An investigation of rhythm and meter perception in infancy using electroencephalography

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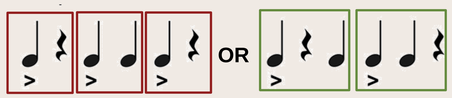
Background

Mismatch Response (MMR):

- An event-related component occurring in infants at ~150 to 250 ms post-stimulus onset in responses to occasional deviants in a stream of auditory stimuli.
- Typically appears as a positive MMR in young infants or in older infants to complex or small deviants. An adult-like mismatch negativity appears around 4-6 months[1].
- Can be modulated by top-down (i.e. internally derived) processes. For example, perceived meter can lead to larger MMN magnitude for metrically strong beats[2-3].



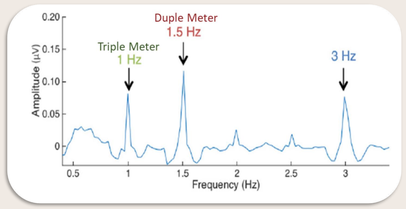


Fig. 1 (Top) Example of the 6-beat stimulus grouped as either duple (red) or triple (green) meter. **(bottom; adapted from [4])** Infant SSRs in response to an *ambiguous* 6-beat rhythm

Steady-State Responses (SSRs):

- Adults that imagined an ambiguous 6-beat auditory rhythm as either three groups of 2 beats (duple meter) or as two groups of 3 beats (triple meter; Fig. 1), show steady-state responses (SSRs; measured with electroencephalography (EEG)), with energy peaks at frequencies corresponding to their metrical interpretation[4].
- 7-month-olds presented with the same 6-beat rhythm show energy peaks at all three frequencies: beat (3 Hz), duple (1.5 Hz) and triple (1 Hz) meter frequencies[5].

Methods

Participants: *N* = 24 infants (M age = 6.56 months), two groups: one primed with duple meter (*n* = 13) and one primed with triple meter (*n* = 11).

Procedure: Infants listened to a repeating rhythmic stimulus (Fig 2-3) while EEG was recorded. A visual cue with circles expanding and shrinking on each beat one was used to capture infant attention. Parents also completed a language & music background questionnaire.

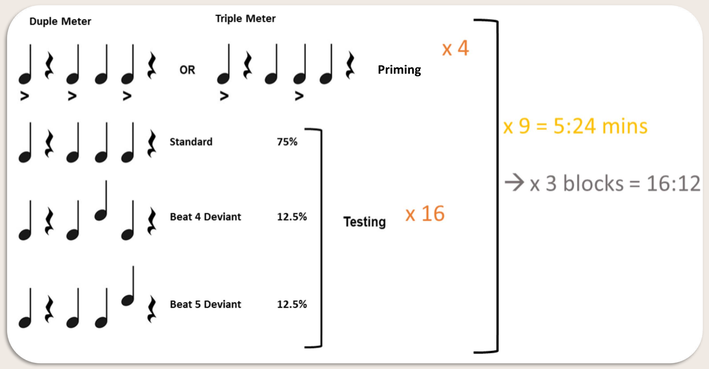


Fig. 2. Stimulus order. Testing trials were the same between groups. Deviants were quarter-tone pitch increases. Each block varied in either pitch (Piano A4, C#4, or E4), or timbre (piano, guitar or vibraphone A4) every 20-trials.Only unaccented trials were used for subsequent ERP and SSR analyses.

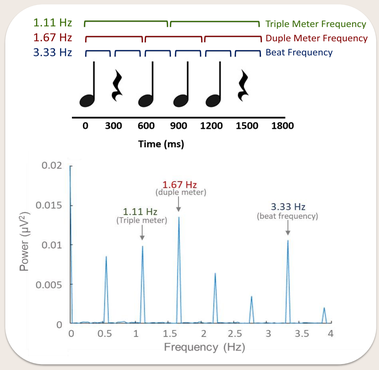


Fig.3. Stimulus timing (top) and envelope (bottom)

Predictions

If 6-month-olds can be primed to hear an ambiguous rhythm with one metrical structure over another, and maintain it by means of top-down processes, then:

1. **MMR should be present, and larger for perceptually strong vs weak beats.**
2. **SSR power (μV2) should be highest at the primed frequency**

Results & Conclusions

Event-Related Potentials (ERPs)

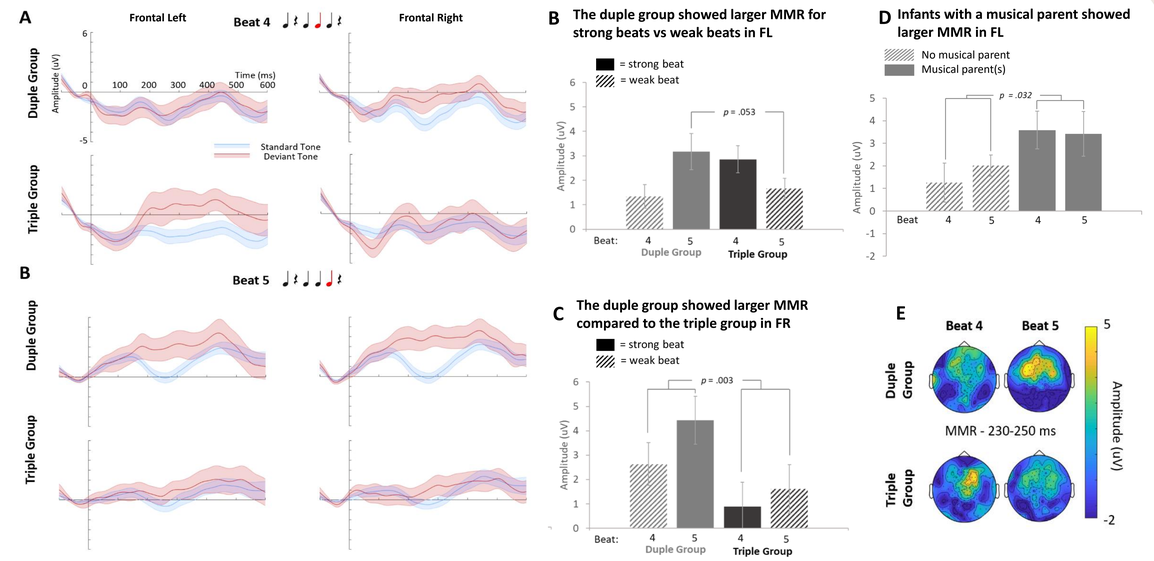


Fig. 4. A) Infant ERPs. Significant MMR found at 200-325 ms. **B)** Beat position x group interaction for the MMR (deviant - standard difference). **C)** Main effect of priming group in frontal right (FR) sites for the MMR. **D)** Main effect of having at least one parent that plays an instrument on FL MMR responses (collapsed across priming group). **E)** MMR topography. Note: All shaded regions and error bars are the standard error of the mean.

- ✓ We found clear positive MMR at ~250 ms, that was larger for the strong beat vs the weak beat in the duple group in FL **– evidence for a top-down internalization of meter that is lateralized to left hemisphere.**
- ✘ No significant priming effect for the triple group, but MMR was also larger in the duple group in FR. – perhaps reflects Western enculturation to duple meter, allowing for a processing advantage in the duple group.
- ✓ Infants with at least one musical parent showed larger MMR compared to those without a musical parent – could reflect some epigenetic effect of music for processing rhythms, but we did not control for other external factors.

SSRs

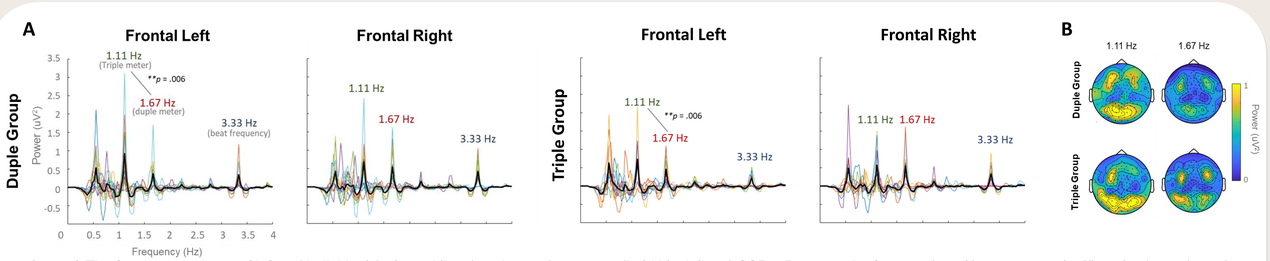


Fig. 5 A) The frequency spectra of infants' individual (coloured lines) and group's average (bold black lines) SSRs. Power at the frequencies of interest was significantly above the noise floor, and power at the triple frequency (1.111 Hz) was significantly greater than the duple frequency (1.667 Hz; *p* = .006) in the frontal left sites. **B)** Topographies for the triple (left column) and duple (right column) frequencies.

- ✓ We found clear SSR peaks at expected frequencies.
- ✘ Unexpectedly, power at the triple frequency was greater than other frequencies of interest overall – perhaps our priming wasn't strong enough to induce a sustained metrical interpretation via attention[6], and the triple meter frequency might be more interesting.

Next steps: Time-frequency analyses to compare duple to triple meter representation, & add a behavioural measure.

References

[1] Trainor, L., Mcfadden, M., Hodgson, L., Darragh, L., Barlow, J., Matsos, L., & Sonnadara, R. (2003). Changes in auditory cortex and the development of mismatch negativity between 2 and 6 months of age, 51(03), 5–15.
[2] Bouwer, F. L., Van Zuijen, T. L., & Honing, H. (2014). Beat processing is pre-attentive for metrically simple rhythms with clear accents: An ERP study. PLoS ONE, 9(5), 1–9.
[3] Winkler, I., Haden, G. P., Ladinig, O., Sziller, I., & Honing, H. (2009). Newborn infants detect the beat in music. Proceedings of the National Academy of Sciences, 106(7), 2468–2471.
[4] Nozaradan, S., Peretz, I., & Missal, M. (2011). Tagging the Neuronal Entrainment to Beat and Meter, 31(28), 10234–10240.
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[6] Celma-Miralles, A., & Toro, J. M. (2019). Ternary meter from spatial sounds: Differences in neural entrainment between musicians and non-musicians. Brain and Cognition, 136(August), 103594.