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Assessing the Role of Auditory Access in Infancy

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BACKGROUND & SIGNIFICANCE

- Even with the widespread adoption of newborn hearing screening and Early Hearing Detection and Intervention systems, infants who are hard-of-hearing (**IHH**) remain at increased risk for poor or delayed development of auditory and speech perception skills.
- The development of speech perception, including speech discrimination, depends partially on early exposure to and experience with highly salient and behaviorally relevant acoustic input.
- We have demonstrated that the speech evoked mismatch response (**MMR**) is modulated by the neural encoding of speech and may be useful in predicting later behavioral outcomes in infants.
- Speech perception is positively correlated with better auditory development on functional auditory skills and a variety of language outcomes.
- There is wide variability in discrimination outcomes that may affect the utility of **MMR** as a biomarker; for example, the absence of a response may not be an accurate indicator of discrimination but a reflection of the still developing neural generators for engaging in and completing the task.
- Perceptual attunement – or "narrowing" – is a model of perceptual learning positing that perceptual abilities are shaped by environmental experiences over the first year of life.
- Here we describe our adapted EEG methods to examine the development of infant speech perception to study periods of perceptual attunement between **IHH** and infants with normal hearing (**INH**).

OBJECTIVE

The objective of this study was to examine developmental changes in spectral-temporal features of the **MMR**, which may provide insight to neurophysiological processes underlying perceptual attunement in both **IHH** and **INH** populations. The data presented here represent preliminary results (N = 57) of an ongoing, longitudinal study of ~240 infants to be completed in 2028.

METHODS

Participants

Time 1: Age ≈ 3 Months

- N=35 (17 female, 3 IHH)
- Mean age = 3.26 months
- SD age = 0.37 months

Time 2: Age ≈ 6 Months

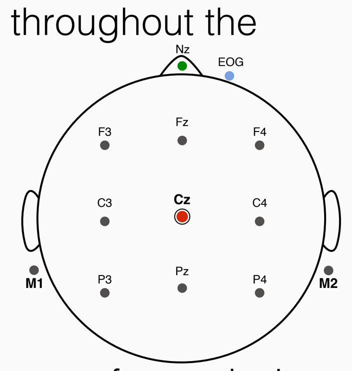
- N=22 (14 female, 4 IHH)
- Mean age = 6.36 months
- SD age = 0.54 months

Time 3 Age ≈ 12 Months

- *Data collection for Time 3 (in noise) is now in progress

Electroencephalography

- Continuous EEG was recorded during sleep throughout the session
- 11 electrode montage
- Nasion (Nz) reference during acquisition; average reference for analysis
- Ocular activity (EOG) was monitored for wakefulness & eye movement



Stimulus Parameters

- Vowel contrasts consisted of a **Native** contrast (/a/ vs /i/) and a **Nonnative** (Hindi) contrast (/ऐ/ vs /औ/). The Native contrast was presented during the Time 1 visit only.
- Consonant contrasts consisted of a **Native** contrast (/ba/ vs /da/) and a **Nonnative** (Hindi) contrast (/ट/ vs /त/).
- All stimuli had a duration of 400 ms and were equated for loudness.

Stimulus Presentation

- Each stimulus block used an alternating standard to deviant paradigm.
- Stimuli were presented at 70 dB SPL with a stimulus onset asynchrony (SOA) of 1,054 ms.
- Stimuli were presented as repeated **Standard** stimuli with a minimum of three repetitions and a maximum of 13 repetitions.
- After reaching the minimum repetition, the probability of switching to the **Deviant** stimulus was 65%, and the probability of switching to the alternate contrast was 15%.

EEG Analysis

- EEG Data were epoched around the onset of each target stimulus (see Figure 1); the number of **Standard** trials were randomly selected to match the number **Deviant** trials.
- The continuous wavelet transform (CWT) was used to compute inter-trial spectral-temporal coherence estimates for each condition (512 log-spaced Morlet wavelet scales).
- References contain links to detailed CWT methods.

SPECTRAL-TEMPORAL FEATURE IDENTIFICATION

To determine the spectral-temporal features for classifying discrimination responses, we first analyzed the grand averaged responses of all contrasts for both **Standard** and **Deviant** sequences separately for Time 1 and Time 2 (**Figure 1**). For those analyses, we included a wide window that spanned from -2.25 to 2.10 seconds around the onset of the target window. This large analysis window allowed us to verify response repetition and verify that changes in the response to a **Deviant** stimulus were not attributed artifact or other sources of variance.

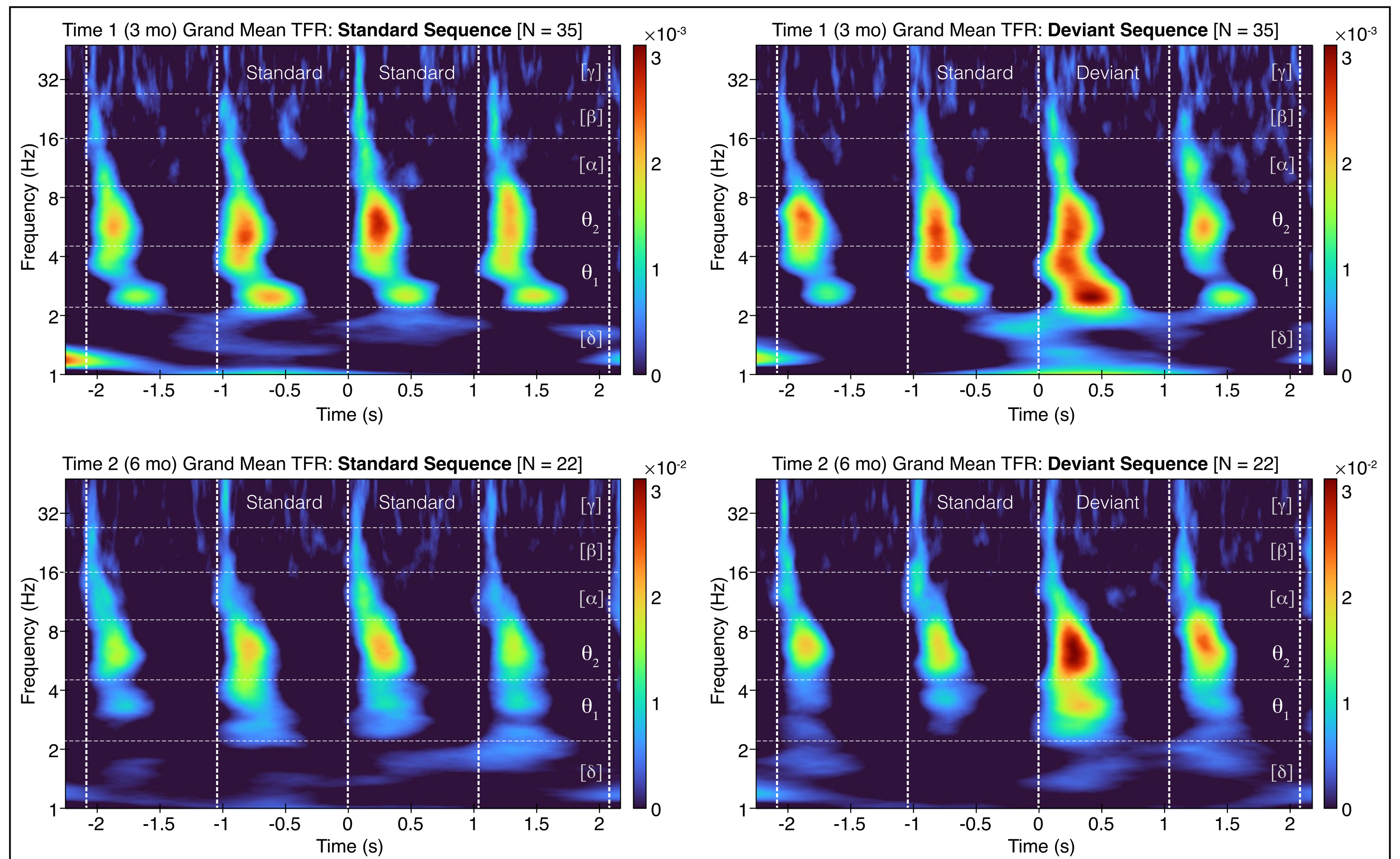


Figure 1. Grand mean spectral-temporal coherence estimates for Time 1 (top row) and Time 2 (bottom row). The "**Standard**" sequences (left panels) represent a series of repeated speech sounds. The "**Deviant**" sequences show a stimulus change at the target presentation time = 0 seconds.

In order to narrow the spectral and temporal regions of interest, we computed the temporal envelopes of the grand mean responses. We sought to determine the time range of increased magnitude when a **Deviant** response was present; that range was determined to be approximately 0 to 0.7 seconds from stimulus onset. Next, using only the time window in the target range, we computed the spectral envelopes for both **Standard** and **Deviant** responses in order to determine the spectral bands that contributed to a change detection (i.e., a discrimination response). We identified two different spectral bands with consistently larger magnitudes in the **Deviant** than in the **Standard** conditions: **Theta-1** (~2.2 - 4.4 Hz) and **Theta-2** (~4.8 - 9.8 Hz). While other activity at higher frequency bands (e.g., Beta and Gamma) was detected, we limited the remaining analyses to the two Theta bands with observable magnitude differences for a stimulus change.

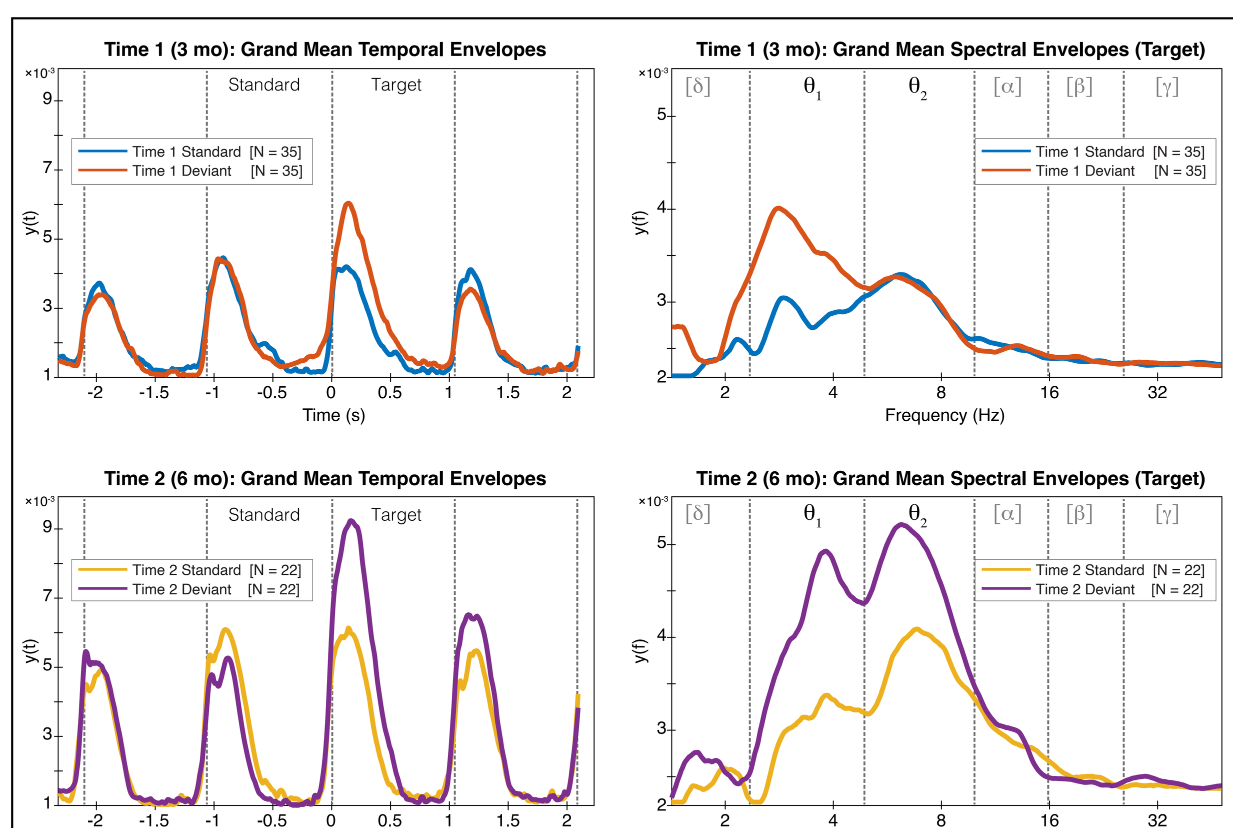


Figure 2. Grand mean spectral & temporal envelopes. These plots show the temporal envelopes (left panels) and spectral envelopes (right panels) extracted from the coherence responses shown in Figure 1 (above). The top row shows responses from Time 1 (3 mo) and the bottom row shows responses from Time 2 (6 mo). The "Target" regions represent the onset of a standard or deviant stimulus in each analyzed sequence.

THETA-BAND CONTRAST DIFFERENCES

To test whether magnitude differences were present for each of the four contrasts, we computed the mean spectral activations separately for the **Theta-1** and **Theta-2** bands at each of the two time points. For the **INH** groups, we tested the hypothesis that band activations to a **Deviant** stimulus were greater than activations to a **Standard** stimulus by performing a series of one-sided, paired t-tests. Activations with significant effects are noted in Figure 3a and 3c (left). We did not perform hypothesis testing in the IHH groups due to the small sample size.

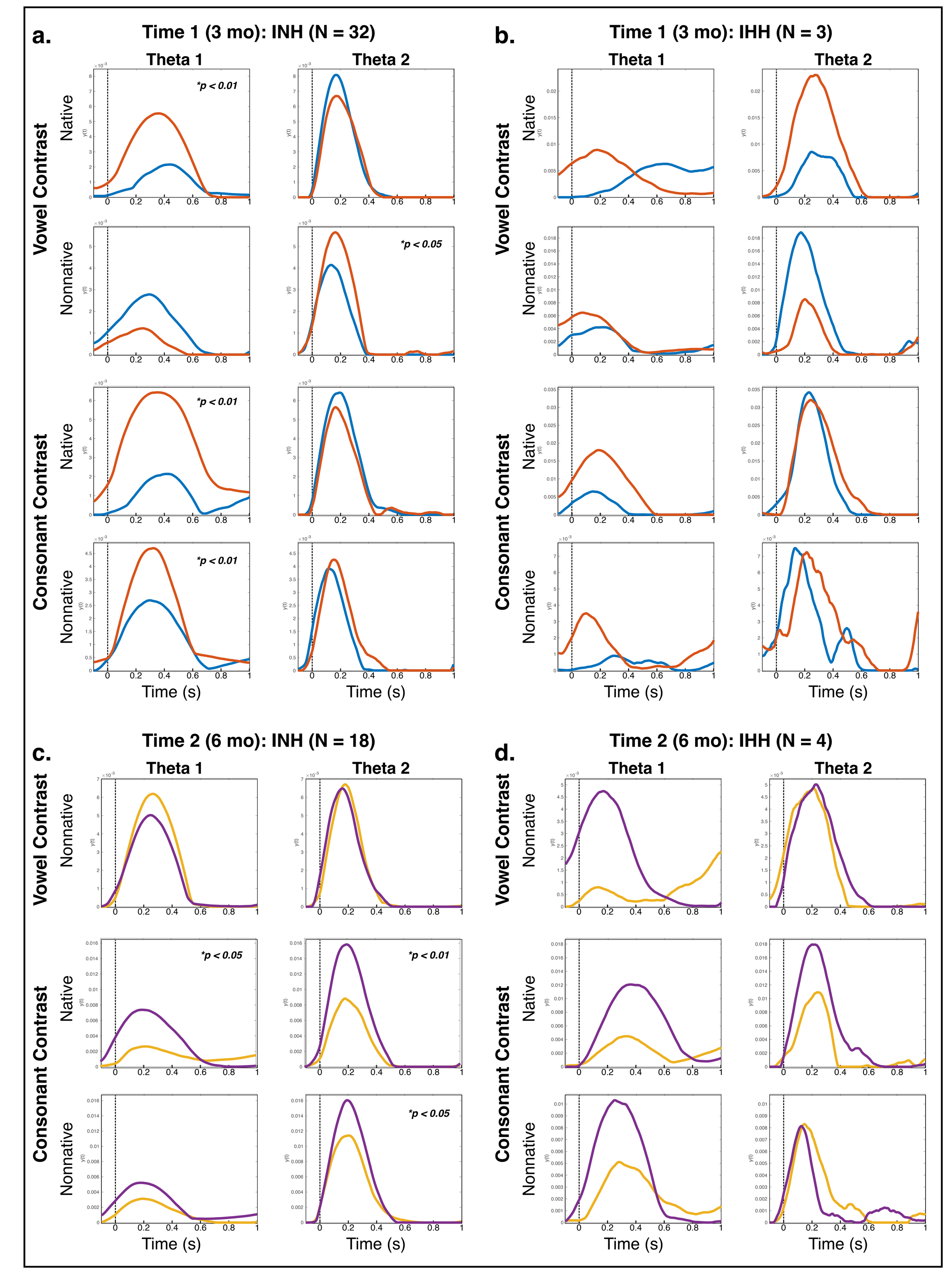


Figure 3. Theta-1 and Theta-2 activation envelopes for each contrast condition and hearing group. In each panel, responses are separated for the native and nonnative stimulus conditions and for the vowel and consonant contrasts within each stimulus condition. Each sub-panel shows the mean activation for the both **Standard** and **Deviant** responses. a.) Theta activations at Time 1 (3 mo) for the **INH** group (N = 32); b.) Theta activations at Time 1 (3 mo) for the **IHH** group (N = 3). For panels a & b (Time 1), the blue lines represent the **Standard** response and the red lines represent the **Deviant** response. c.) Theta activations at Time 2 for the **INH** group (N = 18); d.) Theta activations for the **IHH** group (N = 4). For panels c & d (Time 2), the gold lines represent the **Standard** response and the purple lines represent the **Deviant** response. Note that responses at Time 2 do not include the native vowel contrast.

DISCUSSION

- Neural encoding represented in the low-frequency Theta band corresponds with detection of a change in stimulus features; that is, responses reflect the discrimination of two speech sounds.
- We observed discrimination responses in two separate Theta ranges, **Theta-1** (~2.2 - 4.4 Hz) and **Theta-2** (~4.8 - 9.8 Hz), that differ with age.
- The lower frequency **Theta-1** response was dominant in the younger age group (3 mo), while the older age group (6 mo) showed both **Theta-1** and **Theta-2** discrimination responses.
- Oscillatory EEG of infants while listening to speech sounds can provide valuable information about the neural encoding of speech features important for language development.

ACKNOWLEDGMENTS & REFERENCES

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Scan QR code to obtain reference links and additional study information.