Infant-directed speech is consistent with teaching

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Abstract.
Infant-directed speech (IDS) has distinctive properties that differ from adult-directed speech (ADS). Why it has these properties -- and whether they are intended to facilitate language learning -- is matter of contention. We argue that much of this disagreement stems from a lack of a formal, guiding theory of how phonetic categories should best be taught to infant-like learners. In the absence of such a theory, researchers have relied on intuitions about learning to guide the argument. We use a formal theory of teaching, validated through experiments in other domains, as the basis for a detailed analysis of whether IDS is well-designed for teaching phonetic categories. Using the formal theory of teaching, we generate ideal data for teaching phonetic categories in English. We qualitatively compare the simulated teaching data with human IDS, finding that the teaching data exhibit many features of IDS, including those that have been taken as evidence IDS is not for teaching. The simulated data reveal potential pitfalls for experimentalists exploring the role of IDS in language learning. Focusing on different formants and phoneme sets leads to different conclusions, and the benefit of the teaching data to learners is not apparent until a sufficient number of examples have been provided. Finally, we investigate transfer of IDS to learning ADS. The teaching data improves classification of ADS data, but only for the learner they were generated to teach (the naive, infant-like learner) and not universally across all classes of learner. This research offers a theoretically-grounded framework which empowers experimentalists to systematically evaluate whether IDS is for teaching.

The problem.
Researchers disagree whether IDS is for teaching, mostly because no formal theory of teaching has been used to characterize teaching behavior. In the absence of such a theory, researchers have substituted intuitions about learning (see Kuhl et al, 1997; McMurray et al, 2013; Cristia & Seidl, 2014).

Our approach.
1) Formalize the problem in mathematical language. 2) Generate data to teach. 3) Compare the teaching data with real-world IDS.

What is being learned?
The phonetic category model of normal, adult, American English (Hillenbrand et al, 1995), mathematically formalized as a mixture of Gaussian distributions (Feldman et al, 2013).

How is it being learned?
In addition to the location (means) and shapes (covariance matrices), infants must learn the number of categories in their native language. This is formalized by the infinite mixture model framework (Rasmussen, 1999).

How is it being taught?
A teacher chooses data to lead a learner to a specific hypothesis, by choosing data in proportion with the posterior of the target hypothesis they induce in the learner (Shafto & Goodman, 2008; Shafto et al, 2014).

What do teaching data look like?
The model predicts that the simulated teaching data do not simply parrot the target distribution but modify it in ways that match infant-directed speech (Figure 1). Consistent with previous research, the corner vowels are hyper-articulated. Also present in the teaching data are features researchers have used to argue against the potential pedagogical intent of IDS: hyper-articulation (Figure 2) and within-category variance increase (Figure 3).

Does teaching data improve learning?
The teaching were more easily classified for every algorithm we tested. However, the teaching data only improved classification of ADS examples for the class of learner they were designed to teach (Figure 4).

Conclusion.
The qualitative properties of IDS are consistent with formant data designed to teach a phonetic category model to infant-like learners, and teaching data only improve transfer for the algorithm they were designed to teach.

References.