Stimulus discriminability and predictiveness modulate alpha oscillations in a perceptually demanding memory task

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Introduction

- **Selective attention** to target speech in the presence of a distracting talker (masker) increases **listening effort** [1].
- Compensatory mechanisms: (1) Utilize **acoustic cues** to perceptually discriminate target and masker, (2) use **listening strategies**, such as the prediction of upcoming information [2].
- **Listeners of different age** vary in the way they make use of these cues [3, 4].
- Cortical **alpha (~10 Hz) oscillations** are a candidate neural signature of task demands during effortful listening, possibly reflecting the functional inhibition of task-irrelevant information [5, 6] like interfering maskers.
- **Aim of the study**: Understand the role of cortical alpha oscillations in a perceptiually demanding memory task in younger and older listeners.
  - Do Perceptual Discriminability and Stimulus Predictiveness lower listening effort similarly in younger and older listeners?
  - Is alpha power modulated by Discriminability and Predictiveness and does alpha power correlate with listening success?

Methods

- **Participants and stimuli**: 18 younger (20–30 y.) and 20 older (60–70 y.) participants listened to two spoken numbers (S1, S2) while ignoring a masking talker.
- **Task**: Retain S1 in memory and indicate whether S2 was smaller or larger.
- **Individual adjustments:** Frequency-specific adaptation of stimulus intensity to hearing acuity. Required target-to-masker ratio (TMR) for ~70 % accuracy was individually titrated (adaptive tracking, *Two-down one-up* procedure).
- **Perceptual Discriminability**: Spectral detail (temporal fine structure) was parametrically preserved from low frequencies (0–1.45 kHz). Higher levels of spectral detail were intended to improve perceptual discriminability of target and masker.
- **Predictiveness:** The larger the numerical distance between S1 and the center of all possible numbers ("60"), the better S1 was predictive of S2.
- **Data recording and analysis:** Electroencephalogram (EEG) recorded from 26 scalp electrodes against nose reference. Time-frequency analysis using wavelets (width: 7 cycles); multilevel cluster statistics using FieldTrip [7].

Experimental design

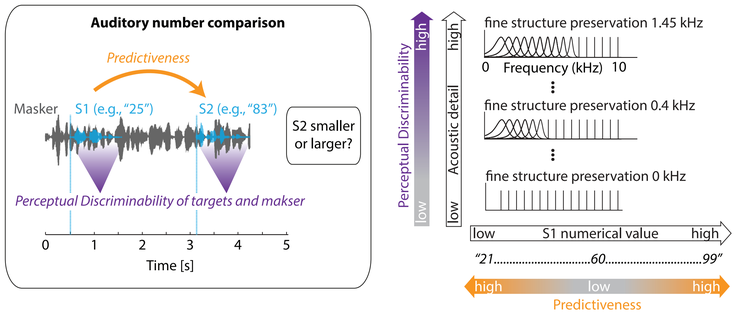

Figure 1. In the auditory number comparison task, Perceptual Discriminability of targets (S1 & S2) and masker was operationalised by the amount of preserved acoustic detail (temporal fine structure). S1 Predictiveness was operationalised by the numerical distance between S1 and the center of all possible numbers ("60").

Results

Performance improves with Perceptual Discriminability and Predictiveness

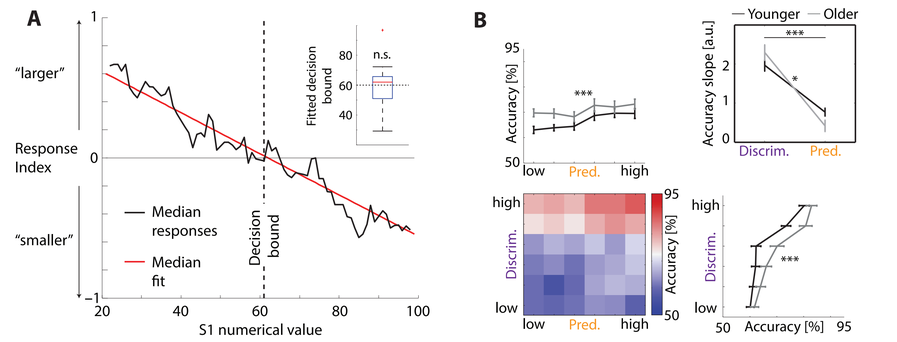

Figure 2. (A) Participants' responses dependend on S1 Predictiveness (i.e., numerical distance of S1 from the center of all possible numbers). (B) Performance improved with Perceptual Discriminability (relatively stronger for older listeners) and Predictiveness (relatively stronger for younger listeners). Accuracy was weighted by confidence ratings. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Overall alpha power is enhanced during the auditory number comparison task

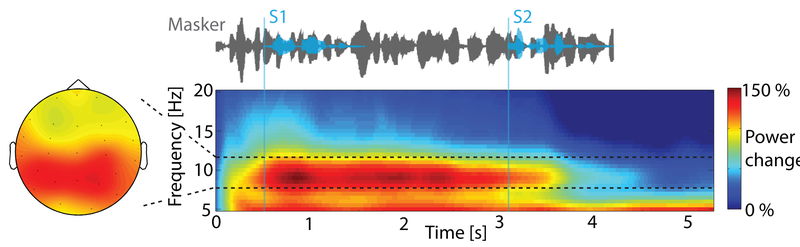

Figure 3. Across experimental conditions, alpha (7–12 Hz) power at parietal electrodes was prominently enhanced during the auditory number comparison task.

Alpha power decreases with Perceptual Discriminability and Predictiveness

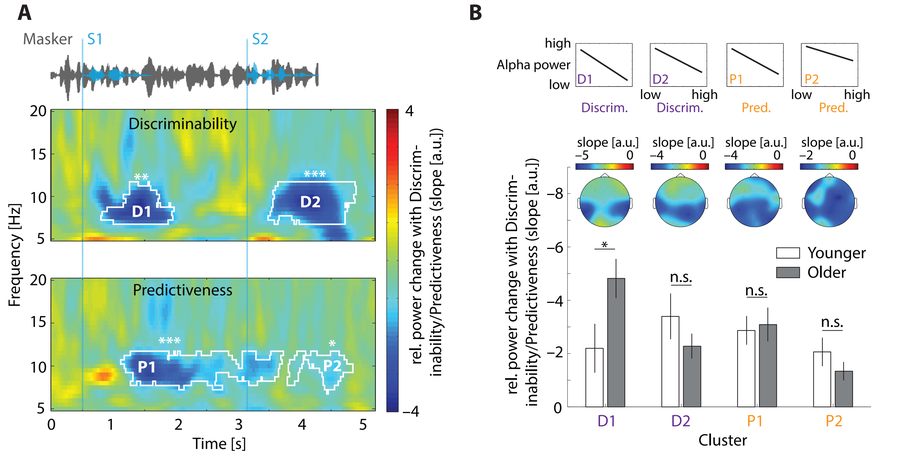

Figure 4. (A) Alpha power decreased with higher Perceptual Discriminability (Clusters D1 & D2) and higher Predictiveness (Clusters P1 & P2). (B) The alpha power decrease (slope) in Cluster D1 was stronger for older listeners. * $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$.

Lower alpha power is associated with enhanced performance

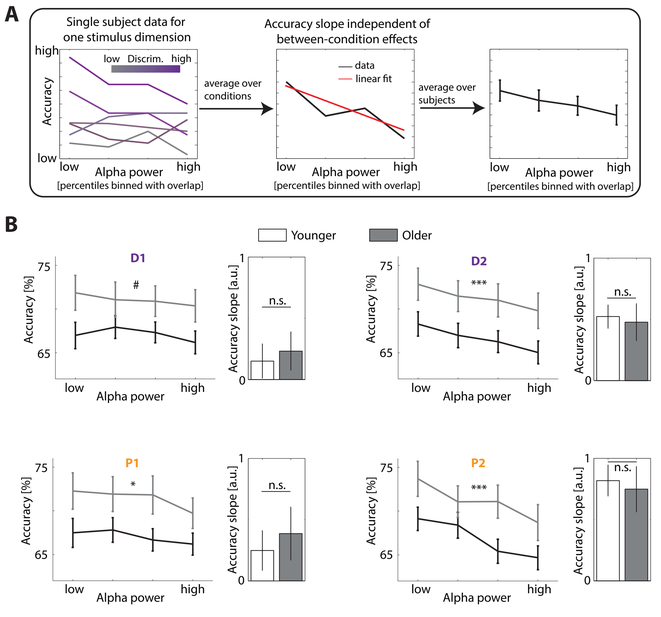

Figure 5. (A) Example analysis of binned alpha power for one representative subject. (B) In clusters of Discriminability (D1 & D2) and Predictiveness (P1 & P2), lower alpha activity was associated with higher accuracy in both age groups. # $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Discussion

- Improved performance and lower alpha power suggest reduced listening effort with higher Perceptual Discriminability and, to a smaller degree, with higher Predictiveness.
- Within levels of Discriminability and Predictiveness, lower alpha power was associated with higher accuracy, highlighting the impact of alpha power on listening success under demanding conditions.
- In older listeners, performance and alpha power depended stronger on Discriminability. This suggests that older listeners are especially driven by perceptual ("bottom-up") features during auditory perception [4].

Conclusion

Lower alpha power is a robust indicator of reduced listening effort with more acoustic detail and predictiveness of upcoming information in younger and older listeners. Lower alpha power might index the reduced need for inhibiting the processing of irrelevant information (e.g., the masker) if listening conditions become more favourable.

References

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