Development of neural mechanisms underlying joint attention during infancy using live-interaction electroencephalography (EEG)

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Background

Context

- Experience-dependent neural mechanisms support learning by forming synaptic connections in response to environmental input[1].
- In Canada, the child poverty rate was projected to rise by nearly 40% in 2022, with over half of these families experiencing financial stress[2,3].

Baseline EEG Trajectories

Mid-High SES Infants[4]
display

higher relative **alpha**
lower relative **theta**

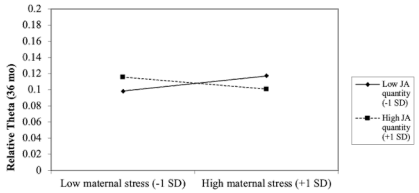
Low SES Infants[5]
display

lower relative **alpha**
higher relative **theta**

- When coupled with **low** power in the higher-frequency bands, **high** theta power has been linked to ADHD, and poorer top-down control[6].

How might parental stress influence infant neural development?

- **Joint attention (JA):** engagement in shared attention between an infant and their caregiver over a common object or event[7].
  Engaging in JA enables children to gain important linguistic and social cues to scaffold their socioemotional development.
- Variations in the **3–5 Hz (theta)** and **6–9 Hz (alpha)** frequency ranges in infants have been previously associated with **neural activation during JA interactions**[8].
- By exploring 5 dimensions of JA[9], we can test how stress might influence different facets of early caregiver-child interactions, such as:
  - Duration / Frequency
  - Initiation: Mother directs, Mother follows, Infant initiates
  - Termination: Mother vs infant terminated
  - Coordinated vs Passive
- Previous work supports **maternal education** (b=-.011; p=.012) and **JA quality** (b=.004, p=.042) as significant predictors of **theta at 24 months**.
- **JA quantity** moderated the relationship between **stress** and **theta at 36 months** after adjusting for SES covariates (B = -.008, p = .027)[10].



Purpose

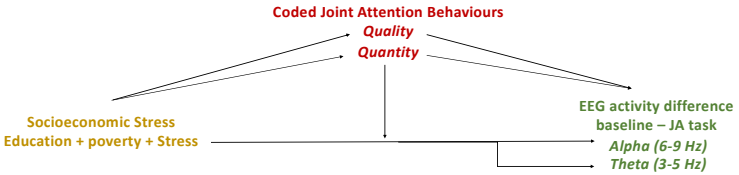
Using a live-interaction EEG task, we aim to a) examine neurodevelopmental processes underlying the development of joint attention in a socio-demographically diverse sample, b) test whether early life stress is associated with patterns of early neurodevelopment, and c) explore the mediating and moderating role of joint attention in these associations.

This study seeks to understand how stress influences infant brain development via research protocols which serve families from diverse backgrounds. The goal is to expose the misunderstood variabilities present across affluent and nonaffluent communities.

References

PIERCE EXPERIENCE & DEVELOPMENT LAB
pierce-lab.com

Proposed Models



Pilot Data

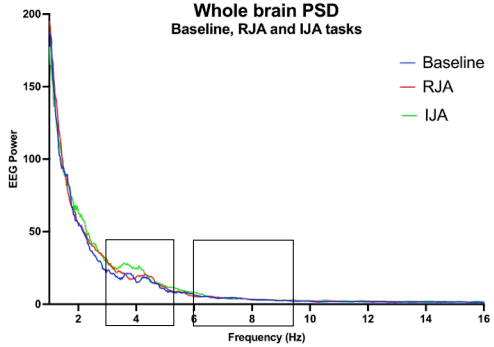


Figure 1. Power spectral density (PSD) plotted for each task and averaged across participants (n = 3). Frequency bands of interest include theta (3 - 5 Hz) and alpha (6 - 9 Hz).

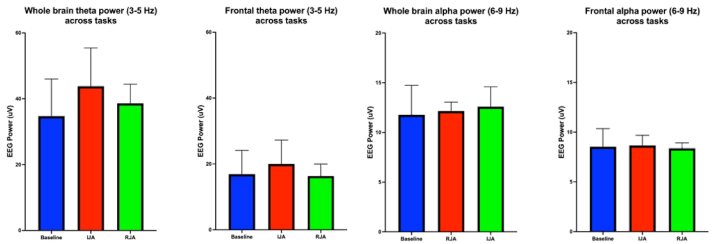


Figure 2. Average power across pilot participants (n = 3) in frequency bands of interest plotted for each condition: a) whole brain theta (3 - 5 Hz), b) frontal theta (3 -5 Hz; ROI: F3, Fz, F4) c) whole brain alpha (6 - 9 Hz), d) frontal alpha (6 – 9 Hz; ROI: F3, Fz, F4).

- EEG power is extracted from the first 20 seconds of the baseline and JA tasks. Inferential statistics have not been performed on this small pilot sample.
- Visually, expected differences are apparent in the theta band (3-5 Hz) across 3 pilot participants. 6-month-old infants displayed higher theta during JA (RJA and IJA) compared to baseline.
- Visually, no differences were evident in the alpha band (6-9 Hz).
  - Observable differences in alpha activity may arise at later time points.

Participants

- 6-month-old infants and their mothers
- Lab visits at 6, 10, 12 and 24 months
- Recruited in Toronto from neighbourhoods varying in socioeconomic status (SES)

Measures & Procedure

At every timepoint we collect

1. Mother's SES + stress (SE-stress) and demographic information
2. Infant-Mother free-play coded for 5 JA dimensions
3. Infant baseline EEG
4. Infant EEG during JA book-reading task[11] with mother

10-minute free-play sessions are audio and video recorded while mom and infant **"play as they normally would at home"** using a set of age-appropriate toys.

Infant EEG activity will be recorded during a 2-part structured book reading task[11]. First, **responding to JA (RJA)** is assessed while mothers go through a booklet of emotional pictures while seated in front of their infant. Then, mothers are instructed to look at the wall while a puppet is shown behind them to measure activity while infants **initiate JA (IJA)**. The task is video recorded to capture eye gazes from mother and infant.

Infant resting EEG activity is recorded during a 3-minute baseline task where infants watch a video of moving toys while sitting on their mother's lap.

Predictions & Proposed Analyses

H1: Infants will display **higher theta** and **lower alpha activity** during JA compared to baseline.

- A t-test will assess differences between infant alpha and theta activity during the JA task compared to baseline.
- Alpha and theta power during the JA tasks will be subtracted from alpha and theta power during baseline.

H2: **High SE-stress** will be associated with a **smaller difference in theta and low alpha** during JA compared to baseline.

- Hierarchical linear regressions will test associations between SE-stress and infant EEG differential scores.

H3: **JA quantity and/or JA quality** mediate associations between **SE-stress** and the **difference in theta and alpha during JA compared to baseline.**

- Mediation analyses will test whether coded JA behaviours mediate the significant associations reported between SE-stress and infant EEG differential scores

H4: **JA quantity and/or JA quality** will moderate associations between **SE-stress** and the **difference in theta and alpha during JA compared to baseline.**

- Moderation analyses will test whether coded JA behaviours buffer the association between SE-stress and infant EEG differential scores.

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