Preferred auditory temporal processing regimes associated with audio-motor interactions

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Introduction

Neuronal oscillations might be one critical mechanism for temporal processing of natural sound, with preferred oscillatory regimes in the delta (0.5-4 Hz), theta (4-8 Hz), and low gamma ranges (25-80 Hz) in auditory cortex [1,2]. This should constrain auditory perception by facilitating auditory temporal processing at these timescales. Temporal predictions from motor cortex have been shown to facilitate auditory processing and are reflected in audio-motor coupling [3].

Hypothesis 1 | Auditory sensitivity for rate discrimination is optimal in the theta range (4-8 Hz) and decreases in the alpha range (8-12 Hz).

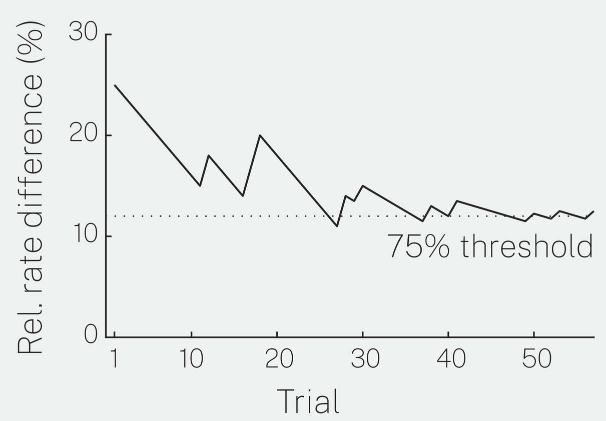
Hypothesis 2 | Interindividual differences in audio-motor speech synchronization behavior [4] modulate auditory temporal sensitivity.

Methods

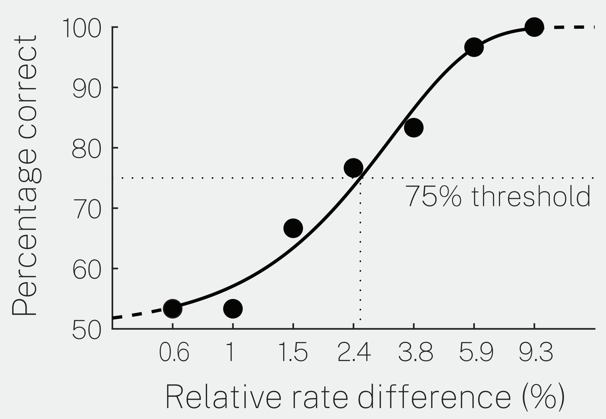
We measured relative difference thresholds for rate discrimination within a 4-15 Hz range using two psychophysical procedures (n = 55).

2-IFC rate discrimination task [5]

Weighted up-down (4-15 Hz) [6]

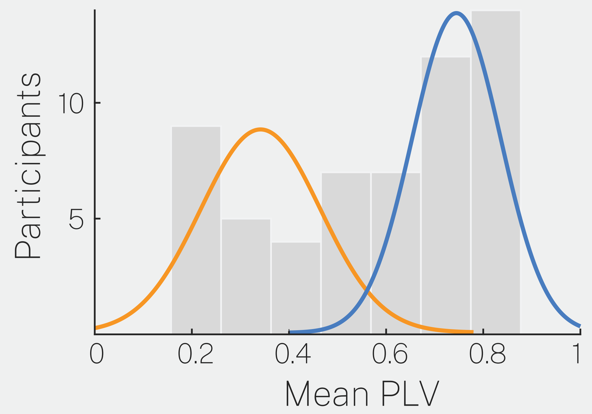


Constant stimuli (4, 11.86 Hz) [7]



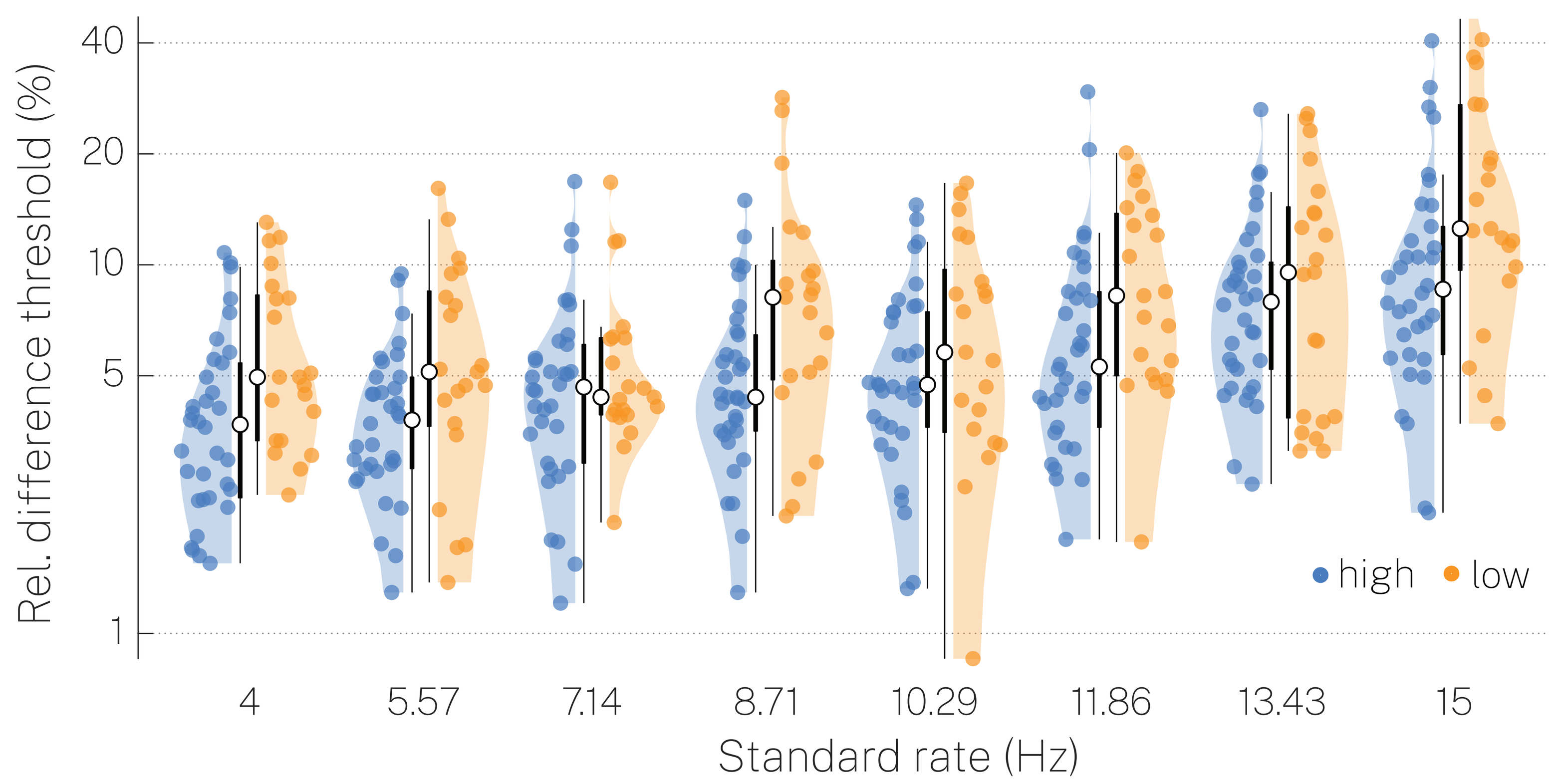
Interindividual differences in audio-motor synchronization behavior [4]

Speech synchronization test



Results

Weighted up-down method



Relative difference thresholds for rate discrimination measured at eight standard rates for high and low synchronizers. Colored dots: individual participants, white dot: median, thick line: quartiles, thin line: quartiles ± 1.5 × interquartile range.

Bayesian model comparison

Impact of stimulation rate and audio-motor synchronization behavior on rate discrimination thresholds (NUTS MCMC sampling in Stan)

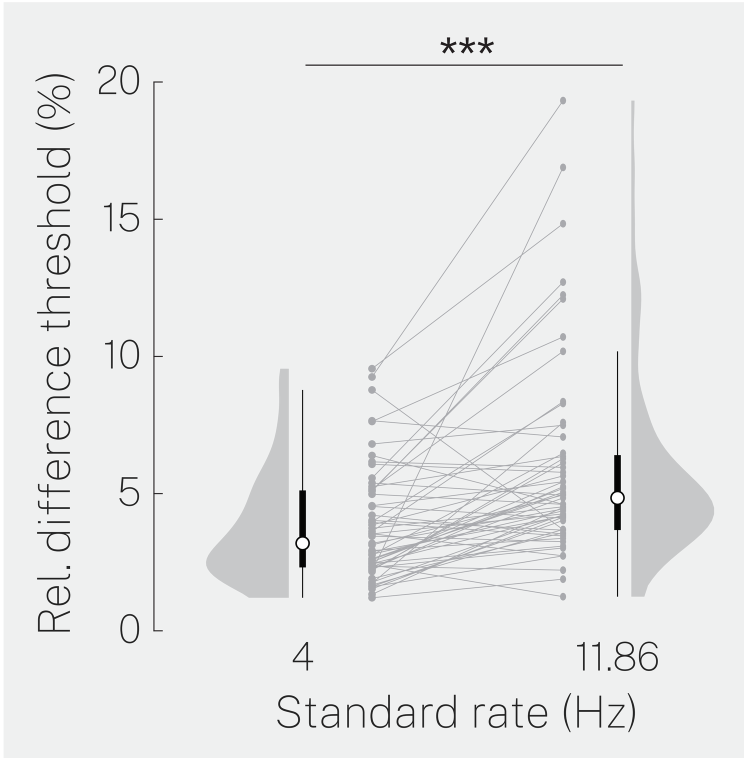
Model	1	2	3	4	5	6	7	8	**9**	10
Start point increase (Hz)			8.71	10.29	11.86	13.43	8.71	10.29	**11.86**	13.43
P(M|D) in %	≈0	≈0	≈0	0.01	6.16	0.002	0.001	1.82	**82.45**	9.55

The posterior probability of ten models given our data that included either a constant threshold (1), a difference between high & low synchronizers (2), a linear threshold increase at different starting points (3-6), or both (7-10).

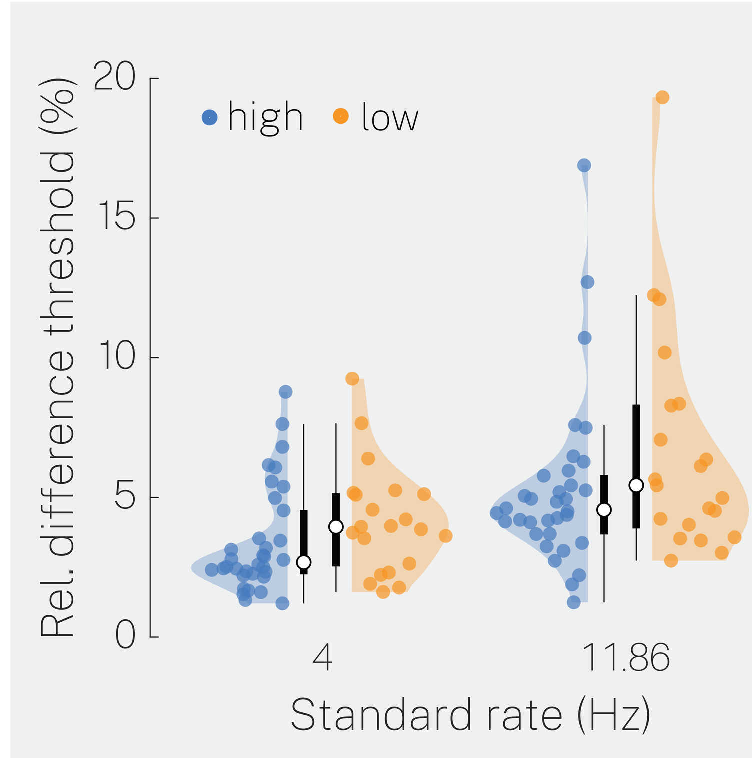
- Thresholds were constant from 4 to 10.29 Hz and increased from 11.86 Hz on (Bayes factor = 4.7).
- Lower thresholds in high compared to low synchronizers (BF = 9.45)
- Mean thresholds correlated with PLVs for audio-motor speech synchronization (r = -0.41, p = 0.002) even when controlled for musicality (Gold-MSI [8], r = -0.27, p = 0.049).

Constant stimuli method

All participants



High vs. low synchronizers



Relative difference thresholds estimated at two standard rates by fitting a Weibull function to individual data [9]. Colored dots: individual participants, white dot: median, thick line: quartiles, thin line: quartiles ± 1.5 × interquartile range.

- Thresholds correlated strongly between the weighted up-down and constant stimuli method (4 Hz: r = 0.68, 11.86 Hz: r = 0.5).
- Mean thresholds did not correlate significantly with PLVs for audio-motor speech synchronization (r = -0.25, p = 0.067).
- The difference in mean thresholds between high and low synchronizers did not reach statistical significance (p = 0.1)

Conclusions

Optimal auditory temporal sensitivity in the theta vs alpha range

We found a constant rate discrimination threshold in the theta range (4-10.29 Hz) that increased in the alpha range (11.86-15 Hz), in line with oscillatory theories of auditory processing [1,2].

Audio-motor interactions modulate auditory temporal sensitivity

Higher audio-motor synchronization behaviour was associated with lower rate discrimination thresholds across the whole range. This suggests that audio-motor coupling enhances auditory temporal processing through top-down motor predictions [3].

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References [1] Giraud & Poeppel (2012), Nat. Neurosci., [2] Giraud et al. (2007), Neuron, [3] Rimmele, Morillon, Poeppel & Arnal (2018), TiCS, [4] Assaneo et al. (2019), Nat. Neuroscience, [5] Drake & Botte (1993), Percept Psychophys, [6] Kaernbach (1991), Percept Psychophys, [7] Kingdom & Prins (2010), Elsevier, [8] Muellensiefen, Musil & Sterwart (2014), PLOS ONE, [9] Schuett, Harmeling, Macke & Wichmann (2016), Vision Research

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