Form-function relationship in the amplitude and frequency modulations of infant-directed speech: A predictive processing perspective

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Introduction

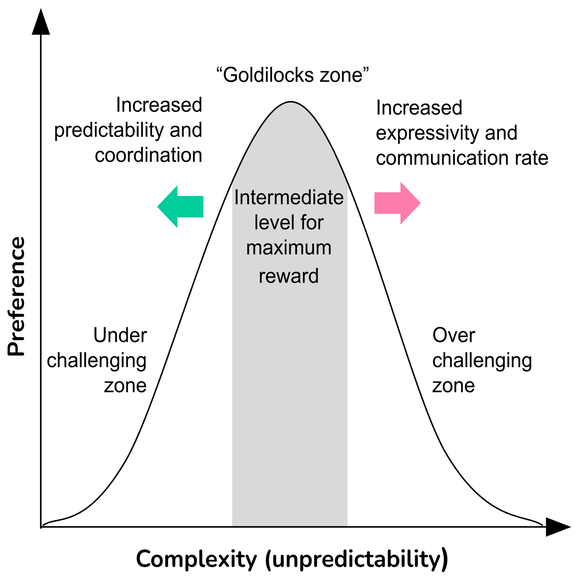
Infants prefer infant-directed speech (IDS) over adult-directed speech (ADS)[1]. IDS is thought to serve specific functions compared to ADS :

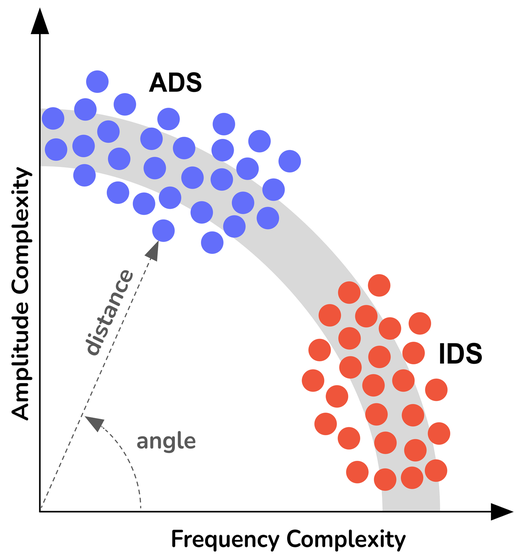
- Attracting infant attention to the speech signal[2]
- Conveying clear opportunities for easier word segmentation[3].

Infants are powerful predictive agents[4], orienting their attention towards stimuli that maximise learning potential[5,6].
Two independent domains of complexity that are embedded in the speech stream :

1. Amplitude complexity. Lower amplitude complexity associates with greater ease in identifying word boundaries[7,8].
2. Frequency complexity. Higher frequency complexity associates with more attention eliciting speech attention by inducing uncertainty[9,10].

Overall complexity is U-shaped : trade-off between amplitude complexity and frequency complexity. This trade-off is shaped by the opposing roles of IDS : securing temporal alignment by reducing temporal complexity and attracting attention by introducing novelty.





Hypothesis

- Different functions : IDS and ADS should be clustered apart on the frequency-envelope-complexity plane.
- Amplitude complexity of IDS envelope would be lower in order to facilitate word segmentation.
- Frequency complexity of IDS envelope would be higher in order to elicit attention.
- Overall complexity (distance) should be the same for IDS and ADS.
- Strategies (angle) should be different.

Procedure

Caregiver vocalisations were extracted from naturalistic and semi-naturalistic interactions using a voice type classifier and then manually classified as infant- or adult-directed depending on the context.

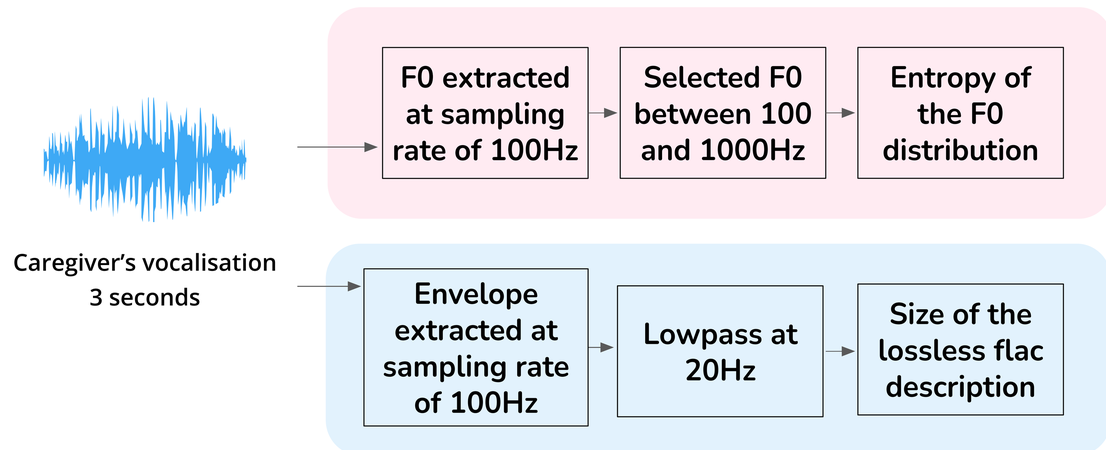
- ADS vocalisations were mainly extracted from the naturalistic interaction, where caregiver and researchers were casually talking while in the presence of the infant in the room.
- IDS were extracted both from the naturalistic interaction and the semi-naturalistic interactions where caregiver and infant sat at either side of a table and asked to play with a set of toys for 6 minutes.

Analysis

Each caregiver vocalisation over 3s was cut into 3s chunks.

1. Pitch was extracted between 100 and 1000Hz using a Python implementation of Praat.
   Entropy was computed from the F0 distribution with 1Hz bins, where high entropy indicates unpredictability.
2. Envelope predictability was assessed using the size of the envelope after lossless compression. Lossless compression algorithms can represents the amplitude envelope in a condensed description. The short the description, the less complex the envelope[11].

Frequency and envelope unpredictability were scored using min-max normalisation to obtain values between 0 and 1.



Results

- IDS and ADS are clustered apart in the frequency-envelope-predictability plane ($t_{(327)} = -4.25$, $p < 0.001$)
- IDS envelopes are more complex than in ADS ($t_{(327)} = -4.10$, $p < 0.001$)
- IDS frequencies are less complex than in ADS ($t_{(327)} = 8.44$, $p < 0.001$) }Fig A
- Similar overall complexity (distance) from IDS and ADS.
- Different strategies (angle) from IDS and ADS ($t_{(327)} = 8.60$, $p < 0.001$) }Fig B

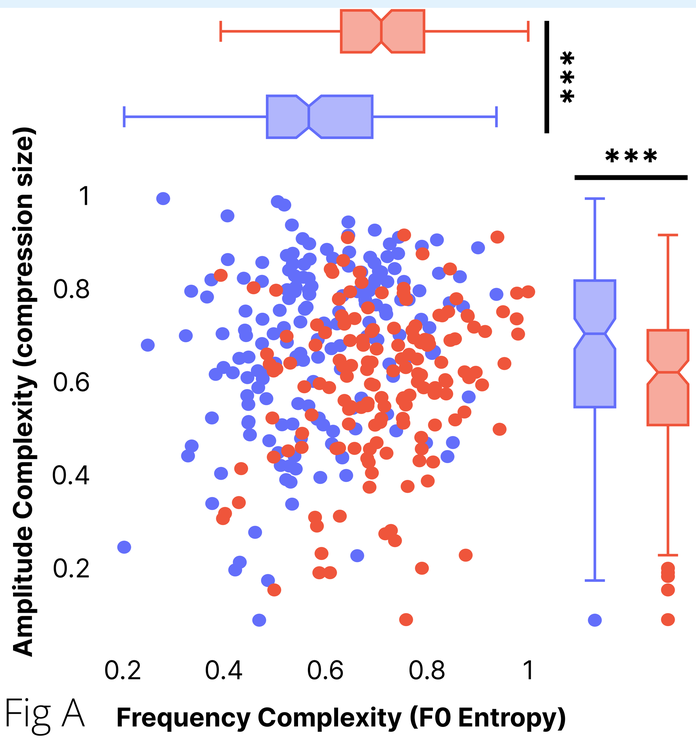


Fig A

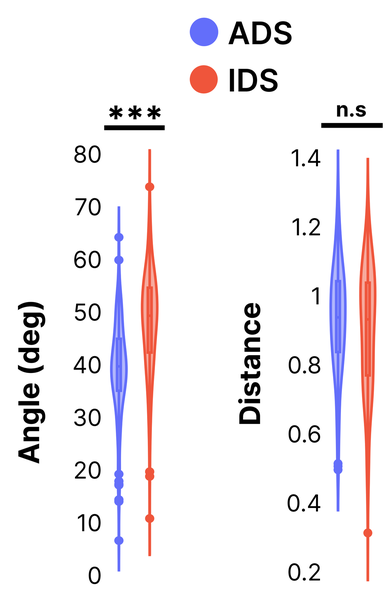


Fig B

Conclusion

- Evidence for form/function adaptation of two different co-occurring features of IDS compared to ADS.
- The complexity trade-off between the two features is the result of the multiple and opposing roles of IDS.

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