

Early prosodic boundary perception: Innate biases in preterm newborns

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For infants acquiring language, segmenting continuous speech into meaningful linguistic units is an important step. Before acquiring vocabulary and grammar, they must rely on non-lexical cues, such as the prosodic structure of speech, to identify word and phrase boundaries. Major speech units, e.g., Intonational Phrases (IPs), are generally marked by three types of prosodic cues: pitch change, pre-boundary syllable lengthening, and pauses [1]. Although infants are sensitive to prosodic boundaries from an early age [2,3], the mechanisms underlying this sensitivity remain unclear. We hypothesised that infants' earliest processing of prosodic boundaries is driven by innate perceptual biases, defined as physiologically-motivated or cross-species perceptual mechanisms, in the form of the Respiratory Code (RC) and the Iambic-Trochaic-Law (ITL) [4]. The RC links respiratory physiology to prosodic structure, associating high pitch with phrase beginnings and low pitch with phrase endings, with inhalation-related pauses typically occurring between phrases [5]. The ITL predicts that listeners universally tend to perceive lengthened or low-pitched elements as phrase-final [6, 7], a pattern observed in non-human species, suggesting an evolutionary origin [8]. Together, these principles provide innate biases for perceiving pitch changes, duration and pauses as potential cues for prosodic boundaries, underlying infants' early sensitivity to prosodic structure [4]. Therefore, we predicted that preterm newborns can process IP boundaries based on these biases, using the individual cues, despite their minimal linguistic exposure since the onset of fetal hearing.

To test this prediction, we examined the processing of IP boundaries in preterm newborns, born to Dutch-speaking parents between 28 and 34 weeks of gestation. Within the first week after birth, 40 preterm newborns listened to short coordinated name sequences in Dutch adult-directed speech, containing or lacking an utterance-medial IP boundary ([*Moni and Lilli and Manu*] vs. [*Moni and Lilli*] [*and Manu*]). The stimuli were presented to each infant in six conditions: a no-boundary baseline; an all-cues condition combining phrase-final pitch rise, final lengthening, and a pause; and four single-cue conditions in which the boundary was marked by a pitch fall, a pitch rise, final lengthening, or a pause alone (see Figure 1). Using EEG, we measured the neurophysiological response to boundary processing, the Closure Positive Shift (CPS), in each condition versus the no-boundary baseline.

Linear mixed effects modelling showed a significant positive difference in ERP amplitude in the right-frontotemporal region for the pause-only condition, relative to the no-boundary condition ($\beta = 1.85$, $SE = 0.52$, $t = 3.58$, $p = 0.002$). This amplitude difference was manifested as a CPS, emerging approximately 600 ms after preboundary syllable onset (see Figure 2). This finding suggests preterm newborns initially process major prosodic boundaries based solely on pauses, partially supporting our hypothesis. However, no significant effects were observed in any region for the remaining boundary conditions, including the all-cues condition, which also featured a pause. The absence of an effect in the all-cues condition may be the result of conflicting information provided by the phrase-final pitch rise. This high final pitch contrasts with the low phrase-final pitch described by both the RC and the ITL, potentially overriding or weakening the boundary cue provided by the pause, and consequently preventing boundary perception.

Overall, our results suggest that preterm newborns use pauses as robust indicators of major prosodic boundaries, consistent with an innate bias as captured by the RC. This experience-independent sensitivity may also be present in fetuses at a comparable gestational age, providing a prenatal mechanism for early speech segmentation. Future research could test whether stronger final lengthening and pitch fall, exceeding those typically used in Dutch adult-directed speech, may be required to elicit neural responses to boundary perception in preterm newborns, thereby further clarifying the role of innate biases related to these cues.

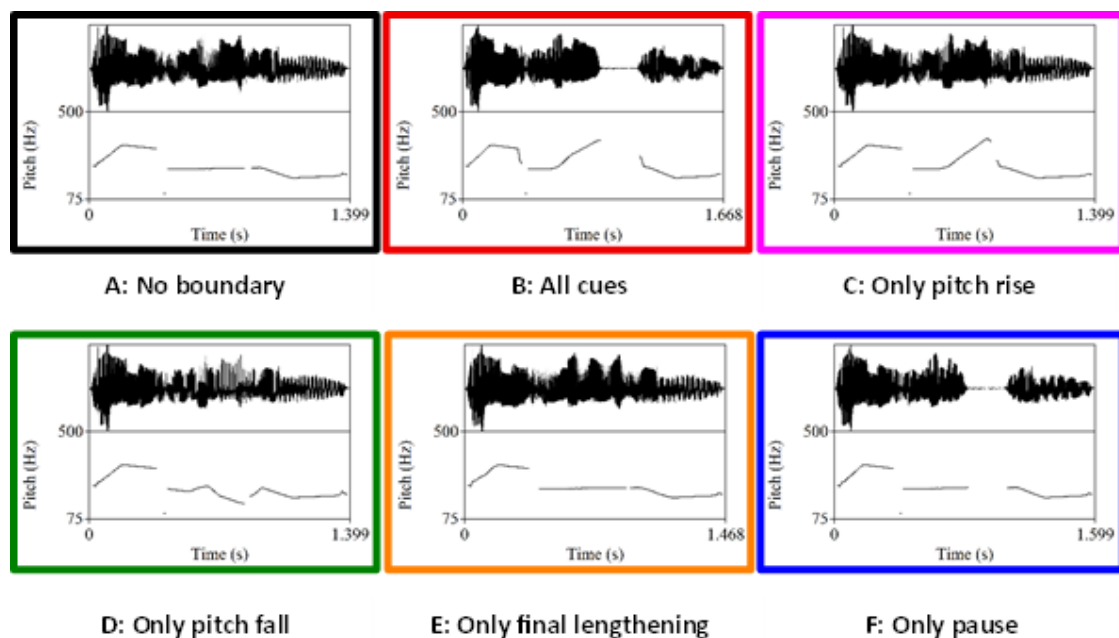


Figure 1. Example waveforms and pitch contours for the coordinated name sequence across stimulus conditions

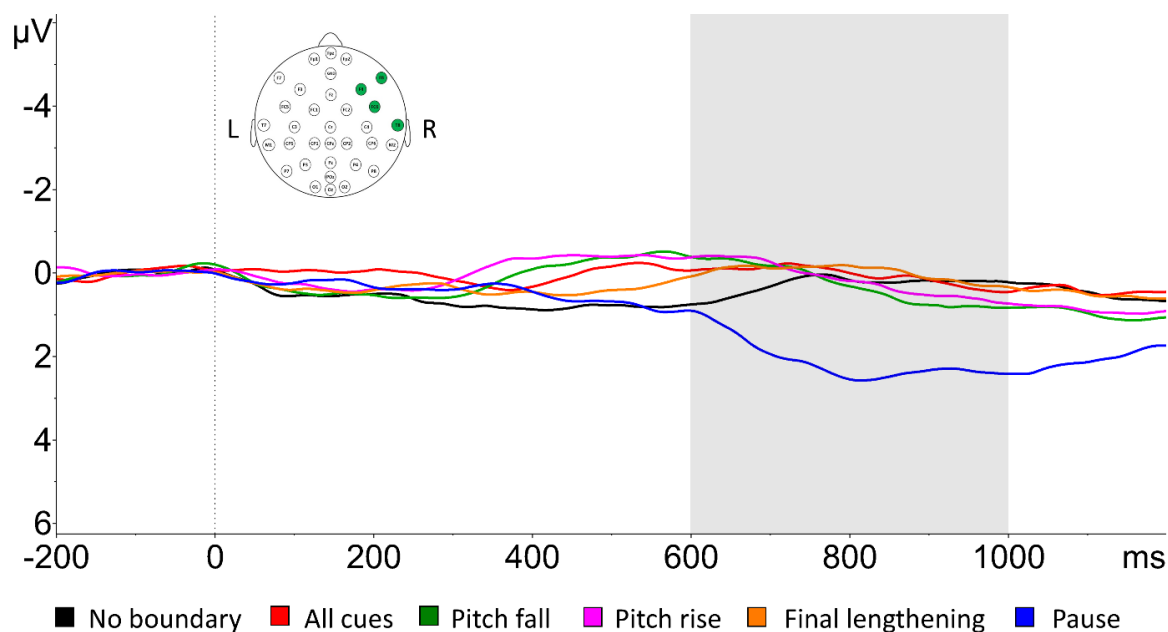


Figure 2. ERP waveforms for frontotemporal electrodes on the right hemisphere, timelocked to the onset of the preboundary syllable. Typically, CPS is a positive (downward-facing) deflection observed on frontal electrodes between 500-800ms after detecting a prosodic boundary. This response may be delayed in preterm newborns due to incomplete myelination of the brain (e.g. 600-1000ms, indicated by the grey area).

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