Neural sensitivity to context over multiple time and frequency scales

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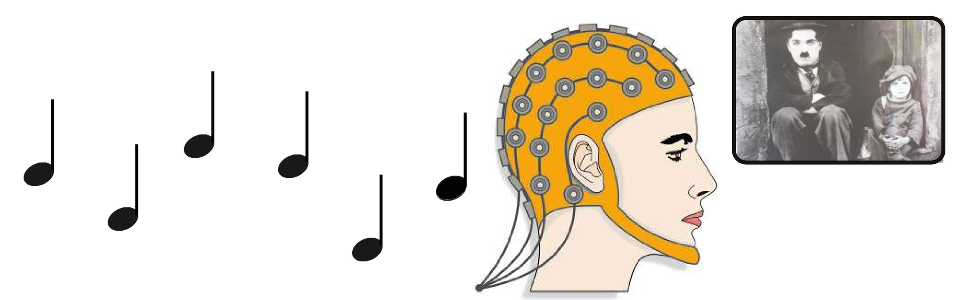
Introduction

- We studied context-dependent auditory processing by examining the dependence of the N1 and P2 auditory evoked potentials (AEP) on recent sensory history.
- EEG responses were measured to pure tones embedded in unattended sequences.
- Context was manipulated by varying the total frequency spread in the sequences.
- Using computational modelling, we suggest a unifying mechanism and estimate effective time and frequency scales of processing.

Methods

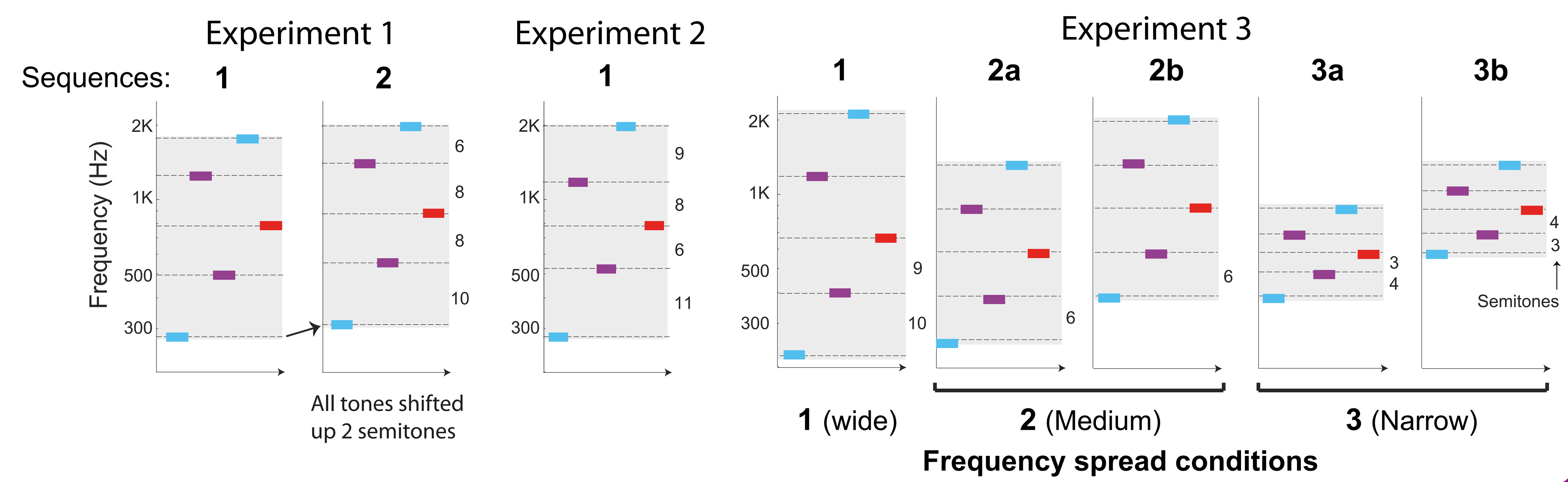
Stimuli:
Random sequences comprised of 5 equi-probable pure tones (20% each).
Duration - 100 ms. SOA - 500 ± 50 ms.
Tones displayed through headphones
Particiants were asked to ignore the sounds while concentrating on a silent film.



3 EEG experiments:
Experiment 1 - 21 musicians
Experiment 2 - 27 musicians
Designed for a previous study[1]

Experiment 3 - 31 non-musicians
Designed to replicate and test varying frequency spread

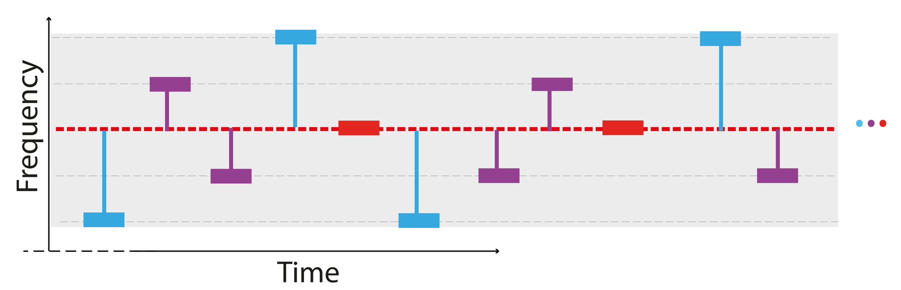
79 participants overall

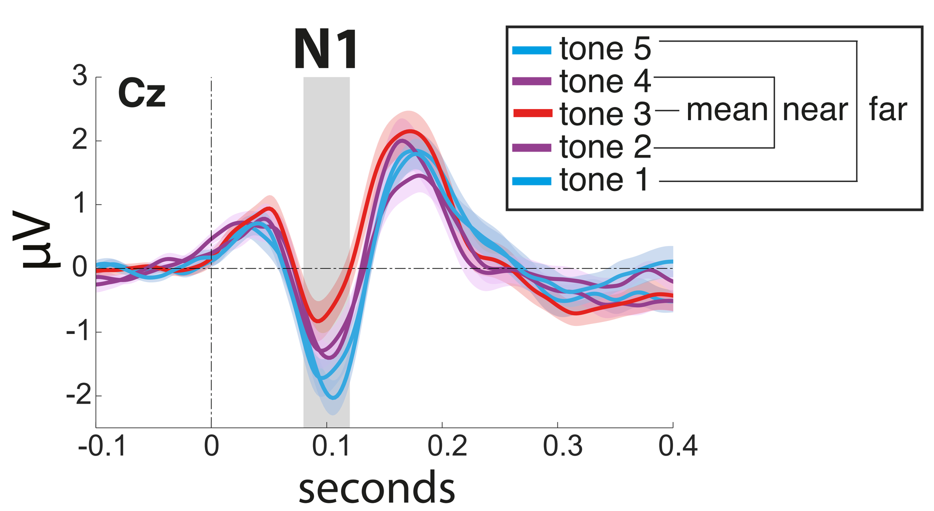


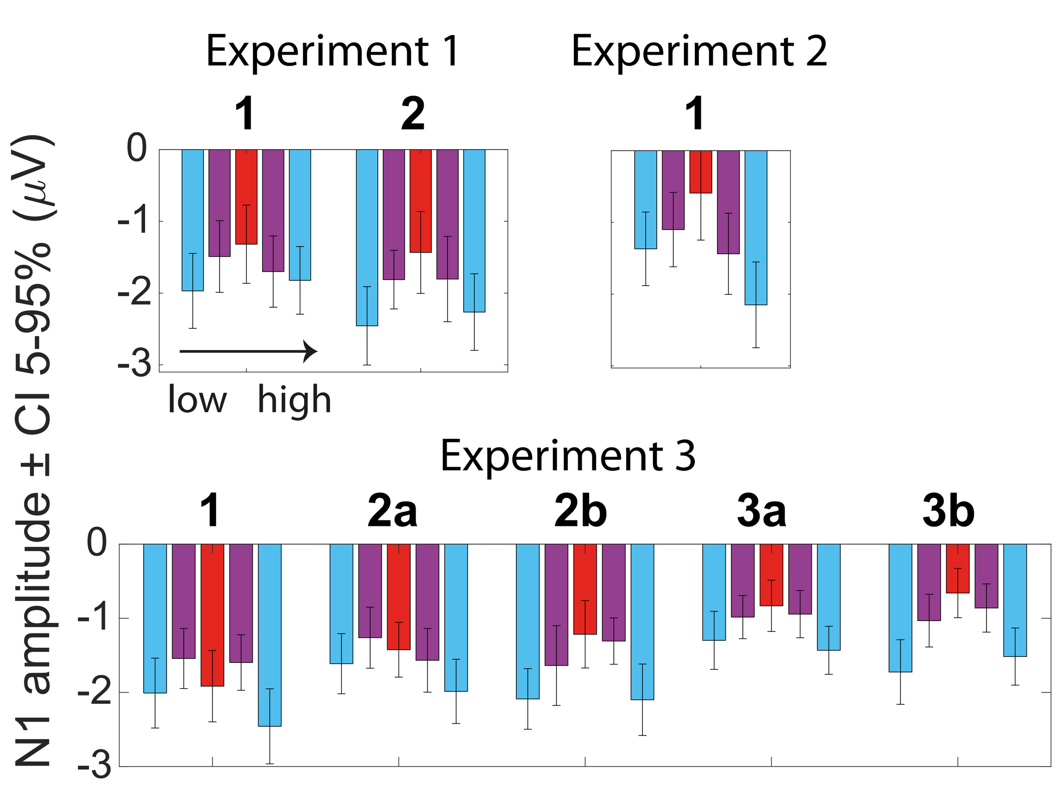
ERP Results

N1 is sensitive to long term context

Color denotes proximity to mean frequency:

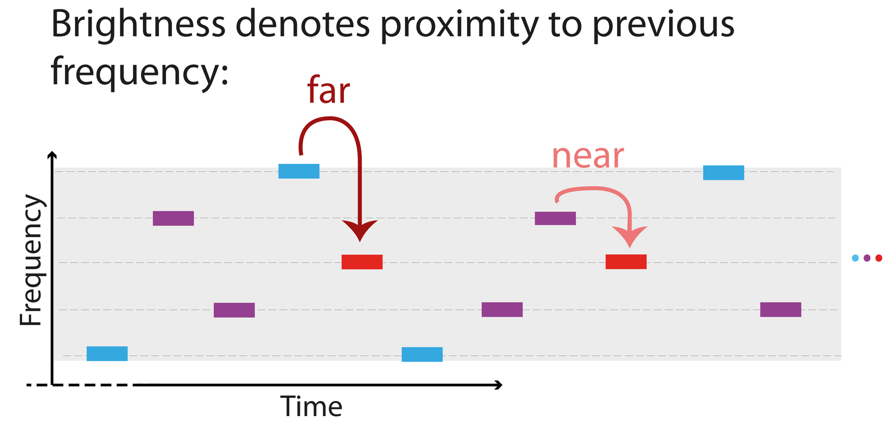


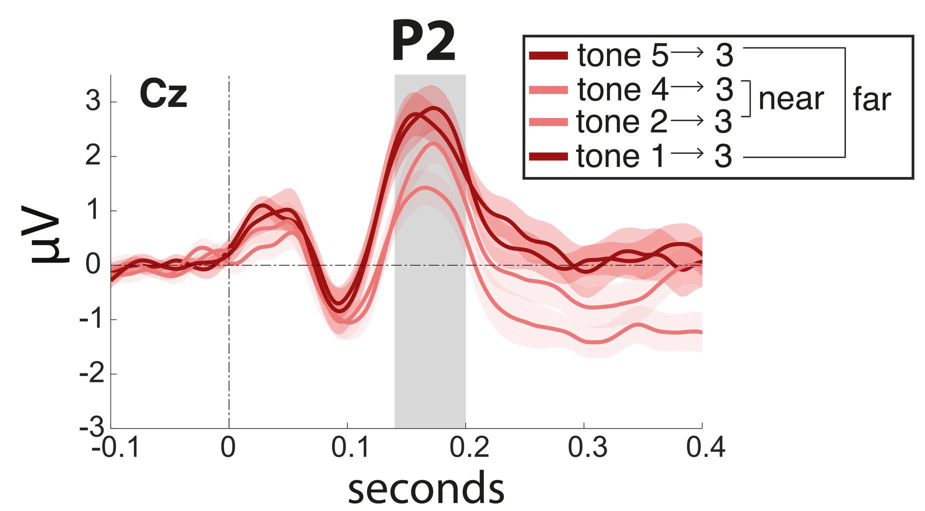


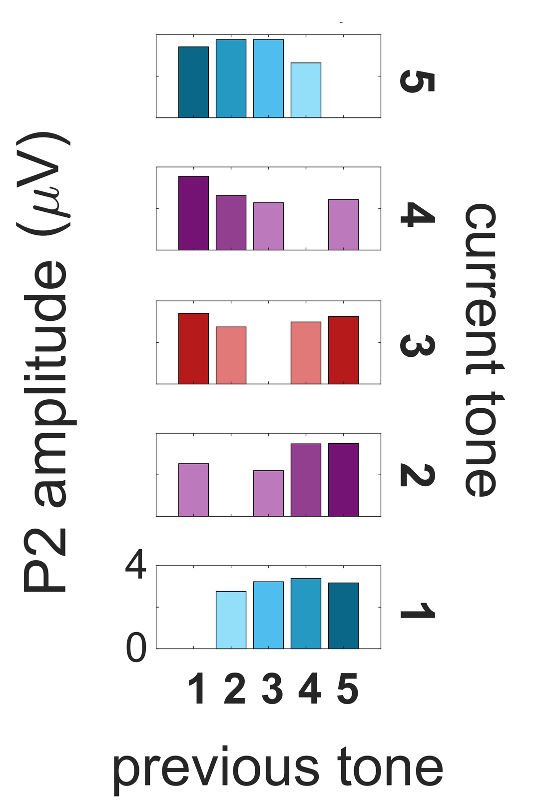


P2 is sensitive to short term context

Brightness denotes proximity to previous frequency:







Model

Adaptation with distinct recovery rates explains the N1/P2 variable context effect

- Neurons with gaussian frequency tuning curves and exponential recovery from adaptation[2,3,4]:

$$RA_{i,t+1} = \left(RA_{i,t} + (1-RA_{i,t})\, e^{-\frac{1}{2}\left(\frac{\log(f_i)-\log(fs_t)}{\sigma}\right)^2}\right) e^{-\frac{\Delta t_{s_t \to s_{t+1}}}{\tau}}$$

RA - response adaptation (0 = no adaptation 1=full adaptation)
i - neural population with best frequency f_i
s_t - stimulus at time t with frequency fs_t
$\Delta t_{s_t \to s_{t+1}}$ - time interval between stimuli s_t and s_{t+1}

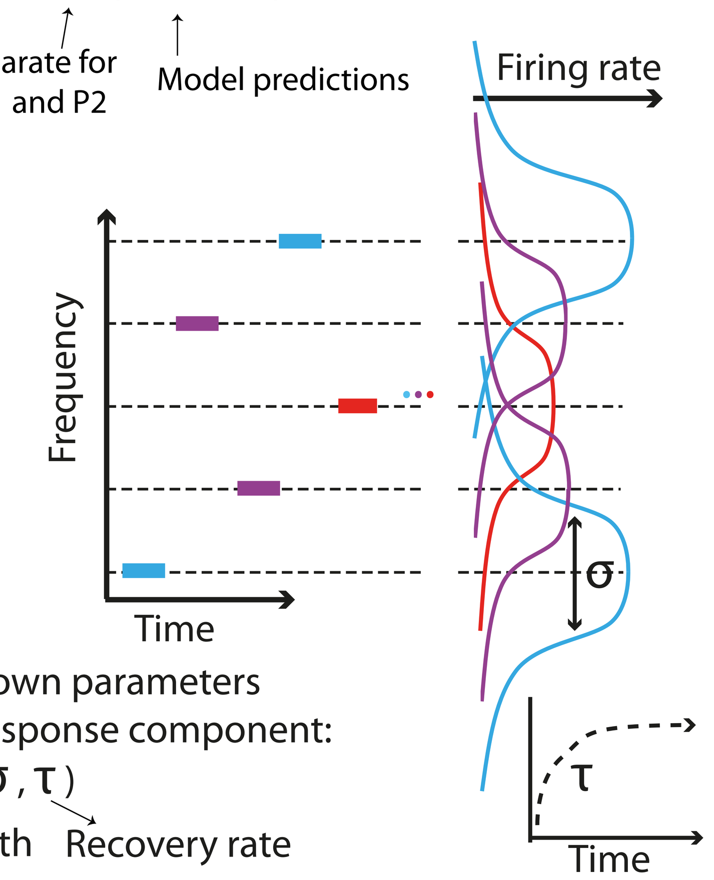
- Linear relations between model predictions (1-RA) and single trial N1 or P2 responses (P):

$$P = a + b\,(1 - RA)$$

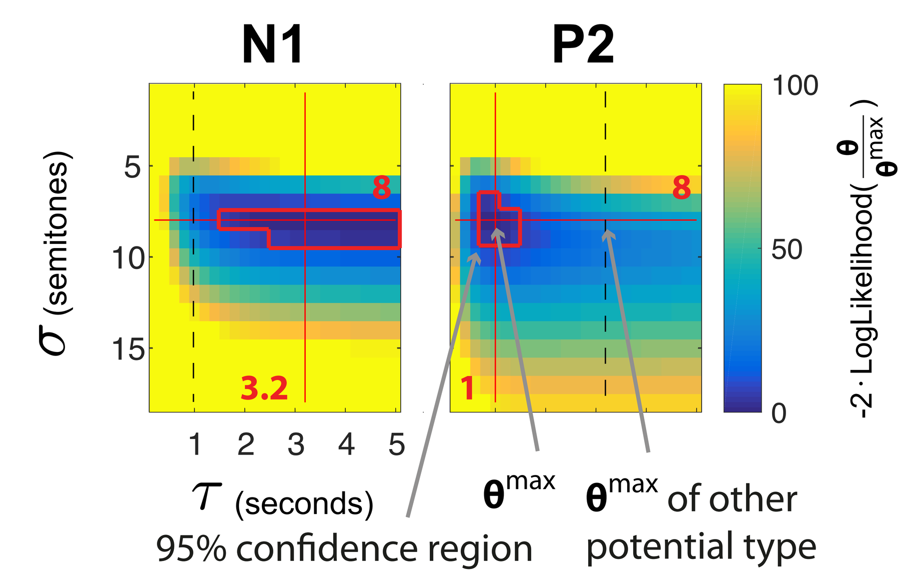
Data; Separate for N1 and P2; Model predictions

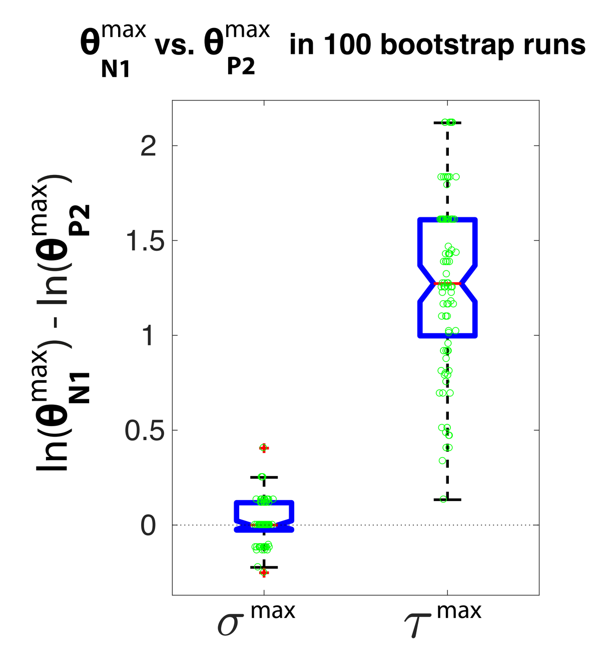
- Two unknown parameters for each response component:

$\theta = (\sigma, \tau)$
Tuning width, Recovery rate



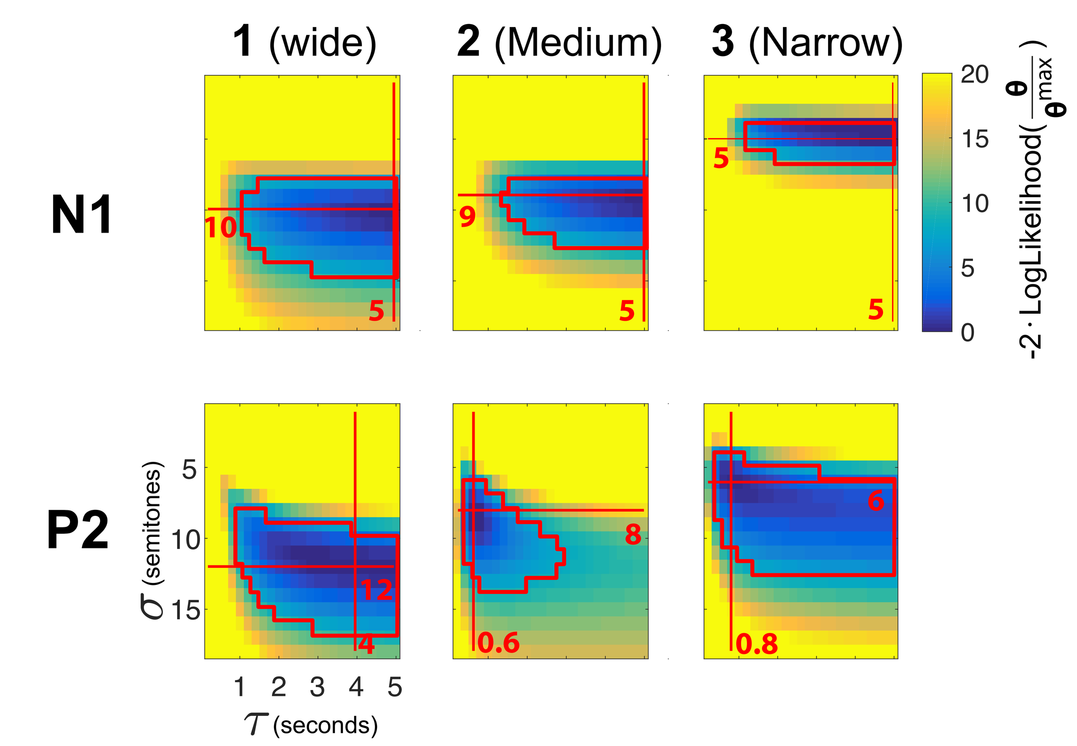
- Parameters were estimated using linear mixed effects (LME) regression followed by maximizing likelihood. Confidence regions were based on the chi2 distribution (Wilk's theorem).

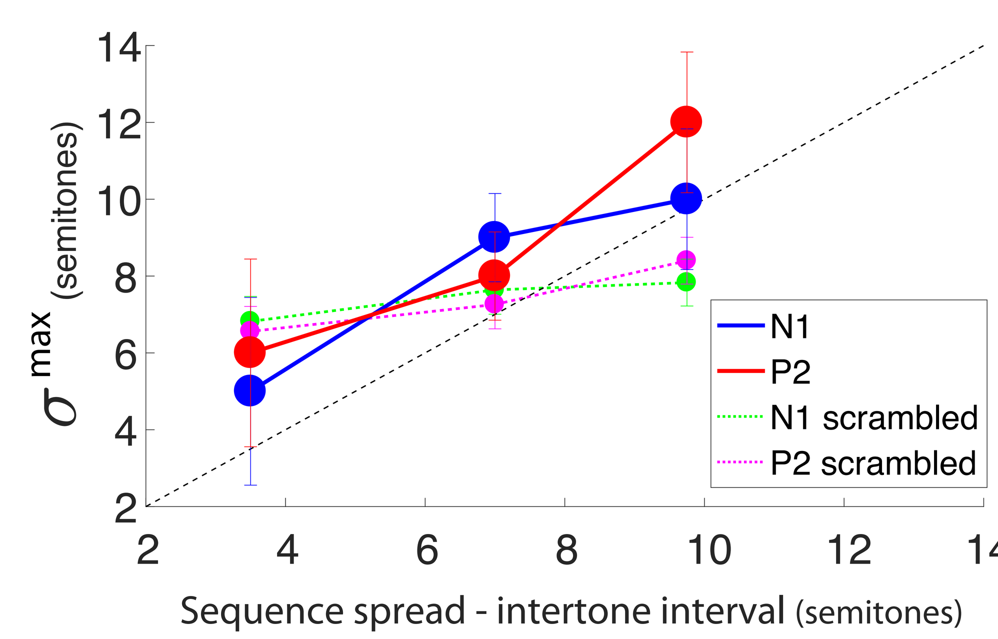




Tuning width depends on spectral context

- Estimating parameters for each frequency spread condition:



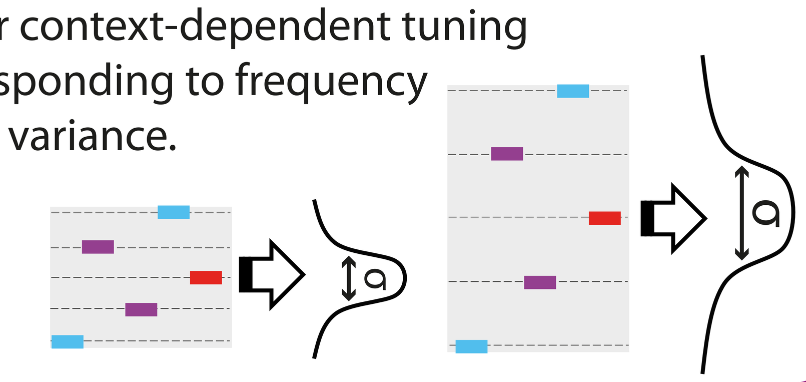


Conclusions

- N1 and P2 manifest mutiple timescale context sensitivity.
- This can be explained by adaptation of neruons with wide frequency tuning, and distinct recovery rates.

$$\tau_{N1} > \tau_{P2}$$

- Evidence for context-dependent tuning width corresponding to frequency distribution variance.



Ref: 1 - Regev et al. (2019). J Cog Neurosci, 31(5) 669-685. 2 - Herrmann et al. (2013). J Neurophysiol, 109, 2086-2096. 3 - Herrmann et al. (2014). J Neurosci, 34(1), 327-331. 4 - Taaseh et al. (2011) PloS One, 6(8), e23369.

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