Neural Rhythm Tracking in Prematurely-Born Infants

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Background

Premature infants are at risk for language and social deficits[1]. Hearing becomes functional around 25 weeks gestation, starting a sensitive period for auditory development[2]. Premature infants in the NICU are exposed to sub-optimal stimuli that lack the patterned sensory experiences of the womb, potentially disrupting their auditory development

Rhythm Processing

Rhythm processing is crucial for language and social development; impaired rhythm processing is associated with developmental language disorders[3]

Neural rhythm tracking studies (EEG)

- Full-term infants already exhibit neural tracking to the beat and meter[4]
- Premature infants born (30-33 wGA) also track the beat and meter[5]

However, the impact of premature birth and NICU exposure on later neural rhythm tracking is unknown.

Social Attention

Infant-directed singing and speech provide rich facial and auditory cues, helping infants parse speech and promoting social bonding[6]

Eye-tracking studies

- During infant-directed singing, infants gaze more toward the caregivers' eyes at the times of strong beats of the song[6]

The gut microbiome

The gut-brain axis enables bidirectional communication between gut microbiota and the brain, with the microbiota and their by-products affecting cognitive functions[7]. Premature infants' gut microbiome composition differs at birth compared to full-term infants[8]

- Disruptions in the microbiome are associated with developmental disorders and cognitive impairment[7]
- A pilot study in our lab found correlations between specific microorganisms and metabolic pathways and both neural rhythm-tracking and social attention in full-term infants[9]

It is unknown how differences in the premature microbiome are related to cognitive challenges in premature infants.

Objectives: How do prematurity and the early microbiome mediate rhythm perception and social attention to language and music, and how do these associations relate to early language, cognitive, and social developmental outcomes?

Methods

Participant recruitment: McMaster Children's Hospital Maternity Ward and Level III NICU

- Early premature infants (born 26-29 wGA) (n=100)
- Late premature infants (born 30-33 wGA) (n=100)
- Full-term control infants (born 38-42 wGA) (n=100)

EEG collection and analysis

Age: 6 months/6 months corrected age

Stimulus: Listening task - 6-beat metrically ambiguous pattern (~15 min)

Analysis:

- Time-frequency analysis to determine how the infant's brain tracks the beat and meter
- Phase-amplitude coupling
- Brain-stimulus synchronization

Eye-tracking collection and analysis

Age: 4, 6, and 12 months/corrected age

Eye-tracking task: watching videos of adults engaging in infant-directed singing and speech (~15s each)

Analysis:

- Amount of time spent looking at the eyes and mouth
- Measure rhythmic alignment of gaze to the music and speech

Microbiome collection and analysis

Age: discharge from NICU, 2 months/corrected age

Analysis: Shallow shotgun analysis

- Diversity of taxa present
- Gene families
- Pathways related to microbiota metabolites

Questionnaires

Age: 2, 4, 6, and 12 months/corrected age

Parent-filled questionnaires

- Musical background
- Early development
- Microbiome environment

Bayley Scales of Infant and Toddler Development

At 18-24 months, all infants will complete the Bayley-4

Questions

1: Does prematurity negatively impact neural rhythm tracking, slowing language development?

Hypothesis:

- Auditory rhythm tracking and language outcomes will be worse in prematurely-born than full-term-born infants

2: Does prematurity reduce social attention to infant-directed singing and speech, and does rhythm processing mediate this developmental challenge?

- Prematurely-born infants with deficits in rhythm processing will show the least mature gaze tracking

3: How does the premature infant microbiome relate to early development?

- The microbiome of prematurely-born infants will show less diversity, and fewer beneficial microorganisms compared to full-term infants
- Beneficial microorganisms and pathways related to neurodevelopment will associate with better neural tracking of rhythms, social gaze tracking and developmental outcomes

Implications

- The study of premature infants is significant in elucidating the importance of rhythm processing in development
- Results may point to rhythmic interventions in the NICU to improve language, music and social development in this population

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