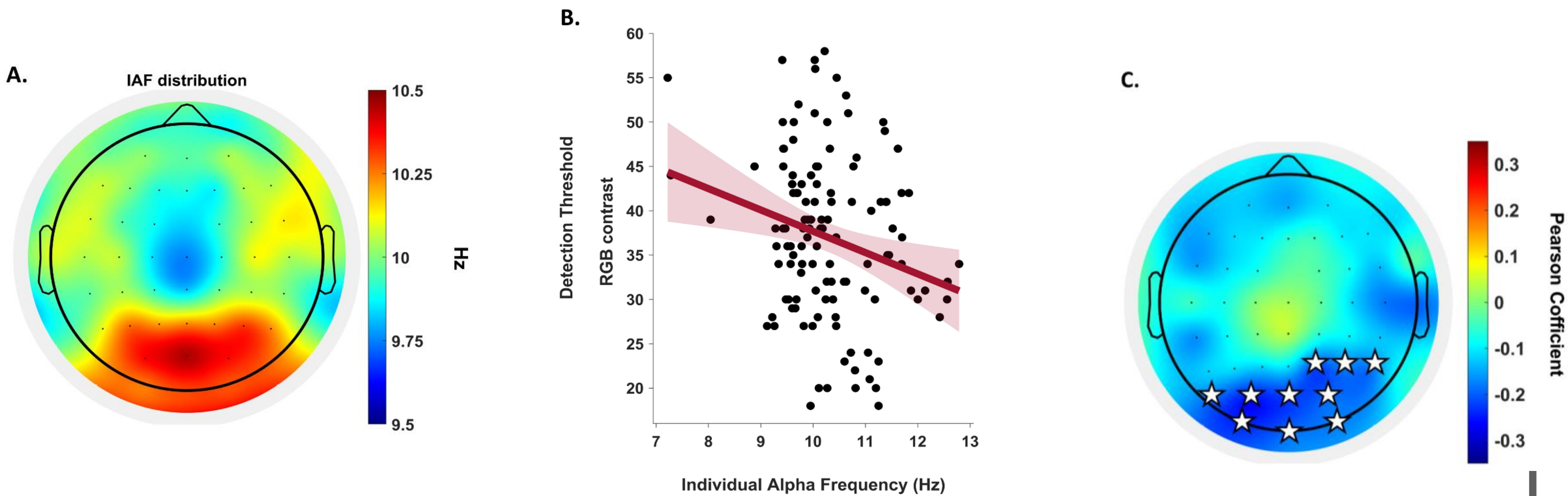
+ Resting-state EEG.



Target **absent**

Target **contrasts**

Results: The slower/faster the resting alpha, the higher/lower the contrast needed to reach the treshold



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SAMPLING RATE Hypothesis

Seminal works supporting the sampling rate hypothesis

Murphree, 1954;
Harter, 1967;
Kristofferson, 1967;
Coffin, 1977;
Coffin & Ganz, 1977;
Varela et al., 1981;

Recent literature supporting the sampling rate hypothesis

Gotz et al., 2013;
May et al.,2014;
Samaha & Postle, 2015;
Cecere et al., 2015
VanRullen, 2016;
Baumgarten et al., 2018;
Di Gregorio et al., 2022;
etc.

Recent replications supporting the sampling rate hypothesis

Keil & Senkowski, 2017;
Gray & Emmanouil, 2020;
Venskus & Hughes, 2021;
Drewes et al., 2022;
Noguchi, 2022;
Noguchi, 2023;
Deodato & Melcher, 2023;
Ronconi et al., 2023;

Recent literature against the sampling rate hypothesis

Grabot et al., 2017;
Buergers & Noppeney, 2022

Samaha & Romei, JOCN, 2023