

## BACKGROUND

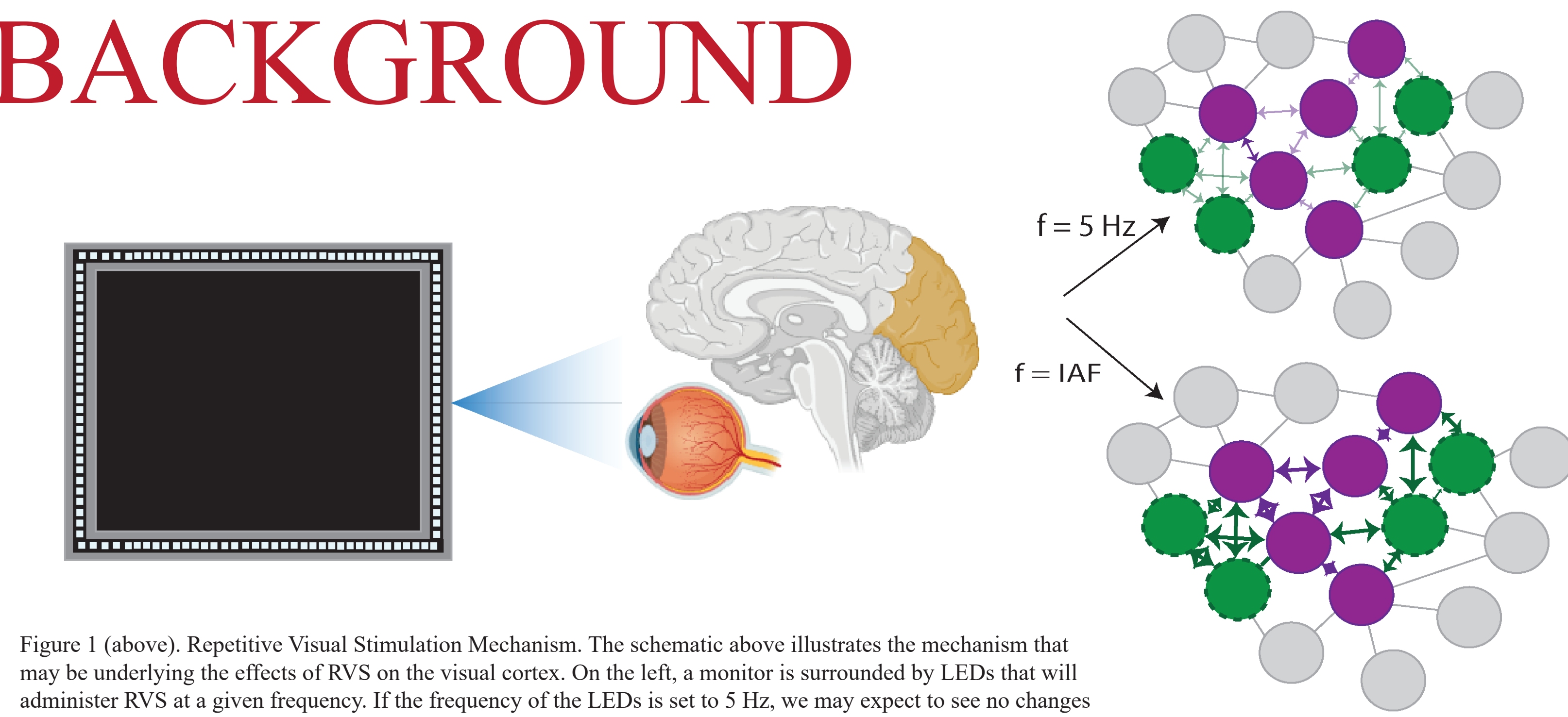


Figure 1 (above). Repetitive Visual Stimulation Mechanism. The schematic above illustrates the mechanism that may be underlying the effects of RVS on the visual cortex. On the left, a monitor is surrounded by LEDs that will administer RVS at a given frequency. If the frequency of the LEDs is set to 5 Hz, we may expect to see no changes in the response of neurons (active neurons = green; nonactive = gray). If the frequency is set to an individual's alpha frequency, we may expect to see an increase in the response of neurons, strengthening the connection between active neurons.

- RVS has received interest as a neuromodulation tool because of its LTP-like effects on the hippocampus. Previous research as also confirmed these findings in the visual cortex.
- There have been few studies exploring the parameter space of RVS, such as frequency of stimulation.
- The alpha frequency (8 - 10 Hz) is a dominant frequency in the visual cortex, especially during a resting-state paradigm.
- Individualizing the stimulation frequency to an individual's alpha frequency may enhance the LTP-like effects of RVS.
- **Hypothesis:** Participants who receive RVS near their individual alpha frequency (IAF) will have an enhanced response potentiation.
- We tested the hypothesis by measuring high density EEG and behavioral outcomes of the visual detection paradigm before, during, and after exposure to RVS at IAF and, as a control, exposure to RVS at IAF + 2 Hz.

## METHODS

### Detection Paradigm

Participants were instructed to perform button-press responses when they detected a light patch appear at either four quadrants. They were instructed to respond as soon as they detected the light patch. Participants also heard three different audio tones: a tone for if the light already appeared and there was no response within 1500 msec, a tone for if they are correct, and a tone for if they are incorrect.



Figure 2 (above). Visual Detection Paradigm.

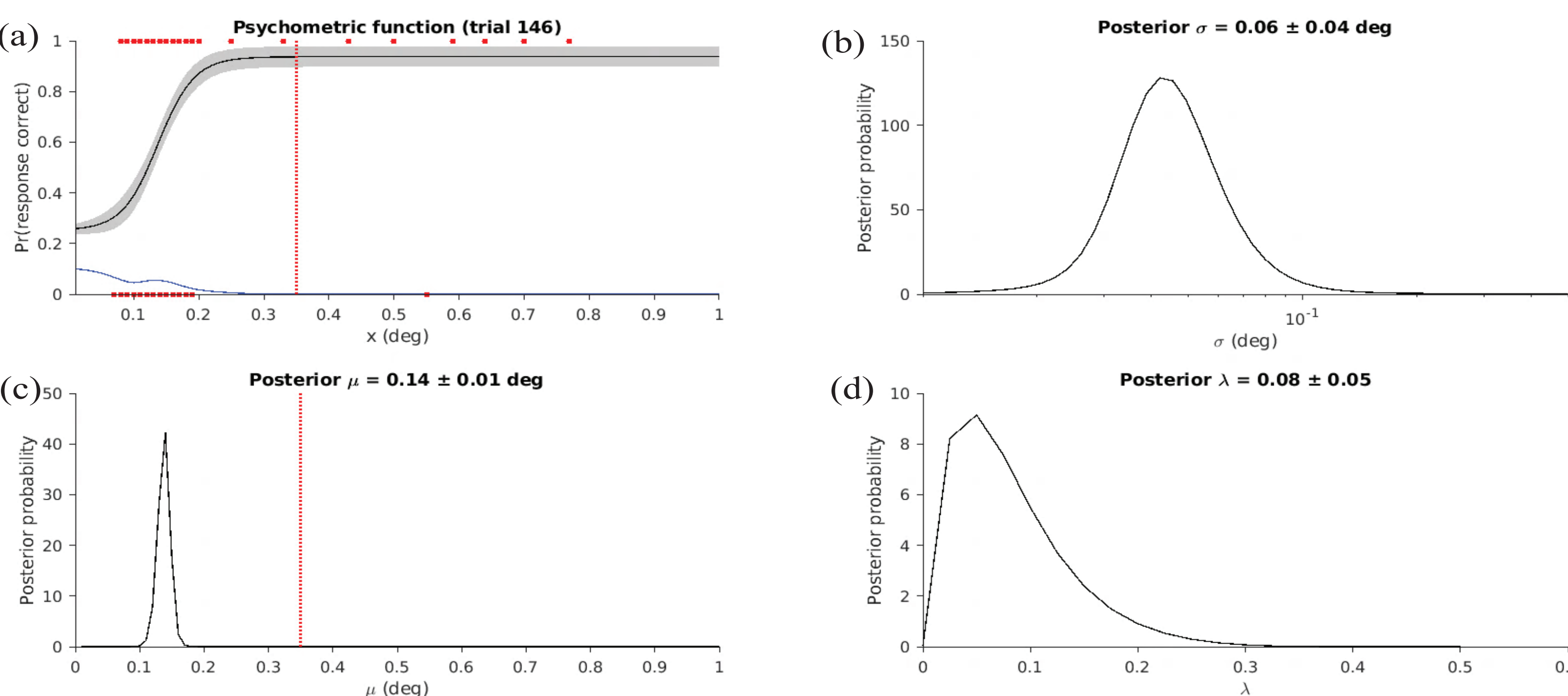


Figure 3 (right). Example Participant. This figure shows the output of the psyBayes toolbox, implemented using the psybayes\_plot() MATLAB function. (a) The horizontal axis represents degrees and the vertical axis represents the percentage of correct responses. The red, dotted line denotes standard deviation of the psychometric function. (b,c,d) This plot depicts the posterior probability of  $\sigma$  (b),  $\mu$  (c),  $\lambda$  (d).

### Psychometric Function.

To assess participants' performance in the detection paradigm, we implemented the psychometric function through the psyBayes toolbox via GitHub (<https://github.com/lacerbi/psybayes>). This toolbox implements Kontesevich and Tyler's (1999) Bayesian adaptive  $\Psi$  method for estimation of parameters of the psychometric function.

### Determining the IAF.

The resting-state data was divided into time bins of 1s. If the power calculated at that time bin was over 3 standard deviations away from the mean, that epoch was removed. For each time bin, a peak frequency was detected. The peak frequency with the largest number of counts was selected as the IAF.

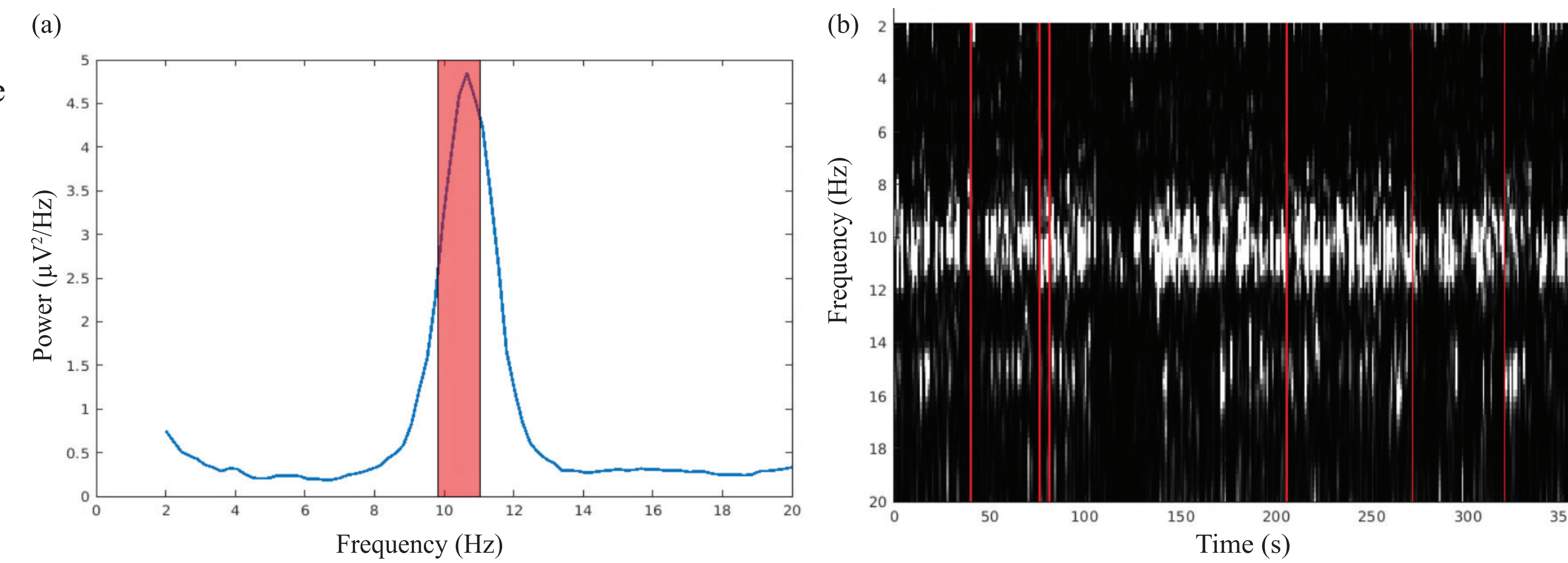


Figure 4 (above). IAF: Example Participant. (a, left). This figure shows the power spectrum of one participant. The vertical axis represents the average power and the horizontal axis represents frequency. The shaded red area represents the range of frequencies where the peak was detected. (b, right) This figure shows the spectrogram from the same participant. The vertical axis represents frequency and the horizontal axis represents time. The color scale represents power. Together, these figures illustrate the precision of the algorithm and the stability of the IAF measurement across time.

## RESULTS

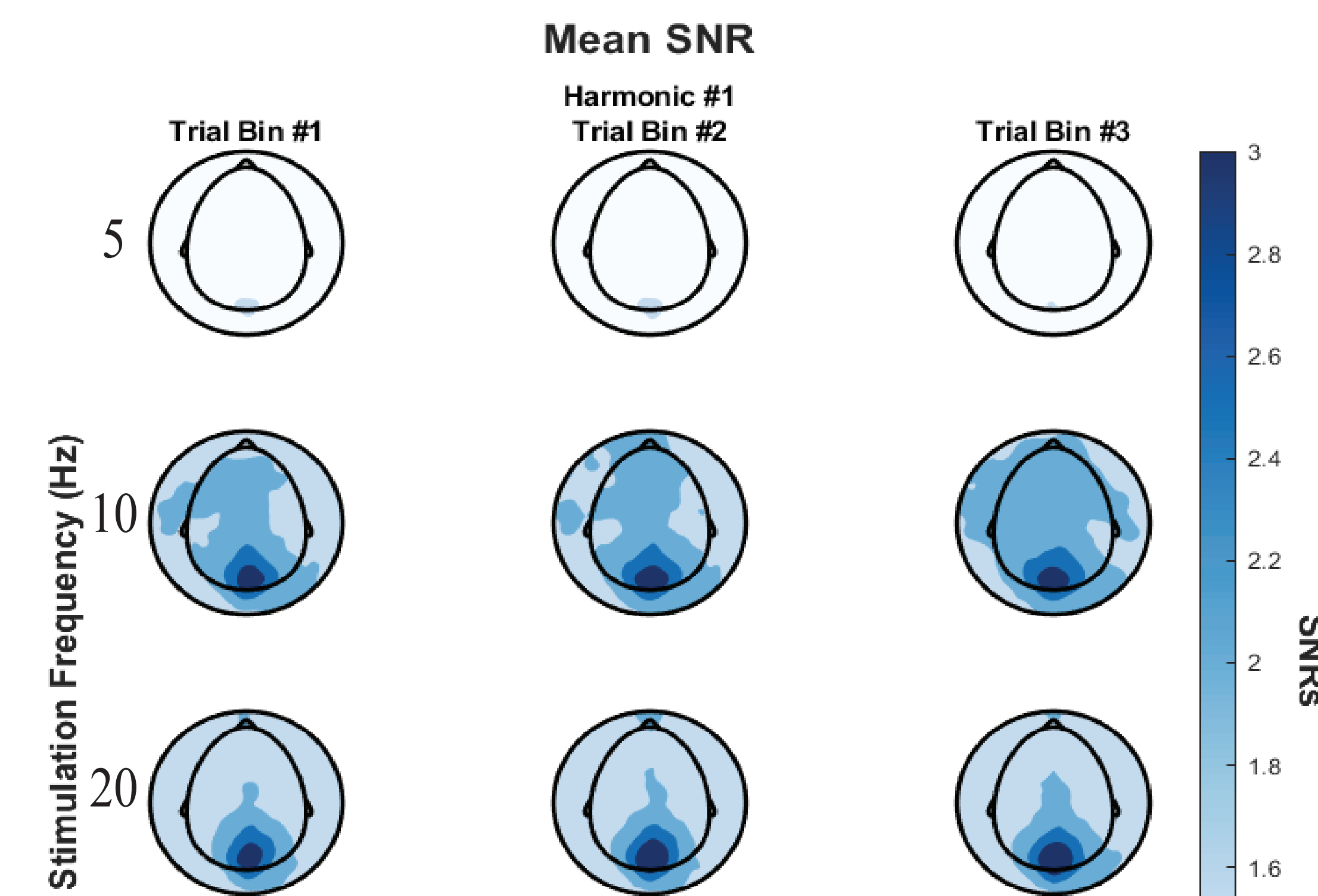
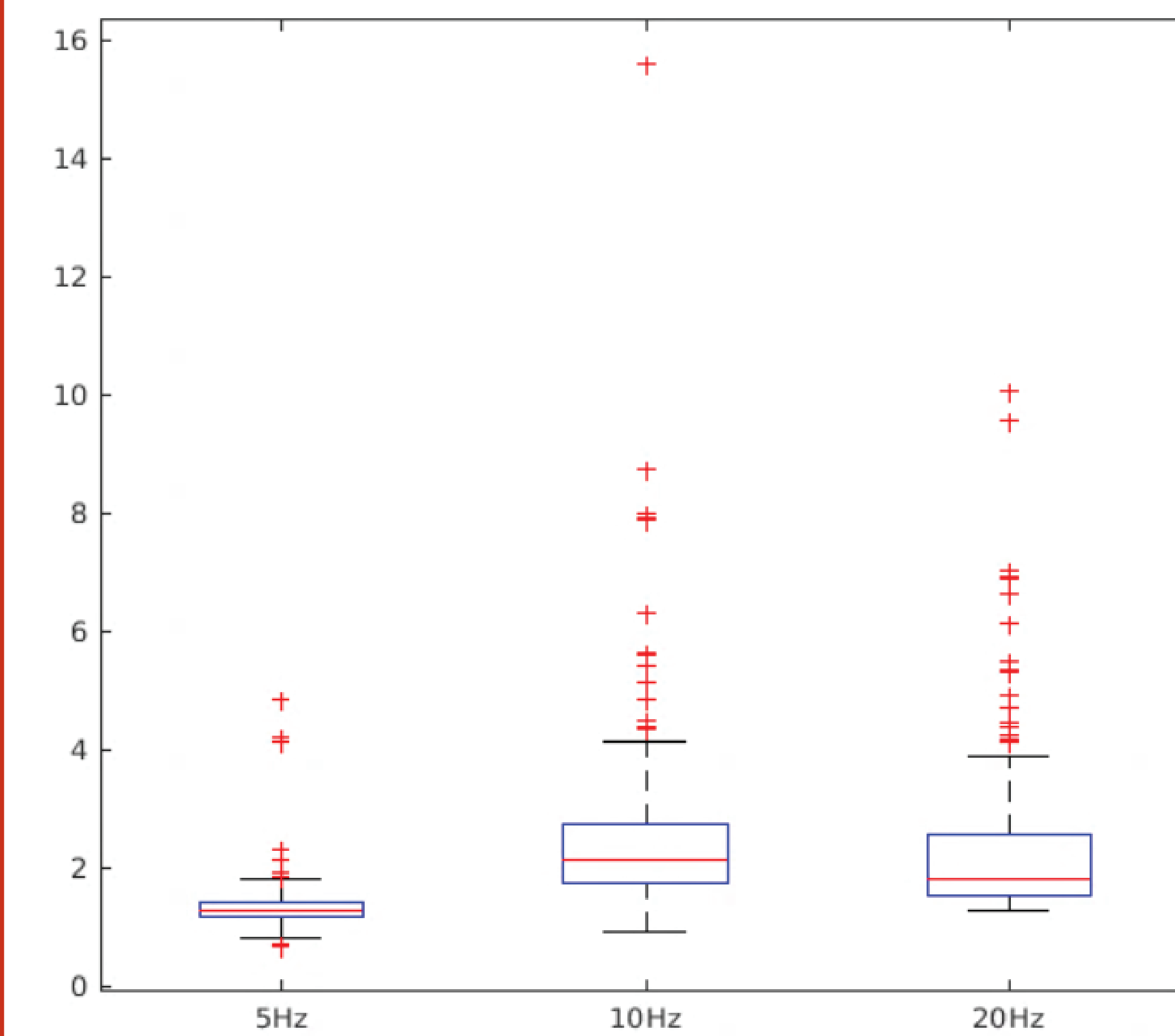


Figure 5. Signal-to-Noise Ratio across Stimulation Frequencies. (a, top) The figure above depicts the SNR calculated for stimulation frequencies 5, 10, and 20 hertz. The vertical axis denotes SNR, and the horizontal axis denotes the stimulation frequencies. The red line within the box plot represents the median, and the red crosses represent outliers. (b, bottom) This figure represents the average SNR across different trial bins (Trial Bin 1 = beginning of experiment; Trial Bin 2 = middle of experiment; Trial Bin 3 = end of experiment). Each column represents a trial bin, and each row represents a stimulation frequency. The color scale represents the average SNR.

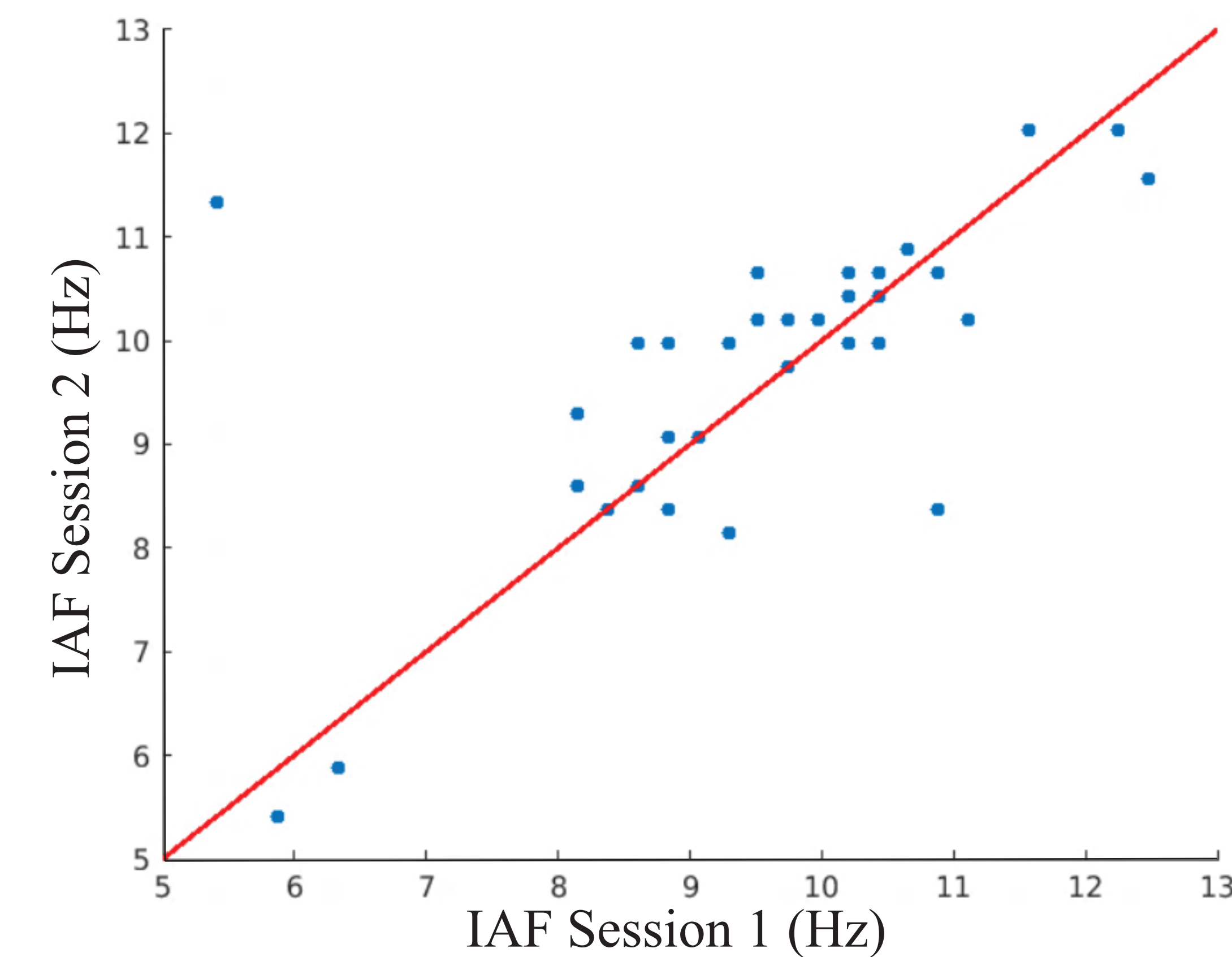


Figure 6. Stability of IAF. This figure shows the correlational relationship between IAF values measured across days. This figure shows IAF values measured at the beginning of the first session on the horizontal axis, and IAF values measured at the beginning of the second session on the vertical axis. The solid red line is represented by the equation,  $y = x$ . A Pearson's correlation test also revealed a significant positive relationship ( $r = 0.6625$ ,  $p < 0.001$ ).

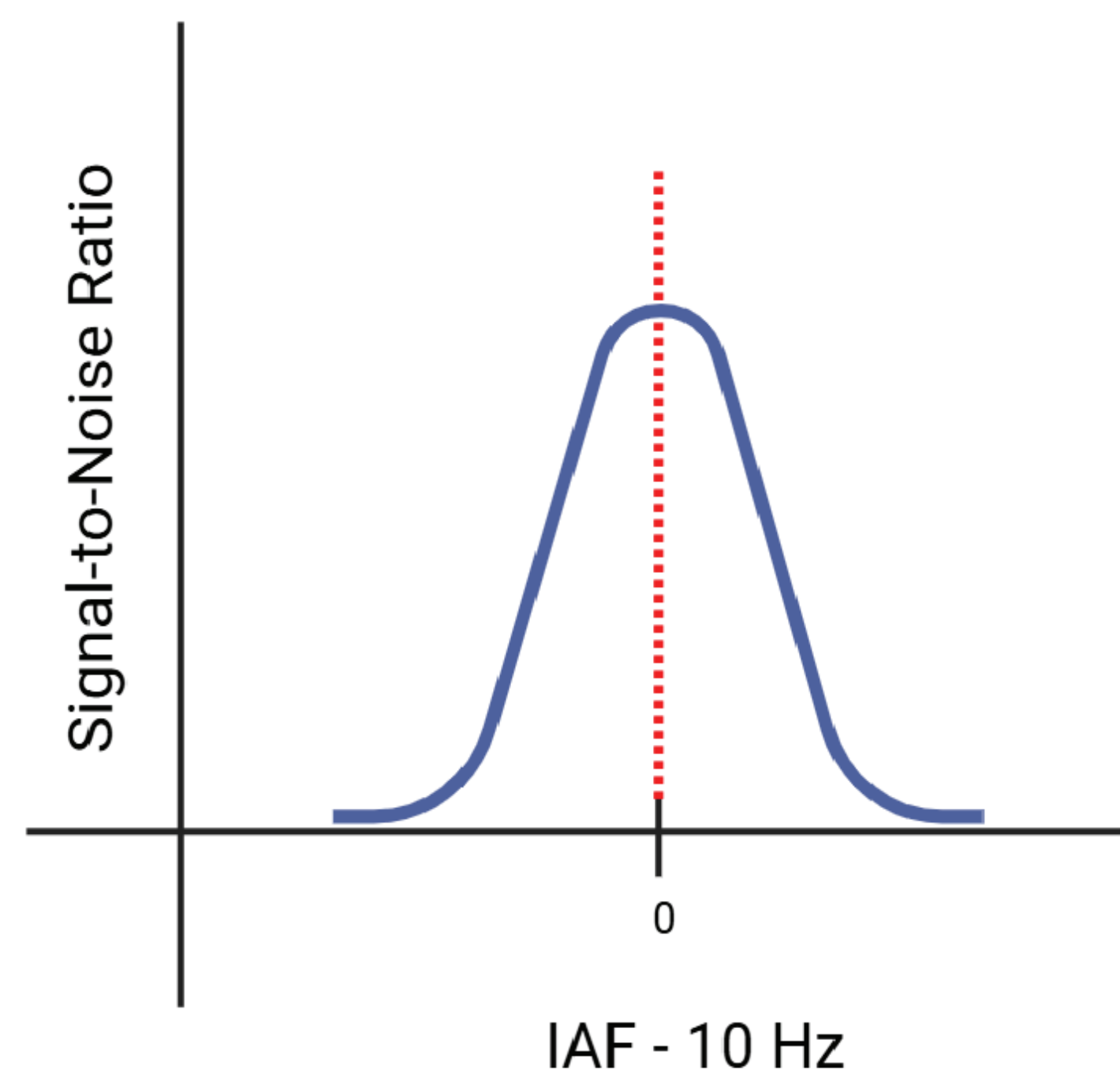


Figure 7 (left). This schematic illustrates how participants who received RVS near their IAF had the largest increase in their signal-to-noise ratio (SNR) when the stimulation frequency is 10 Hz. The vertical axis represents the SNR, and the horizontal axis represents the difference between IAF and 10 Hz.

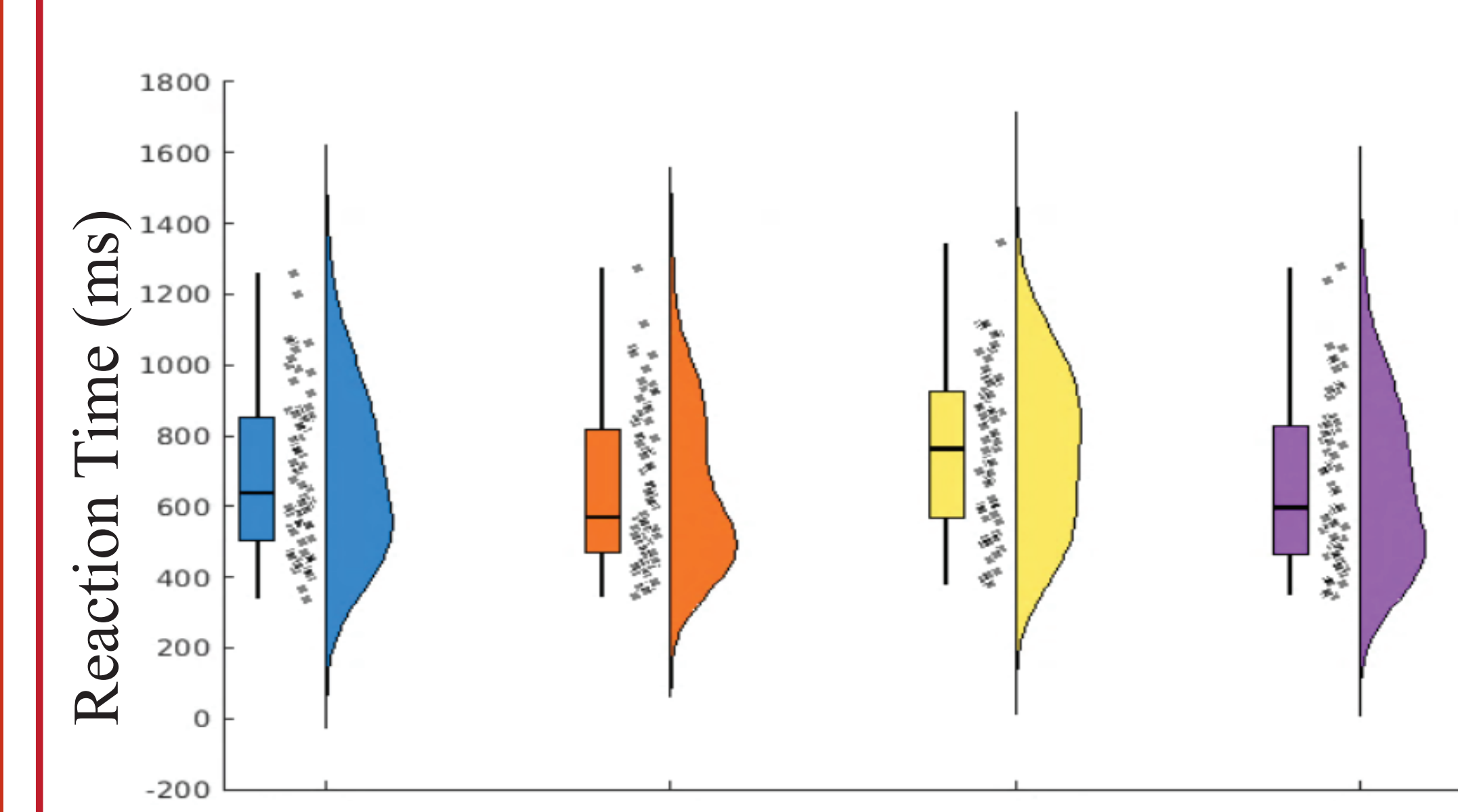


Figure 8. Average Stimulus Threshold by Condition. The vertical axis represents the stimulus threshold as calculated through the psychometric function.

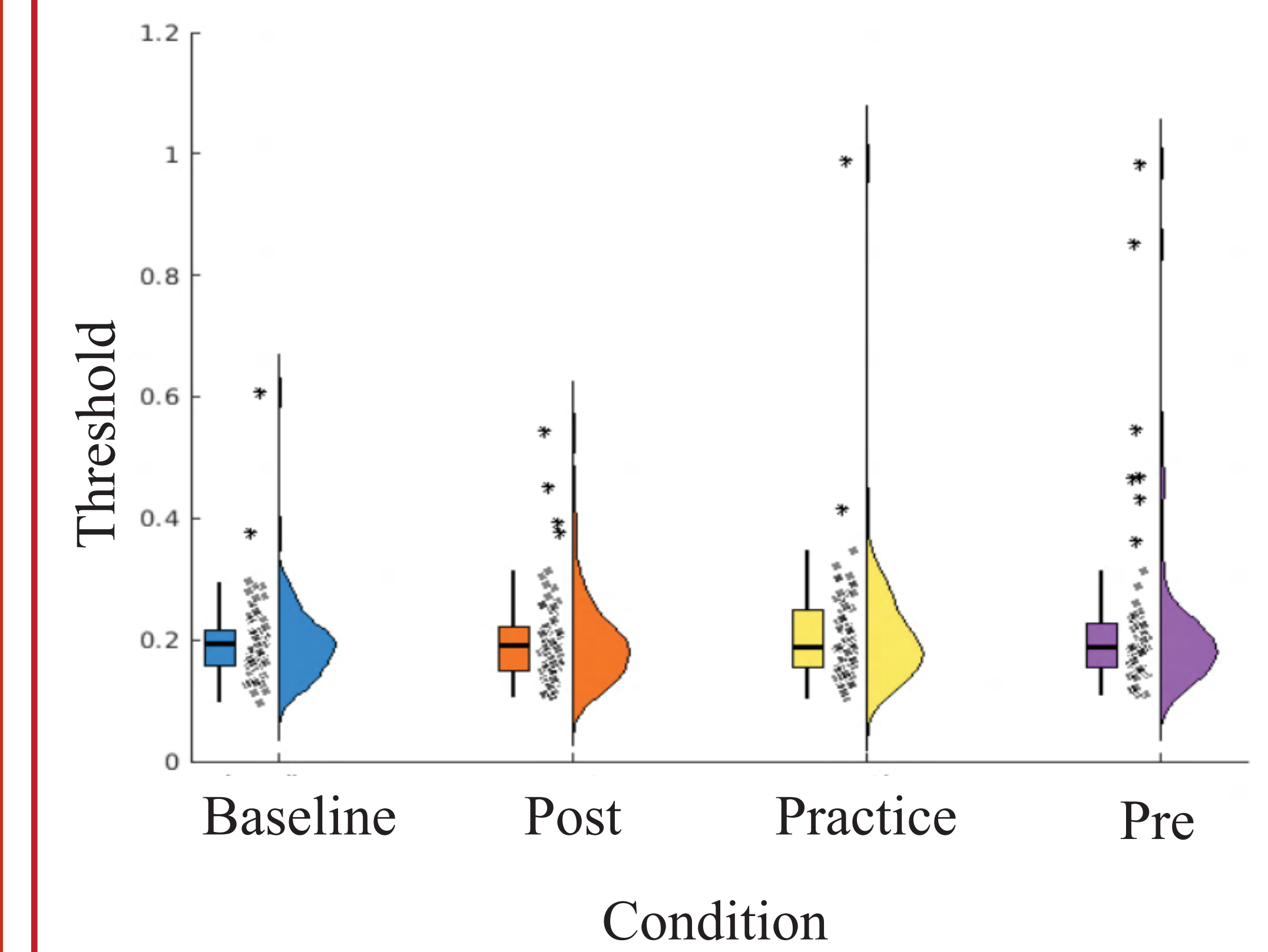


Figure 7. Average Reaction Time by Condition. This figure shows the average reaction time in the visual detection paradigm by condition. The vertical axis depicts reaction time in milliseconds (ms).

## STATISTICAL ANALYSIS

### General Linear Mixed Effects Model

$$\mu \sim 1 + \text{condition} + \text{day} + \text{order} + (1 | \text{subject})$$

Day predicted stimulus threshold,  $F(1,186) = 9.03$ ,  $p = 0.00302$ , (Effect: 0.00972 CI [0.0034, 0.0161]).

Condition predicted stimulus threshold,  $F(3,186) = 3.87$ ,  $p = 0.0116$ , (Max Effect: -0.0133 CI [-0.0223, -0.00436]).

$$\Delta\mu \sim 1 + \text{day} * \text{isIAF} + (1 | \text{subject})$$

IAF predicted the difference in stimulus threshold between post-RVS and pre-RVS,  $F(1,43) = 5.64$ ,  $p = 0.0221$ , (Effect: -0.017 CI [-0.0314, -0.0255]).

$$RT \sim 1 + \text{condition} + \text{day} + \text{order} + (1 | \text{subject})$$

Condition predicted reaction time,  $F(3,280) = 16.5$ ,  $p = 6.98e-10$ , (Max Effect: -0.161 CI [-0.21, -0.113]).

Day predicted reaction time,  $F(1,280) = 28$ ,  $p = 2.5e-07$ , (Effect: 0.0947 CI [0.0595, 0.13]).

$$\Delta RT \sim 1 + \text{day} * \text{isIAF} + (1 | \text{subject})$$

Day predicted the difference in reaction time between post-RVS and pre-RVS,  $F(1,44) = 5.14$ ,  $p = 0.0283$ , (Effect: -63.1 CI [-119, -7.02]).

## CONCLUSION

- Previous experiments revealed that IAF is a stable and reliable measure.
- Additionally, the participants who had their SNR peak at 10 Hz on-screen RVS, also had their IAF near 10 Hz.
- When those same participants received on-screen RVS away from 10 Hz, their SNR decreased.
- The following experiment revealed there may be a learning effect because of the significant effect of day for both reaction time and stimulus threshold, and reaction time and condition.
- The significant effect of IAF for the difference in stimulus threshold suggests that after receiving RVS at IAF, participants can detect stimuli at a lower contrast threshold compared to before receiving IAF.

## ACKNOWLEDGEMENTS

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