The role of prosody in infants’ early syntactic analysis and grammatical categorization

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Abstract: This study tested the hypothesis that phrasal prosody assists early syntactic acquisition. Stimulus-sentences consisting of French determiners and pseudo-lexical-words were ambiguous between two syntactic structures, e.g., [[TonDet felliAdj crale_N]NP [vurv laDet gosine_N][vp]] versus [[TonDet felli_N][NP craleV vurPrep laDet gosine_N][vp]], which had distinct prosodic cues. French-learning 20-month-olds were familiarized with the sentences either in the prosody of one structure, or the other structure. All infants were tested with DetþN (e.g., LeDet crale_N) versus PronþV (e.g., TuPron craisV) trials containing non-familiarized functors. Infants perceived the test-stimuli according to the familiarized structure. They used prosody to categorize words and interpret adjacent and non-adjacent syntactic dependencies.

1. Introduction

Infants show remarkable sensitivity to prosody from the onset of life. At birth they can discriminate languages based on their rhythmic differences.1 Newborns can distinguish lists of minimal-pair words that differ only in pitch.2 From the middle of the first year of life, infants begin to acquire the typical stress pattern of their native language, for example, a trochaic preference in English-learning infants3 and in German-learning infants.4 Moreover, they use the dominant stress pattern of their native language to segment words.5

Natural languages contain prosodic structures,6 and the boundaries of prosodic units coincide with certain syntactic constituent boundaries. Prosodic cues such as final lengthening, distinct pitch, and pause may thus appear at the boundaries of clauses and phrases. Such cues may guide the initial segmentation and grouping of syntactic units. Indeed, 4-month-olds have been shown to use prosodic cues to segment clauses from continuous speech stream.7 Infants also perceive prosodic cues that mark the boundary of syntactic phrases.8 Furthermore, infants’ prosody-based phrasal grouping is in line with the head direction of their native language. For example, French-learning 8-month-olds prefer groupings with weak-initial and strong-final syllables,9 the typical prosody found in a head-initial language.

In the present study we asked directly whether prosody affects infants’ initial analysis of syntactic categories and relations. Assigning words to basic grammatical categories (e.g., Determiner, Noun, Verb, Pronoun, etc.), acquiring higher-level categories [e.g., NP (noun phrase), VP (verb phrase), PP (prepositional phrase), etc.], and understanding category relations at different levels are essential for syntactic knowledge. Little is known about the role of prosody in the initial acquisition of these representations. It is known that prosodic cues in the input support the broad distinction of function words and lexical words,10 and that newborns categorically discriminate the two types of words based on such cues.11 Infants begin to categorize nouns, verbs, and grammatical genders shortly after age 1,12–15 and they can do so by using distributional cues.16 The role of prosody for initial grammatical categorization has not been tested. Moreover, it is unknown how infants analyze different levels of syntactic categories, for example, the equivalence between full subject-NPs and subject-Pronouns, both of which belong to the same higher category. The present study examined the role of prosody in these aspects of acquisition.

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The idea that prosody can bootstrap initial syntactic analysis is plausible. Adults and preschoolers use phrasal prosodic cues to resolve local ambiguity of grammatical categories of familiar words. In a recent study French-learning 28-month-olds correctly interpreted the meanings of transitive sentences (e.g., *Il mange le canard*; “it eats the duck”) versus right-dislocated sentences (e.g., *Il mange, le canard*; “the duck eats”) based on their distinct prosody, although they failed to do so for a novel verb whose meaning was newly taught.

Our study tested younger infants during initial grammatical acquisition, using syntactically ambiguous sentences containing multiple ambi-categorical words, which were only disambiguated by prosodic cues. All lexical words were novel, allowing us to examine generalized representations of grammatical categories and phrase structures.

2. Method

Participants were 32 Canadian-French-learning 20-month-old infants (Mean: 629 days; Range: 612–650; 15 girls). The data of another 12 infants were excluded due to looking time too short (1), fussiness (9), and ceiling looking (2).

Speech stimuli included French function words (Determiners: *ton*, “your”; *des*, “some”; *un*, “a”, *le*, “the”, *la*, “the”; Pronoun: *tu*, “you”) and pseudo lexical words (*felli*, *mige*, *crale*, *vure*, *gosine*). The pseudo-words conformed to the phonology of French. Using these words, we created familiarization sentences (e.g., *Ton felli crale vure la gosine*), which were ambiguous between two syntactic structures: Structure 1 (e.g., *[[Ton|Det felli|Adj] crale]|NP [vure|V] Det|Det gosine|N]VP|S) and Structure 2 (e.g., *[[Ton|Det felli]|NP [crale|V] Prep|Prep Det|Det gosine|N]VP|S*). Except for *gosine*, which was always a pseudo-noun, the other pseudo-words were all ambiguous in their grammatical categories, as shown in the above examples. Besides familiarization stimuli, we created two kinds of test stimuli, noun phrases (e.g., *Le|Det crale|N]*NP and short sentences (e.g., *[[Tu|Pron crale|V]S], where the non-word (e.g., *crale*) occurred as a noun and verb, respectively, with function words that were not in familiarization sentences. Table 1 shows all familiarization and test stimuli. We note that although a given non-word may have different spellings due to morphosyntactic context, the phonemic representation was identical (e.g., *vure-vur:* /vyr/, *felli-fellis:* /feli/, *crale-crales-cralent:* /kral/).

The two structures for each sentence were, however, unambiguous prosodically. Since the phonological phrase boundaries coincided with the boundaries of the major constituents in our sentences (subject-NP, VP), Structures 1 and 2 were distinguished by prosodic cues. A native Quebec-French female speaker recorded the stimuli in infant-directed speech. To elicit the prosody of the two structures, we constructed unambiguous sentences containing entirely real French words, in Structures 1 and 2, respectively. For example, to obtain a stimulus sentence intended for Structure 1, we asked the speaker to read a Structure-1 elicitation sentence (e.g., *Ton petit chat mord le ruban.* “Your little cat bites the ribbon.”) and then a nonsense sentence (e.g., *Ton felli...*

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>*[[Un felli mige]</td>
<td>NP [vure la gosine]VP</td>
</tr>
<tr>
<td>*[[Ton felli mige]</td>
<td>NP [vure la gosine]VP</td>
</tr>
<tr>
<td>*[[Un felli crale]</td>
<td>NP [vure la gosine]VP</td>
</tr>
<tr>
<td>*[[Ton felli crale]</td>
<td>NP [vure la gosine]VP</td>
</tr>
</tbody>
</table>

Table 1. Stimuli and design.

<table>
<thead>
<tr>
<th>Familiarization Grammatical (Det + N):</th>
<th>Test Grammatical (Pron + V):</th>
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<tbody>
<tr>
<td><em>Le mige</em></td>
<td><em>Tu mige</em></td>
</tr>
<tr>
<td><em>Le crale</em></td>
<td><em>Tu crale</em></td>
</tr>
<tr>
<td>Ungrammatical (Pron + V):</td>
<td>Ungrammatical (Det + N):</td>
</tr>
<tr>
<td><em>Tu mige</em></td>
<td><em>Le mige</em></td>
</tr>
<tr>
<td><em>Tu crale</em></td>
<td><em>Le crale</em></td>
</tr>
</tbody>
</table>

Note: Structures 1 and 2 for each sentence are phonemically identical despite some orthographic differences. All lexical words are non-words. The French function words are *un* (“a”), *ton* (“your”), *des* (“some”), *la* (“the”), *le* (“the”), and *tu* (“you”).
The final familiarization stimuli were six sentence pairs, each in Structure 1 and in Structure 2. We expected final lengthening and pitch rising at the end of the subject-NP, followed by a pause before the VP. Accordingly, acoustic measures revealed that the third pseudo-word (i.e., mige, crale) was longer in duration and higher in pitch in Structure 1 than in Structure 2. A distinct pause followed Word 3 crale/mige in Structure 1, but followed Word 2 felli in Structure 2. Word 2 felli had a longer duration and a higher pitch in Structure 2 than in Structure 1. Table 2 shows the details of the measures and the statistical comparisons.

The final test stimuli contained three tokens for each utterance. Acoustic analyses on the productions of the pseudo-words mige and crale revealed that duration, mean pitch, and mean intensity of these words used as nouns versus as verbs were comparable, as shown in Table 3.

We created an animation of a cartoon character, who “spoke” the speech stimuli while moving his head and body gently during each trial. His mouth opened and closed in synchrony with the speech. An animation of moving balloons and water bubble sound were used for the pre-trial. The attention-getter was a zooming star with bird singing.

In an acoustic chamber the infant sat on the parent’s lap, facing an LCD screen about 1 m ahead. Loudspeakers adjacent to the screen played the stimuli. The parent wore headphones playing masking music. The experiment started with the pre-trial to acquaint the infant with the equipment. Familiarization trials were then presented, followed by test trials. All trials were initiated and terminated by the infant. Specifically, whenever the infant looked at the screen, a trial would begin with the animated character appearing on the screen and speaking. A trial would stop when the infant looked away for 2 s or more, or when the maximum trial length (i.e., Structure-1 familiarization trial: 21.5 s, Structure-2 familiarization trial: 22.2 s; test trial: 21.2 s) was reached. Between trials, the attention-getter attracted the infant back to the screen. A researcher, blind to all stimuli, observed the infant in the adjacent room through a closed-circuit television and pressed a computer key whenever the infant looked at the screen. A computer program presented the trials and recorded all looks online. The ISI (i.e., the interval between utterances within each trial) was 1 s.

Table 3. Acoustic measures (mean and standard deviation) of the non-words in the test stimuli.

<table>
<thead>
<tr>
<th>NP (Det + N) (Le crale; Le mige)</th>
<th>S (Pron + V) (Tu crales; Tu miges)</th>
<th>Independent t-tests (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>crale/mige</strong> mean duration (s)</td>
<td>0.810 (0.1418)</td>
<td>$t(10) = -0.247; p = 0.810$</td>
</tr>
<tr>
<td><strong>crale/mige</strong> mean pitch (Hz)</td>
<td>241.2411 (45.9221)</td>
<td>$t(10) = -0.147; p = 0.886$</td>
</tr>
<tr>
<td><strong>crale/mige</strong> mean intensity (dB)</td>
<td>71.0990 (1.5420)</td>
<td>$t(10) = -1.098; p = 0.298$</td>
</tr>
</tbody>
</table>
As shown in Table 1, half of the infants were familiarized with the six sentences that had been recorded as Structure 1. The other half heard the sentences in Structure 2. Infants were randomly assigned to the two groups. A trial would present all six sentences if the infant looked to its maximum length. The order of sentence presentation was random within and across trials. The sentences were presented multiple times during the familiarization phase.

Once the infant accumulated 87 s for the familiarization phase, the test phase began. All infants heard the following test trials, NP (i.e., Le crale; Le mige; “The mige/crale”) versus S (i.e., Tu crael; Tu miges; “You miges/crala”). The test trials were of two types, Grammatical vs Ungrammatical, based on familiarization. The two trial types were presented alternatingly for a total of eight trials. For infants who were familiarized with Structure-1 prosody, the NP test trials were the Grammatical type and the S test trials were the Ungrammatical type. Conversely, for infants familiarized with Structure-2 prosody, the NP trials were Ungrammatical and the S trials were Grammatical. Tokens of utterances within each test trial were presented quasi-randomly, with the restriction that the same utterance (e.g., le crale) did not occur consecutively more than twice. The first test trial was either Grammatical or Ungrammatical, counterbalanced across infants.

The test trials assessed several aspects of syntactic knowledge, including the non-adjacent relation between the Det and Noun categories in Structure 1, the equivalence of the full subject-NP and subject-Pronoun as well as their relation with the Verb in Structure 2, and the generalization of grammatical categories to novel words across novel contexts.

If infants used prosody to successfully interpret the intended structure of the familiarization sentences and generalize the grammatical categories to the test stimuli, they should discriminate Grammatical vs Ungrammatical test trials, and the direction of preference should be uniform for the two familiarization groups.

3. Results

Looking times of test trials were analyzed. Following the standard practice in this procedure,\(^{12,20}\) we removed the first test trial of each type, which are usually unstable. Average looking (i.e., listening) time per trial for Grammatical and that for Ungrammatical trials were calculated for each infant. A \(2 \times 2\) analysis of variance (ANOVA), with Trial Type (Grammatical vs Ungrammatical) as the within-subject factor, and Familiarization (Structure-1 prosody vs Structure-2 prosody) as the between-subject factor, revealed a significant main effect of Trial Type (Grammatical: \(M = 10.28\) s, \(SE = 0.995\); Ungrammatical: \(M = 12.27\) s, \(SE = 0.79\)), \(F(1,30) = 7.216, p = 0.012\), and no main effect of Familiarization, \(F(1,30) = 0.526, p = 0.474\). Furthermore, there was no interaction between Trial Type and Familiarization, \(F(1,30) = 0.133, p = 0.718\), indicating that infants in both familiarization groups yielded the same pattern of responses to the test trials. As shown in Fig. 1, both familiarization groups (i.e., Structure-1 prosody and Structure-2 prosody) looked longer while listening to Ungrammatical trials than to Grammatical trials. This direction of looking preference was the same as in previous infant studies with similar designs that showed successful grammatical categorization.\(^{12,13}\) The Structure-1 group seemed to be stronger in their discrimination than the Structure-2 group, although the lack of interaction in the ANOVA showed no group difference. Overall, infants’ responses to the grammaticality of the test trials depended on the prosody of the structure of the familiarization sentences.

Fig. 1. Looking (listening) times to Grammatical versus Ungrammatical test trials for infants who were familiarized with Structure-1 prosody and those familiarized with Structure-2 prosody.
4. General discussion

Our study revealed several novel findings. Infants used prosodic cues to correctly interpret the intended syntactic structure. Infants who heard the prosody of Structure-1 sentences (e.g., $[\text{Ton felli crale}]$ $[\text{vure la gosine}]$) grouped the first three words as an NP, and perceived the NP test stimuli ($\text{Le crale}$) as more acceptable than the S test stimuli ($\text{Tu crales}$). Word 3 in Structure 1 was within the NP and thus perceived as a noun. Infants who heard the prosody of Structure 2 (e.g., $[\text{Ton felli}]$ $[\text{crale vur la gosine}]$) responded in an opposite way: they interpreted the S test stimuli ($\text{Tu crales}$) as more acceptable, indicating that they grouped the first two words ($\text{ton felli}$) as an NP and considered Word 3 in familiarization (e.g., $\text{crale}$) as a part of the VP, thus a verb.

Infants in both familiarization groups showed knowledge of grammatical categories and category relations. The Structure-1 group perceived $\text{ton}$, $\text{des}$, $\text{un}$, $\text{le}$ as belonging to an equivalent category (i.e., Det), and they understood the adjacent and non-adjacent dependencies between Det and Noun within an NP. In previous studies\(^1\)–\(^2\) infants preferred non-adjacent dependencies between specific functional morphemes, which may have been memorized from the input (e.g., $\text{is ing}$ in English). We showed that infants perceived the non-adjacent dependency between the Det and Noun categories (in Structure-1 sentences) at a syntactic level. It is interesting to note that in French both prenominal and post-nominal adjectives occur in NPs. Thus, the third word in Structure 1 can in principle be either a noun or an adjective. Our results show that when tested with the word (e.g., $\text{crale}$) as a noun versus a verb, the Structure-1 group accepted it as a noun.

The Structure-2 group treated the full subject-NP (e.g., $\text{ton felli}$) in the familiarization sentence and the subject-pronoun in the test stimuli (e.g., $\text{tu}$) as equivalent. This is thus the first demonstration of infants’ emerging syntactic categorization at a higher, constituent level.

In sum, our results suggest that 20-month-olds have rich syntactic representations. They assign grammatical categories efficiently to novel lexical words and reveal grammatical productivity. We showed that the influence of prosodic phrasing (e.g., phonological phrases) is striking. In our study infants used the prosodic cues to form groupings that correspond to subject-NP and VP. The groupings in turn constrained and guided their analysis of grammatical categories and relations. These results are consistent with the view that prosody can bootstrap grammatical acquisition.\(^24\)–\(^25\)

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