Infant Rule Learning: Advantage Language, or Advantage Speech?

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Abstract

Infants appear to learn abstract rule-like regularities (e.g., la la da follows an AAB pattern) more easily from speech than from a variety of other auditory and visual stimuli (Marcus et al., 2007). We test if that facilitation reflects a specialization to learn from speech alone, or from modality-independent communicative stimuli more generally, by measuring 7.5-month-old infants’ ability to learn abstract rules from sign language-like gestures. Whereas infants appear to easily learn many different rules from speech, we found that with sign-like stimuli, and under circumstances comparable to those of Marcus et al. (1999), hearing infants were able to learn an ABB rule, but not an AAB rule. This is consistent with results of studies that demonstrate lower levels of infant rule learning from a variety of other non-speech stimuli, and we discuss implications for accounts of speech-facilitation.

Rule Learning in Infancy

To investigate infants’ ability to extract abstract rules, Marcus, Vijayan, Bandi Rao, and Vishton [13] familiarized 7-month-olds to sequences of syllables that followed a particular grammar (e.g. ga ti ti, wo fe fe for ABB). At test, infants listened longer to sequences that were inconsistent with the grammar (e.g., la ta ta, which is AAB) than consistent sequences (e.g., la ta ta). Critically, the test syllables had not been used in training, suggesting that infants can extract an abstract rule, generalize it to novel stimuli, and discriminate it from other similar patterns.

Infants learn abstract rules from speech with alacrity. Seven-month-olds appear to extract and discriminate between ABB, AAB and ABA rules [13] and construct hybrid rules combining types and tokens (e.g., AdiA) [14]. Work using optical imaging indicates even newborns can detect ABB patterns [15]. But in contrast to their success learning transitional probabilities, 7-month-olds fail to learn rules from non-speech stimuli, including animal sounds, pure tones, notes of different timbre [10], and chords [11], suggesting that speech specifically facilitates learning.

That is not to say that rule learning is exclusive to speech. Dawson and Gerken [11] reported that 4-month-olds, but not 7-month-olds, can learn rules from chords. In addition, when triplets of dog pictures are presented simultaneously, 7-month-olds extract both ABB and ABA rules [16]. But while rule learning is certainly not all-or-none, the precise conditions under which infants learn regularities, particularly from sequential input, are yet to be established, and regularities in natural language are typically sequential.

Some rather broad generalizations are that infants extract rules more easily from certain stimuli than others, that certain rules are
easier to extract than others, and that it is easier to discriminate between certain pairs of rules than others. Frank, Slemmer, Marcus and Johnson [17] showed that 5-month-olds learn rules that are jointly instantiated in shapes and syllables, but not rules from shapes alone. Johnson et al. [10] demonstrated that 8-month-olds can learn ABB rules from shapes, but not AAB or ABA, and that while 11-month-olds learn AAB, they fail to learn ABA. This difficulty is not likely due to encodability: Even 2-month-olds can learn transitional probabilities over the same shapes [8]. Finally, 8-month-olds provide evidence of learning an ABB rule from shapes when tested against ABA, but do not when ABB is tested against AAB, suggesting that they fail to incorporate serial order into rules extracted from non-linguistic stimuli. By contrast, infants learning rules from speech have no such difficulties with different rules, serial order, or discriminability.

In summary, while rule learning is clearly not exclusive to speech, the generalization that rule learning is at least preferentially evoked by speech appears to be valid, at least compared to the operation of statistical learning, which readily generalizes to sequences of tones [9] and shapes [8]. Why might infants privilege speech for rule learning?

One intriguing possibility is that the communicative aspect of speech might be critical. Abstract structural regularities are vital for human communication, and so infants may search for regularities in speech as part and parcel of an attempt to learn about what is being communicated. Previously tested stimuli, like tones or shapes, are typically not communicative. Under this account, rules should be readily acquired from any communicative signal, even non-auditory ones such as gesture and natural signed languages. Infants who can hear appear to be attuned to such signals. They can learn signed languages [19,20], and perceive signed gestures in a comparable manner to speech (e.g., showing categorical perception [21]). If rule learning is specialized for communication, not just speech, infants should easily extract rules from this alternative modality.

Alternatively, speech may be privileged because infants are predisposed to attend to it [22], or because its familiarity facilitates the types of comparisons that are necessary to extract a rule. Saffran et al. [16] explained their results, where infants learn rule-bound patterns from familiar animals, in this latter way.

To test if the modality-independent communicative value of speech facilitates rule learning, we asked whether 7.5-month-old infants learn abstract rules from sign language-like gestures. These were constructed to be maximally analogous to the language-like syllables of Marcus et al. [13]. Neither set is fully reflective of a complete natural language, with proper syntax and semantics, but both cases reflect communication systems containing often-arbitrary tokens whose combinations are governed by regularities. Like speech, the gestures we used were human, distinct, and potentially communicative. But unlike speech they were novel to the infants viewing them. If infants preferentially analyze patterns in communicative stimuli independently of modality and familiarity, they should successfully extract rules here. But if speech itself is critical then rule learning should be more fragmentary, if it even occurs at all.

Methods

Participants

Twenty-four 7.5-month-old full-term infants participated (range: 214 days – 243 days, M = 233 days, SD = 8.9). Infants had not been exposed to American Sign Language (ASL) at home, and were reported to have normal hearing abilities. All procedures were approved by New York University’s Commit-
Results

If infants extract rules from any communicative stimuli, they should look longer towards sequences generated by a rule that is inconsistent with their training materials. Looking times were log transformed to reduce positive skew and heteroskedasticity, and analyzed using a 2*2 mixed analysis of variance, with training rule (AAB/ABB) as a between subject factor, and test trial type (consistent/inconsistent rule) as a within-subject factor. Mean number of trials to habituation was 8.9 (SD = 4.2), and mean looking time to habituation was 142.5 s (4.2).

Overall, infants did not look any longer to the inconsistent than the consistent test items \((F(1,22) = 2.56, \text{ns})\), nor was there a reliable effect of training rule \((F(1,22) = 3.1, \text{ns})\). However, there was a reliable test trial by training rule interaction, suggesting that infants were able to learn the ABB rule, but not AAB \((F(1,22) = 5.59, p = 0.027, \text{see Figure 2})\).

Follow-up t-tests confirmed this. Infants trained on ABB looked reliably longer to the inconsistent items \((M_{\text{consistent}} = 1.97 (0.56), M_{\text{inconsistent}} = 1.55 (0.49), t(11) = 2.57, p = 0.026)\), but infants trained on AAB exhibited no preference \((M_{\text{consistent}} = 1.52 (0.46), M_{\text{inconsistent}} = 1.47 (0.49), t(11) = 0.51, \text{ns})\).

Finally, to test whether a prior preference for AAB over ABB sequences might confound this result, we compared looking time during the entire habituation period. Infants did not look longer at AAB sequences; instead they looked longer at ABB sequences \((t(22) = 2.7, p = .013)\), which is consistent with the premise that they were learning this rule. Still, this leaves an alternative explanation: Infants who looked longer during habituation learned the rule. To test this, we correlated mean looking time during habituation trials with the difference in looking time between the novel and familiar conditions. Habituation time did not reliably predict the size of this novelty preference \((r = 0.32, t(22) = 1.6, p = .13)\); by contrast rule exposed to did \((r = 0.45, t(22) = 2.4, p = .03)\).

In summary, given the opportunity to learn rules from communicative sign language-like gestures, infants’ performance was fragmentary. They could acquire an ABB rule but not AAB, a level of learning that clearly falls short of infants’ performance when learning rules from speech.

Discussion

Our results suggest that the priority infants give to speech in rule learning does not extend to all potentially communicative signals. Whereas 7-month-old infants extract a variety of different rules from speech, 7.5-month-olds tested using sign language-like gestures apparently could extract an ABB rule and distinguish it from AAB, but could not do the reverse. This occurred even...
though the signs were natural human productions, discriminable, and clearly communicative, suggesting that rule-learning’s tuning for speech reflects some preference for the acoustic qualities of the signal. This tuning could be intrinsic or derive from experience with spoken language, but the present data indicate that it does not simply result from speech having a communicative quality.

Infants’ piecemeal rule learning here accords with previous reports on learning from non-linguistic stimuli [13]. Infants learning from shapes can extract an ABA rule and distinguish it from ABA, but when learning AAB they fail to generalize outside of their training space (in Marcus’s [23] terminology). This is not to say that infants learned nothing. It is likely that they recorded transitional probabilities between elements (statistical learning appears domain general). In addition, even if infants cannot make the distinction for shapes. We concur with Saffran et al. [16] that familiarity with the stimuli might explain the advantage will be particular to infants learning from speech, while any speech stimuli do not (e.g., [11]), leading them to search for particular types of pattern-like rules—when listening to spoken language, and ignore that information for other stimuli. This latter account, but not the former, predicts that younger infants (say, at 3 months), even when not exposed to sign, should be able to learn rules from the sort of gestural stimuli used here. Moreover, any speech advantage will be particular to infants learning from speech, while sign will be special for infants learning from sign.

Supporting Information

Supporting Information S1 List of handshapes used during gestures.

Supporting Information S2 Examples of gestures used in the training and test materials.

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Author Contributions

Conceived and designed the experiments: HR AS SJ GFM. Performed the experiments: HR. Analyzed the data: HR SJ. Wrote the paper: HR AS SJ GFM.
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