

## Supplementary Information

### Supplementary Method 1: OTHER BINNING APPROACHES

We expanded our primary analysis by using a median-split analysis to divide the trials in two-bins. The pattern of results did not change with this new bin configuration as indicated by the significant differences in accuracy (accuracy<sub>above-median bin</sub> = 0.75 ± 0.01, accuracy<sub>below-median bin</sub> = 0.72 ± 0.01,  $t_{115} = -5.03$ ,  $p < 0.001$ ,  $BF > 1000$ ) and  $d'$  ( $d'_{above-median bin} = 1.64 \pm 0.06$ ,  $d'_{below-median bin} = 1.48 \pm 0.06$ ,  $t_{115} = -3.33$ ,  $p = 0.001$ ,  $BF = 18.10$ ) between above-median and below-median IAF bins. The results were further corroborated when we used a quartile approach to bin the data. One way ANOVA showed a significant effect of the quartile on accuracy ( $F_{3,354} = 8.84$ ,  $p < 0.001$ ) and on  $d'$  ( $F_{3,354} = 6.72$ ,  $p < 0.001$ ). Post hoc analysis using two-tails paired t-test showed that accuracy in the first quartile (accuracy<sub>first quartile</sub> = 0.72 ± 0.01) and in the second quartile (accuracy<sub>second quartile</sub> = 0.73 ± 0.01) were statistically different from the accuracy computed when considering the third (accuracy<sub>third quartile</sub> = 0.75 ± 0.01) and the fourth quartile (accuracy<sub>fourth quartile</sub> = 0.75 ± 0.01, all  $t_{115} > 3.14$ , all  $p < 0.002$ , all  $BF > 10.64$ ). Other comparisons did not reach the significance level (all  $t_{115} < 1.2$ , all  $p > 0.231$ , all  $BF < 0.21$ ). Similarly,  $d'$  in the first quartile ( $d'_{first quartile} = 1.39 \pm 0.07$ ) and in the second quartile ( $d'_{second quartile} = 1.37 \pm 0.07$ ) were statistically different from the  $d'$  computed when considering the third ( $d'_{third quartile} = 1.61 \pm 0.07$ ) and the fourth quartile ( $d'_{fourth quartile} = 1.51 \pm 0.07$ , all  $t_{115} > 2.39$ , all  $p < 0.019$ , all  $BF > 1.52$ ). Other comparisons did not reach significance (all  $t_{115} < 1.32$ , all  $p > 0.193$ , all  $BF < 0.24$ ). We conducted an ANOVA comparing accuracy,  $d'$  and criterion across the second phase bin along with the first and third bins. Significant values were obtained when considering accuracy ( $F_{2,230} = 7.22$ ,  $p < 0.001$ ) and  $d'$  ( $F_{2,230} = 5.17$ ,  $p = 0.006$ ), but not criterion ( $F_{2,230} = 2.13$ ,  $p = 0.121$ ). These results testify that a significant difference exists between the three terciles. Post hoc analyses using one-tail paired ttest revealed significant differences in accuracy and  $d'$  between the first and third bins (as reported in the main text). Regarding accuracy, there was also a difference between the first and the second bin using a one-tail direction t-test ( $t_{115} = -1.87$ ,  $p = 0.032$ ,  $BF = 0.56$ ) and between the second and the third bin ( $t_{115} = -1.92$ ,  $p = 0.028$ ,  $BF = 0.66$ ). Moreover, a significant difference emerged between the second and the third bins when considering  $d'$  ( $t_{115} = -1.92$ ,  $p = 0.028$ ,  $BF = 0.61$ ) but no differences when comparing the first and the second bin ( $t_{115} = -1.32$ ,  $p = 0.095$ ,  $BF = 0.24$ ). Additionally, we provide regression analyses that demonstrate a significant positive slope for accuracy when using a one-sample, two-tails t-test (mean slope = 0.016,  $SE = 0.001$ ,  $t_{115} = 3.71$ ,  $p < 0.001$ ,  $BF = 59.79$ ) and  $d'$  (mean slope = 0.09,  $SE = 0.03$ ,  $t_{115} = 3.09$ ,  $p = 0.002$ ,  $BF = 9.32$ ) but not for criterion (mean slope =  $-0.02 \pm 0.001$ ,  $t_{115} = 1.67$ ,  $p = 0.098$ ,  $BF = 0.40$ ) across the three bins, reinforcing the notion of a gradual and monotonic increase in performance with higher IAF.

### Supplementary Method 2: Additional analyses discard the relationship between IAF and perceptual bias

To further demonstrate that the relationship between IAF and response bias is likely spurious (as indicated by the fact that a small IAF-criterion relationship emerged in only one analysis), we conducted three additional analyses that collectively support the absence of a genuine IAF-bias relationship:

1. We repeated the analysis included in the main text that showed higher IAF values in correct compared to incorrect trials. In this new analysis, however, trials were grouped by choice rather than accuracy. The rationale was that if higher IAF promoted a tendency to report target presence over absence (i.e., reflecting a perceptual bias), a significant relationship should emerge between choice type and IAF. However, IAF did not vary with choice; it remained stable whether participants reported the target's presence or absence (IAF report present =  $11.35 \pm 0.09$ , IAF report absence =  $11.33 \pm 0.09$ ,  $t_{115} = 1.60$ ,  $p = 0.112$ ,  $BF = 0.34$ ).
2. We also repeated the trial-by-trial analysis using choice (rather than accuracy) as the dependent variable, examining whether IAF fluctuations predicted variations in choice. Again, IAF fluctuations did not predict whether participants reported the target as present or absent (mean slope = 0.12,  $p = 0.212$ ,  $BF = 0.22$ ).
3. Lastly, we performed a new trial-by-trial analysis including both accuracy and choice as predictors, with IAF as the dependent variable. This analysis showed that only accuracy predicted IAF (mean slope = 0.41,  $p < 0.001$ ,  $BF = 262.49$ ), with correct trials associated with higher IAF, while choice—indicating any potential bias towards reporting target presence—did not predict IAF (mean slope = -0.06,  $p = 0.523$ ,  $BF = 0.12$ ).

### **Supplementary Method 3: Sources analysis confirms that posterior IAF is a robust predictor of perceptual sensitivity**

We addressed the concern that the observed relationship between IAF and behavior might be an artifact of merging alpha activity originating from distinct sources by performing a source-level analysis, inspired by the approach in Haegens et al. (2014). Specifically, we used the Desikan-Killiany atlas to select occipital (Pericalcarine sulcus and lateral occipital cortex) and parietal regions (Inferior Parietal and Superior Parietal cortex). For each region, we identified the sources with the highest alpha power and extracted the IAF separately for occipital and parietal sources, thereby mirroring the procedure used in our sensor-level analysis.

Then, we investigated the influence of pre-stimulus IAF on perceptual sensitivity and bias by employing a binning analysis using the IAF extracted for each individual and separately for the two sources (i.e., occipital and parietal). This analysis involved dividing the trials into three terciles based on pre-stimulus IAF. Firstly, we time-collapsed the IAF data by computing the average values from -800ms to -100ms for each participant. Subsequently, we computed the signal detection indices from trials within the first and third terciles. The results demonstrated that trials in the first tercile were associated with reduced sensitivity compared to trials within the third tercile both in the right occipital (mean  $d'_{\text{first tercile}} = 1.42$ ,  $SE = 0.08$ ; mean  $d'_{\text{third tercile}} = 1.61$ ,  $SE = 0.06$ ;  $t_{101} = -3.56$ ,  $p < 0.001$ ;  $BF = 37.44$ ; Fig. 1A) and in the right parietal sources (mean  $d'_{\text{first tercile}} = 1.46$ ,  $SE = 0.08$ ; mean  $d'_{\text{third tercile}} = 1.61$ ,  $SE = 0.06$ ;  $t_{106} = -2.33$ ,  $p = 0.022$ ;  $BF = 1.43$ ).

Similarly, accuracy was higher in the third compared to the first terciles when considering the occipital (mean accuracy  $_{\text{first tercile}} = 0.71$ ,  $SE = 0.01$ ; mean accuracy  $_{\text{third tercile}} = 0.75$ ,  $SE = 0.01$ ;  $t_{101} = -3.95$ ,  $p < 0.001$ ;  $BF = 129.50$ ) as well as parietal

sources (mean accuracy<sub>first tercile</sub> = 0.72, SE = 0.01; mean accuracy<sub>third tercile</sub> = 0.75, SE = 0.01;  $t_{106} = -2.78$ ,  $p = 0.006$ ; BF = 4.11). Conversely, the criterion indices estimated in the first vs. third terciles were not statistically different (Occipital source: mean c<sub>first tercile</sub> = 0.42, SE = 0.05; mean c<sub>third tercile</sub> = 0.40, SE = 0.05;  $t_{101} = 0.94$ ,  $p = 0.350$ ; BF = 0.17; Parietal source: mean c<sub>first tercile</sub> = 0.44, SE = 0.05, mean c<sub>third tercile</sub> = 0.43, SE = 0.04,  $t_{106} = 0.25$ ,  $p = 0.803$ , BF = 0.11).

It is important to note that the strength of the relationship between IAF and perceptual performance is significantly more pronounced when considering occipital IAF compared to parietal IAF, suggesting that the alpha activity generated in the occipital lobe has a more critical impact on performance. This aspect becomes even more pronounced when we examined the differentiation of IAF in correct and incorrect responses, as well as the trial-by-trial analyses linking accuracy fluctuations to IAF variations. In this context, only the IAF extracted from the occipital source reached full statistical significance when comparing IAF in correct (IAF<sub>correct</sub> = 11.27, SE = 0.1) and in incorrect trials (IAF<sub>incorrect</sub> = 11.24, SE = 0.11,  $t_{101} = 2.48$ ,  $p = 0.015$ , BF = 2.02) as well as in the trial-by-trial analysis (mean slope = 0.31, SE = 0.1,  $t_{101} = 3.22$ ,  $p < 0.001$ , BF = 13.25), while the IAF extracted at the parietal level showed only non-significant trends, further weakened by Bayesian factors indicating a higher probability for the null compared to the alternative hypothesis (IAF<sub>correct</sub> = 11.24, SE = 0.1; IAF<sub>incorrect</sub> = 11.21, SE = 0.11,  $t_{106} = 1.86$ ,  $p = 0.066$ , BF = 0.56; mean slope = 0.20, SE = 0.1,  $t_{106} = 1.89$ ,  $p = 0.061$ , BF = 0.60).

#### **Supplementary Method 4: IAF AND REACTION TIMES**

When examining the relationship between IAF bins and reaction times (RTs), no significant differences were observed between the first and third terciles, whether considered overall (RT<sub>first tercile</sub> =  $0.88 \pm 0.03$ , RT<sub>third tercile</sub> =  $0.88 \pm 0.03$ ,  $t_{115} = -0.19$ ,  $p = 0.850$ , BF = 0.10) or when weighted by response accuracy (RT<sub>first tercile correct</sub> =  $0.85 \pm 0.03$ , RT<sub>first tercile incorrect</sub> =  $1.00 \pm 0.04$ ; RT<sub>third tercile correct</sub> =  $0.86 \pm 0.03$ , RT<sub>third tercile incorrect</sub> =  $0.97 \pm 0.04$ , all  $t_{115} < 1.42$ , all  $p > 0.158$ , all BF < 0.28). We also tested whether IAF fluctuations were associated with RT in the task, demonstrating that variations in IAF did not significantly predict RT on a trial-by-trial basis (mean slope = 0.05, SE = 0.10,  $t_{115} = 0.52$ ,  $p = 0.603$ , BF = 0.12). These results collectively support the notion that IAF has a significant impact on the probability of accurate perceptual responses while leaving reaction time unaffected. This finding is important as it indicates that the impact of IAF on accuracy is not due to a speed/accuracy trade-off. If such a trade-off were present, higher IAF would be expected to correlate with slower reaction times, as individuals might prioritize accuracy over speed. However, since no such effect on reaction time was observed, it suggests that IAF directly enhances response accuracy without affecting response speed.

#### **Supplementary Method 5: Single-trial IAF estimation via aperiodic-free gaussian fitting**

To further validate the reliability of our single-trial IAF estimation, we conducted an additional analysis using an aperiodic-free Gaussian fitting approach. In this procedure,  $1/f$  was removed as in our main analysis, and we picked the electrodes showing used in our main analyses (see Methods). Then, the power spectrum was computed over the prestimulus window using Welch's method per each trial separately, focusing on the alpha band. An initial peak estimate was determined by identifying the frequency with the highest power within 7–14 Hz, a slightly extended range that accommodates single-trial IAF fluctuations that may exceed 13 Hz. Around this peak, we defined a narrow fitting window extending 3 Hz on either side to isolate the region of interest. Within this window, a Gaussian function (Matlab function *lsqcurvefit.m*)—characterized by its amplitude, centre frequency, and width—was fitted to the data. To reduce the risk of poor convergence or local minima, the Gaussian fit is initialized with a sensible starting point. Specifically, the initial amplitude  $A_0$  is set to the maximum observed power in the alpha segment used for peak detection, so the optimizer starts from a peak height comparable to the data. The initial center frequency  $\mu_0$  is set exactly at the frequency of this maximum, ensuring the fit is anchored on the putative alpha peak. The initial width  $\sigma_0$  is set to the standard deviation of the frequency samples in the initial alpha band segment, providing a moderate starting bandwidth rather than an arbitrarily narrow or excessively broad peak. Then, the centre frequency of the fitted Gaussian was taken as the single-trial IAF estimate. An adjusted  $R^2$  was calculated to assess the goodness-of-fit, and trials were excluded if the adjusted  $R^2$  was below 0.9 or if the IAF was estimated at the boundaries of the fitting window, suggesting that the fit was constrained rather than reflecting a true spectral peak. Using the remaining trials, we replicated the main behavioural analyses with Gaussian-derived IAF. First, we compared the goodness-of-fit between correct and incorrect trials and observed no significant differences (Adjusted  $r^2$  correct =  $0.98 \pm 0.01$ ; Adjusted  $r^2$  incorrect =  $0.98 \pm 0.01$ ;  $t_{115} = -0.33$ ,  $p = 0.741$ ). Moreover, the IAF estimates obtained with this method successfully predicted participants' performance, replicating the results presented in the main text. Specifically, terciles analysis confirmed that trials included in the third vs. first terciles are characterized by higher sensitivity and accuracy (all  $t_{115} > 2.96$ , all  $p = 0.004$ ; all  $BF > 6.46$ ). Moreover, correct responses were associated with higher IAF compared to incorrect responses ( $t_{115} = 2.65$ ,  $p = 0.009$ ;  $BF = 2.91$ ) and trial-by-trial fluctuations in IAF predicts variations in perceptual accuracy ( $t_{115} = 2.69$ ,  $p = 0.008$ ;  $BF = 3.24$ )

#### **Supplementary Method 6: FFT-based method for estimating single-trial IAF confirmed the pattern of results observed with the instantaneous frequency approach.**

To further validate the reliability of single-trial IAF estimation, we compared the results obtained using the FFT-based method with those derived from the instantaneous frequency approach. Specifically, we applied the Corcoran et al. (2018) algorithm to the single-trial power spectra, replacing the original Welch-based PSD estimation with EEGLAB's *spectopo*. This procedure allowed us to extract IAF values based on a robust peak detection method rather than phase-based instantaneous frequency calculations. The key advantage of this approach is its reliance on spectral features

rather than time-domain fluctuations, reducing the influence of transient noise. Our analyses revealed a strong correspondence between the two methods. Specifically, trials in which the FFT-based IAF estimates were in the third terciles showed higher accuracy ( $t_{115} = 3.03$ ,  $p = 0.003$ ,  $BF = 7.64$ ) and sensitivity ( $t_{115} = 2.80$ ,  $p = 0.006$ ,  $BF = 4.18$ ), while maintaining the same level of criterion ( $t_{115} = 1.67$ ,  $p = 0.097$ ,  $BF = 0.40$ ). Moreover, correct responses were linked to higher IAF compared to incorrect responses ( $t_{115} = 3.09$ ,  $p = 0.002$ ,  $BF = 9.11$ ). Finally, fluctuation in trial-by-trial FFT-based IAF estimate impacted the probability of making a correct detection of the target ( $t_{115} = 3.48$ ,  $p < 0.001$ ,  $BF = 40.31$ ). Therefore, both methods consistently indicated that higher IAF was associated with better perceptual performance, confirming the robustness of our original findings. These results suggest that different analytical frameworks can reliably capture the same underlying neural dynamics, reinforcing the conclusion that prestimulus IAF fluctuations play a crucial role in shaping perceptual outcomes.

#### **Supplementary Method 7: The FFT-based and instantaneous frequency approaches result in comparable single-trial IAF values.**

A direct comparison of single-trial IAF values obtained through the FFT-based and instantaneous frequency methods revealed a significant association between the two approaches (Mean  $r = 0.65$ ,  $SE = 0.01$ ,  $t_{115} = 40.35$ ,  $p < 0.001$ ,  $BF > 1000$ ). This strong correspondence suggests that the two methods capture the same neural signal properties, albeit from different analytical perspectives.

#### **Supplementary Method 8: IAF extracted from the pooled correct trials was higher than that extracted from the pooled incorrect trials.**

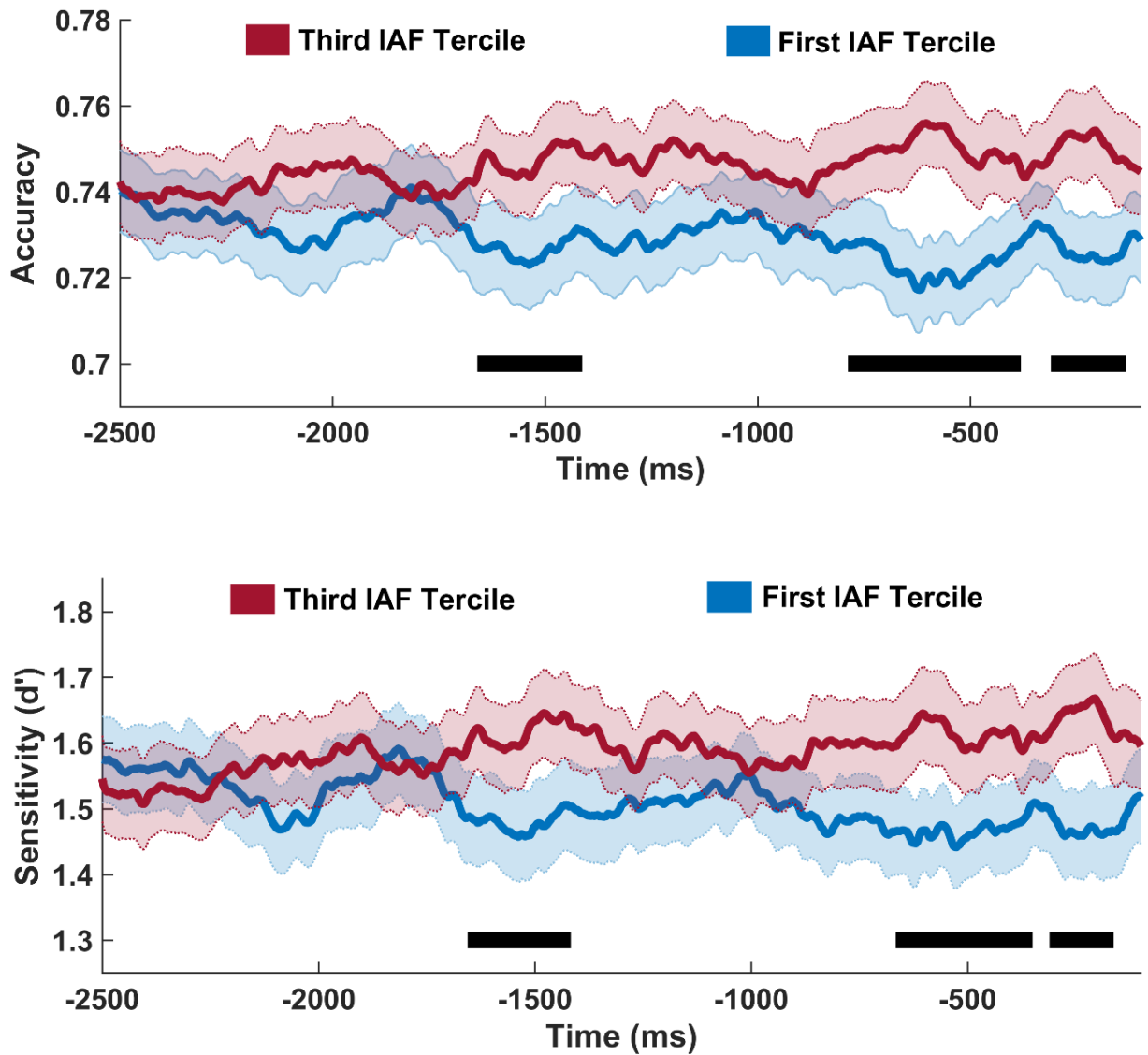
Beyond single-trial analyses, we also examined whether IAF differences between correct and incorrect trials were evident when estimated from pooled data. This approach provides a complementary perspective, as it avoids trial-by-trial variability and instead focuses on broader spectral properties of the prestimulus signal. Specifically, we computed the power spectrum by pooling all trials within each response category (correct vs. incorrect) and identified the alpha peak separately for each condition (*spectopo.m*). Our results revealed a systematic difference: IAF extracted from the pooled correct trials was significantly higher than that extracted from the pooled incorrect trials. This finding was consistent across subjects and was confirmed using both visual inspection of the power spectrum ( $t_{100} = 3.11$ ,  $p = 0.002$ ,  $BF = 9.80$ ) of the spectra and the Corcoran et al. (2018) algorithm for automated peak detection applied to the aperiod-free power spectrum ( $t_{81} = 2.77$ ,  $p = 0.007$ ,  $BF = 3.73$ ). Importantly, this pattern replicated the results obtained using the single-trial approach, reinforcing the conclusion that prestimulus IAF is a key predictor of perceptual accuracy. The consistency across different estimation methods highlights the robustness of the observed effect, ruling out the possibility that it arises from noise-related fluctuations in single-trial analyses.

### **Supplementary Method 9: Confirmation of the Robust IAF–Sensory Precision Relationship Using an Alternative 1/f Removal Method**

We conducted supplementary investigations to assess whether the results linking IAF and sensory accuracy are robust to different methods for removing the 1/f component. Specifically, we applied an alternative approach that uses a polynomial fitting procedure to remove 1/f noise. For each trial, we computed the FFT (MATLAB function *fft.m*) to obtain both the power spectrum and the phase information. The power spectrum was then fitted in log-log space, using a second-degree polynomial to capture the 1/f component (MATLAB function *polyfit.m* and *polyval.m*). By subtracting this polynomial from the log-transformed power spectrum and converting the result back to the original scale, we effectively removed the 1/f noise. The corrected power spectrum was then recombined with the original phase information and transformed back into the time domain using an inverse FFT. We subsequently replicated our original pipeline to extract instantaneous IAF (See methods) using the aperiodic-free signal. We then repeated the bin-based, trial-by-trial and pooled correct vs. incorrect analysis (See methods). Results confirmed that our findings were robust and consistent regardless of the specific approach used for 1/f removal. Specifically, tercile analysis confirmed that trials in the third versus the first tercile are characterized by higher sensitivity and accuracy (all  $t_{115} > 2.80$ , all  $p < 0.006$ ; all  $BF > 4.16$ ). Moreover, correct responses were associated with higher IAF compared to incorrect responses ( $t_{115} = 4.29$ ,  $p < 0.001$ ;  $BF = 439.41$ ), and trial-by-trial fluctuations in IAF predicted variations in perceptual accuracy ( $t_{115} = 4.42$ ,  $p < 0.001$ ;  $BF = 703.19$ ).

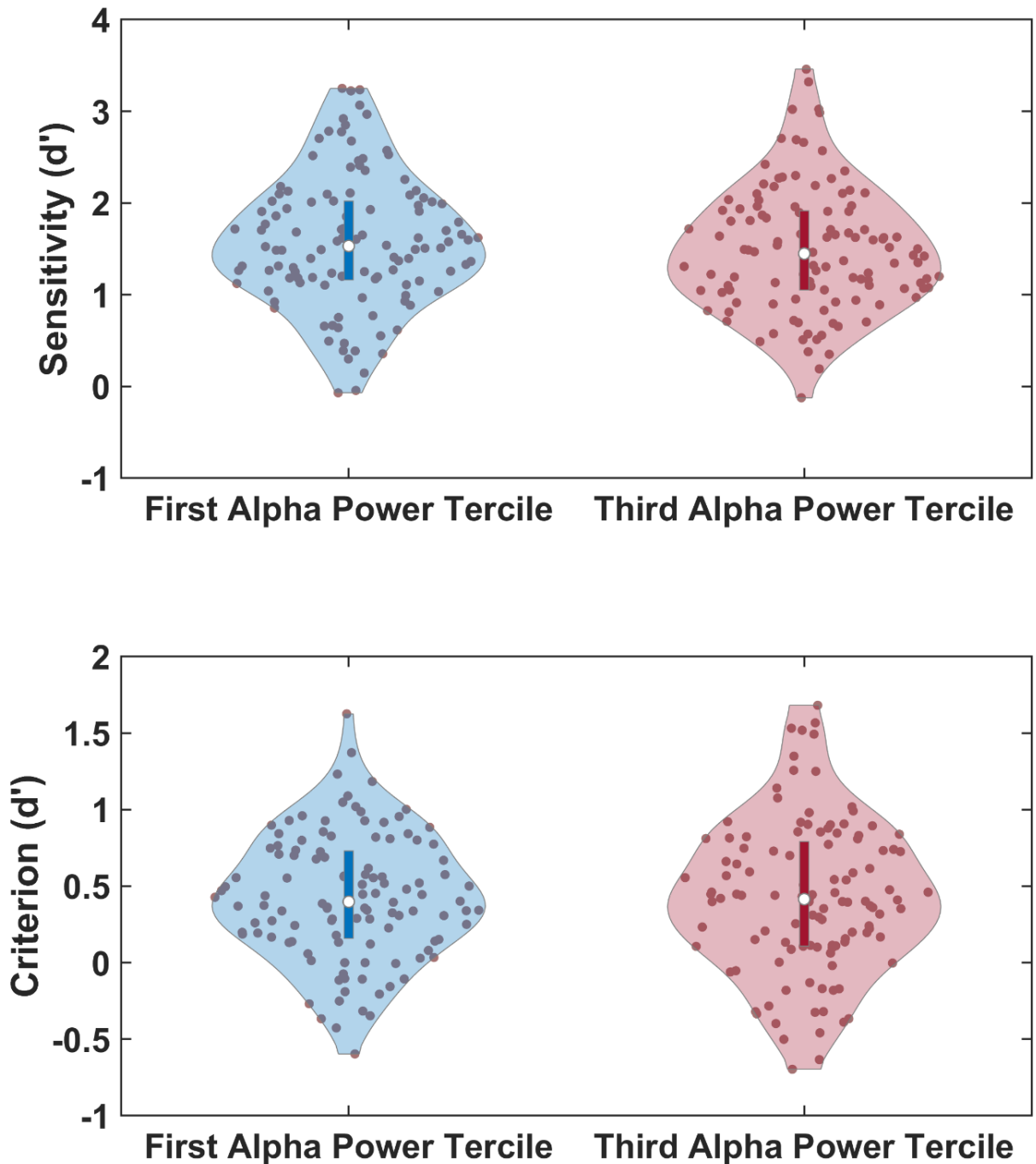
### **Supplementary Method 10: GLMM analysis**

GLMM analysis corroborated the IAF-sensitivity finding derived from the non-parametric multiple regression analysis (see main text) as IAF was a significant predictor of trial-by-trial accuracy (slope = 0.08,  $p < 0.001$ ). This effect remained significant when accounting for trial-by-trial fluctuations in alpha power (slope IAF = 0.07,  $p < 0.01$ ; slope alpha power = -0.03,  $p = 0.136$ ).



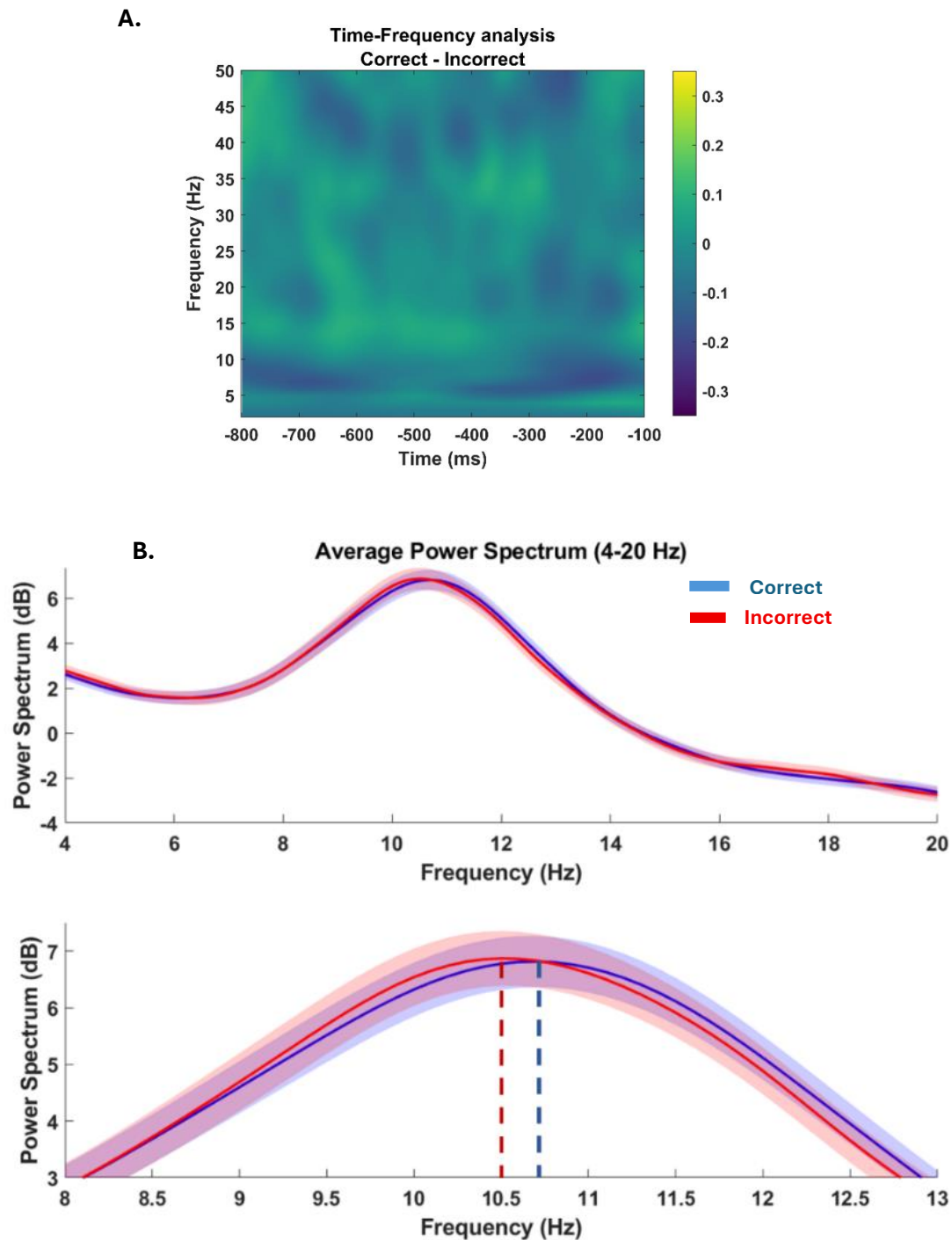
**Figure S1. Time-resolved predictive effect of IAF on perceptual performance on a longer timescale**

Time-resolved regression analyses across sample ( $N = 116$ ) showing the relationship between individual alpha frequency (IAF) and behavioral performance across extended prestimulus windows (-2500 ms; -100 ms). IAF predicts sensitivity ( $d'$ ) beginning  $\sim 1.5$  s before stimulus onset, with effects becoming progressively stronger and more consistent closer to stimulus presentation. A similar pattern is observed for accuracy, with no differences across terciles in very remote periods (-2500 to -1500 ms), but robust predictive effects emerging in the immediate prestimulus interval. Significant time points are indicated with black lines ( $p < 0.05$ ; permutation test; cluster corrected). Shaded regions denote mean  $\pm$  within-subjects SE.



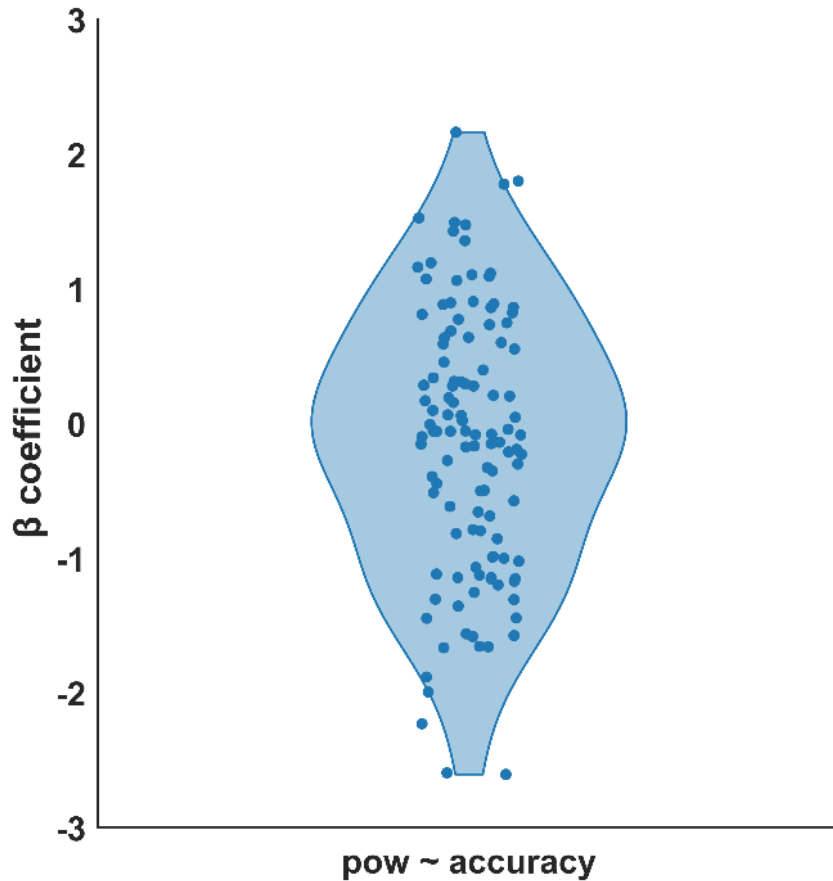
**Figure S2. No significant differences observed in behavioural performance between first and third power tertiles**

We replicated the initial analysis ( $N = 116$ ) included in the main text by binning trials based on pre-stimulus power in the first and third tertiles. The analysis revealed that behavioural performance was unaffected by this binning approach, both in terms of sensitivity (First Alpha Power Tertiles: Mean = 1.58, SE = 0.07, 25<sup>th</sup> percentile = 1.16, 75<sup>th</sup> percentile = 2.02; Third Alpha Power Tertiles: Mean = 1.49, SE = 0.06, 25<sup>th</sup> percentile = 1.05, 75<sup>th</sup> percentile = 1.91), and criterion (First Alpha Power Tertiles: Mean = 0.43, SE = 0.04, 25<sup>th</sup> percentile = 0.16, 75<sup>th</sup> percentile = 0.73; Third Alpha Power Tertiles: Mean = 0.43, SE = 0.05, 25<sup>th</sup> percentile = 0.11, 75<sup>th</sup> percentile = 0.79; all  $t_{115} < 1.69$ , all  $p > 0.093$ , all BF < 0.41).



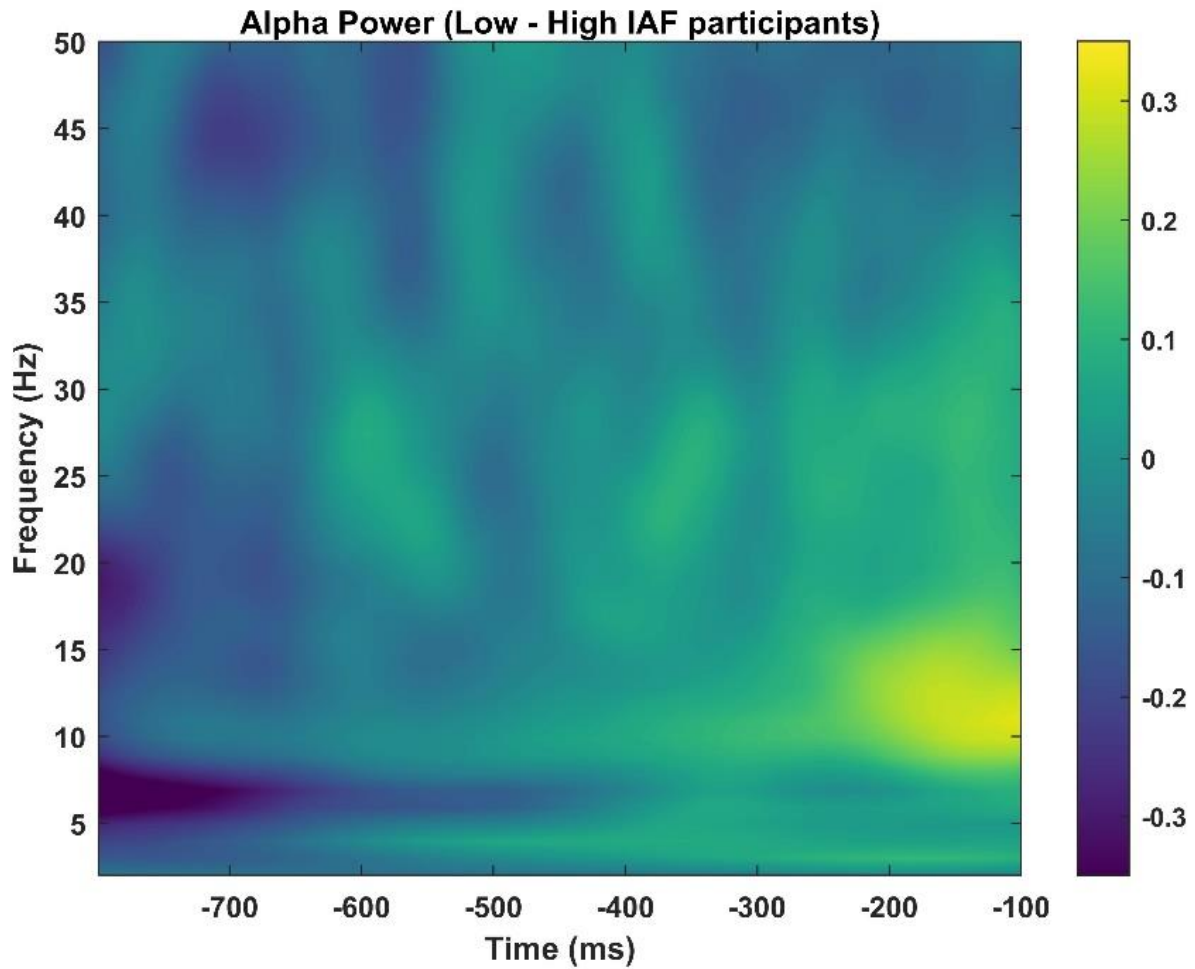
**Figure S3. Correct and Incorrect trials are not characterized by difference in oscillatory amplitude.**

- A. We conducted a time-frequency analysis to assess whether correct responses (in blue) exhibited different amplitudes compared to incorrect responses (in red). The cluster-based analysis revealed no significant differences between the two types of trials, indicating that power, unlike IAF, does not differentiate correctness across trials.
- B. Additionally, we employed a more direct approach by computing the power spectrum (*Spectopo.m*) for pooled correct vs. pooled incorrect trials. This allowed us to assess power spectrum differences between these two conditions within the 4-20 Hz range. In line with previous analysis, we found again no significant differences in power, neither in the alpha band nor in other frequency bands, including theta and beta (all  $t_{115} < 0.61$ , all  $p > 0.539$ , all BF  $< 0.12$ ). Please also note the mean frequency difference between pooled corrected and incorrect responses of the order of magnitude similar to the one observed in the trial-by-trial analysis (~0.20 Hz difference between correct and incorrect responses).



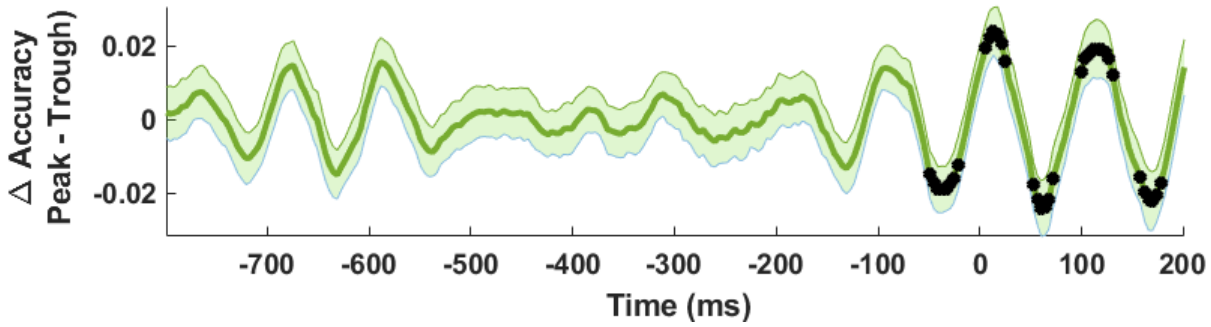
**Figure S4. Trial-by-trial fluctuations in alpha power do not account for perceptual accuracy.**

We conducted an analysis ( $N = 116$ ) to evaluate whether trial-by-trial fluctuations in power, alongside those of IAF, influenced the accuracy of the responses provided. We extracted the power calculated from the time-frequency analysis by taking the alpha frequency closest to the IAF, normalizing it through a z-score transformation. Subsequently, we created a design matrix that included the intercept, IAF, and normalized alpha power. The regression analysis confirmed the significant predictive ability of IAF fluctuations on perceptual accuracy (mean slope = 0.38, SE = 0.09, 25<sup>th</sup> percentile = -0.25, 75<sup>th</sup> percentile = 0.96,  $t_{115} = 4.06$ ,  $p < 0.001$ , BF = 192.36). In contrast, fluctuations in power did not statistically modulate the participant's ability to accurately retain the stimulus (mean slope = -0.14, SE = 0.09, 25<sup>th</sup> percentile = -0.98, 75<sup>th</sup> percentile = 0.61,  $t_{115} = -1.54$ ,  $p = 0.127$ , BF = 0.32).



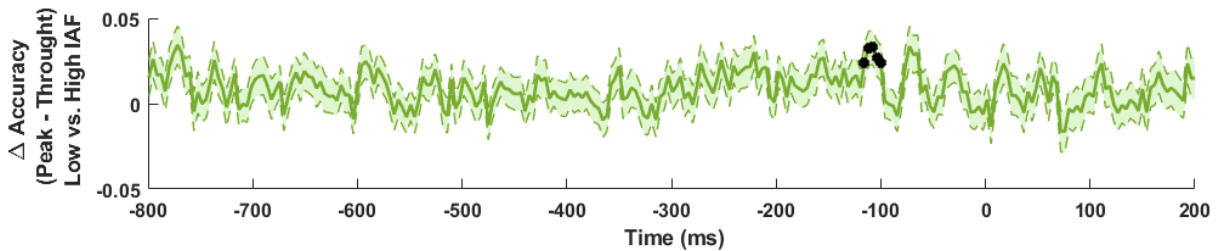
**Figure S5. Low and Fast IAF groups do not exhibit significant differences in oscillatory amplitude.**

We conducted a time-frequency analysis to assess whether participants in the low IAF (N = 39) frequency group exhibited different amplitude profiles compared to those in the high IAF (N = 39) frequency group. The cluster-based analysis (1000 permutations) revealed no significant differences between the two populations, indicating that amplitude does not show any statistical difference between the two groups.



**Figure S6. Alpha phase modulates perceptual accuracy.**

Time course of the difference in perceptual accuracy between the two alpha phase bins ( $0^{\circ}$ – $180^{\circ}$  vs.  $180^{\circ}$ – $360^{\circ}$ ) across the  $-800$  to  $200$  ms window in the whole sample ( $N = 116$ ). Dots indicate significant clusters where perceptual accuracy differed as a function of phase. Significant time periods were observed both before and after stimulus onset ( $-49$  ms to  $-21$  ms,  $5$ – $25$  ms,  $52$ – $71$  ms,  $99$ – $130$  ms, and  $157$ – $177$  ms), indicating that ongoing alpha phase predicts perceptual performance. Significant time points are indicated with black asterisks ( $p < 0.05$ ; permutation test; cluster corrected). Shaded regions denote mean  $\pm$  within-subjects SE.



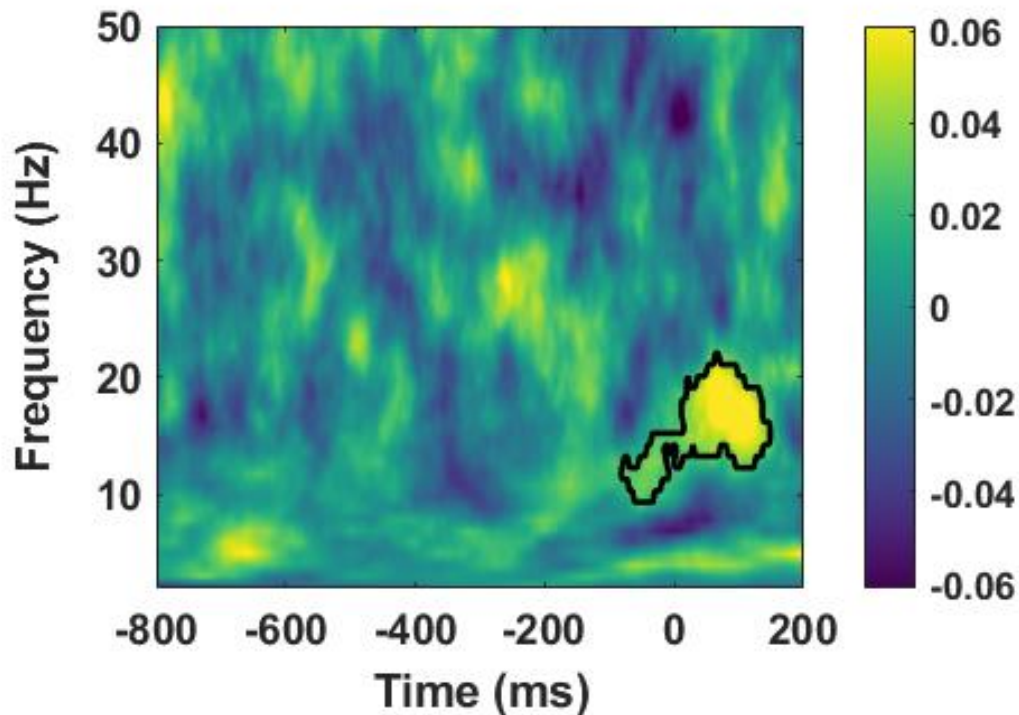
**Fig. S7. IAF  $\times$  Phase interaction analysis**

To formally test whether the modulatory effect of alpha phase on perceptual accuracy differed as a function of instantaneous IAF, we implemented a within-subject  $2 \times 2$  binning procedure with the factors Phase (Peak vs. Trough) and IAF (Low vs. High). For each participant and each prestimulus time point ( $-800$  to  $200$  ms), trials were assigned to a phase bin based on the instantaneous alpha phase (Peak:  $0^{\circ}$ – $180^{\circ}$ ; Trough:  $-180^{\circ}$ – $0^{\circ}$ ) and to an IAF bin based on the distribution of instantaneous frequency values (lowest vs. highest tercile). Within each bin we computed mean accuracy, yielding a  $2 \times 2$  accuracy matrix per participant and time point. From this matrix, we calculated the phase effect separately for Low-IAF and High-IAF trials as the accuracy difference between Peak and Trough bins. To ensure that the analysis captured the strength rather than the direction of this effect, we took the absolute value of these differences. The interaction contrast (IC) was then defined as the difference in the magnitude of the phase effect between Low-IAF and High-IAF trials:

$$IC = |Accuracy_{Peak} - Accuracy_{Trough}|_{Low\ IAF} - |Accuracy_{Peak} - Accuracy_{Trough}|_{High\ IAF}$$

This procedure produced, for each participant, a time course of IC values across the prestimulus interval. To statistically evaluate the IC, we performed a cluster-based permutation test. At each time point, two-sided, one-sample t-tests against zero were computed across participants. Suprathreshold points ( $p < 0.05$ ) were grouped into clusters, whose mass was defined as the sum of absolute t-values. The significance of observed clusters was assessed against a null distribution obtained by a permutation analysis (1000 iterations), in which the sign of IC values was randomly inverted for half of the participants. Clusters exceeding the 95th percentile of this null distribution were considered significant (cluster-level  $\alpha = 0.05$ ). Crucially, during the prestimulus period, the modulatory effect of alpha phase on accuracy was significantly enhanced for trials with low instantaneous IAF relative to those with high IAF, with a significant cluster emerging around  $-100$  ms from stimulus onset. Significant time points are indicated with black asterisks ( $p < 0.05$ ; permutation test; cluster corrected). Shaded regions denote mean  $\pm$  within-subjects SE.

## $\Delta\text{ITPC}$ (Low-IAF $_{\Delta\text{ITPC}}$ - High-IAF $_{\Delta\text{ITPC}}$ )



**Figure S8. IAF modulates the correct–incorrect ITPC contrast in the peri-stimulus window.**

Time–frequency map of the between-group difference in the phase-locking contrast between correct and incorrect trials ( $\Delta\text{ITPC}$ ), calculated as Low-IAF $_{\Delta\text{ITPC}}$  minus High-IAF $_{\Delta\text{ITPC}}$ . Difference in trial counts for correct vs. incorrect responses were controlled via stratified resampling (see Methods). Suprathreshold TF points were defined using a one-tailed z-threshold (testing Low-IAF > High-IAF). Black contours mark clusters significant under a cluster-based permutation test (1000 permutations). Warm colours indicate a larger  $\Delta\text{ITPC}$  in Low-IAF than in High-IAF group. A significant positive cluster emerged in the high-alpha/low-beta band (~9–20 Hz) during the peri-stimulus period (-80 to +150 ms), indicating that the phase-locking difference between correct and incorrect perception was stronger in Low-IAF than in High-IAF participants. Statistically significant time–frequency points (cluster-based permutation test,  $p < 0.05$ ) are delineated by a black contour.