

# Is prosodic information alone sufficient for guiding early grammatical acquisition?

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**Abstract:** An infant perceptual experiment investigated the role of prosody. All-nonsense-word sentences (e.g., *Guin felli crale vur ti gosine*), each in structure 1 ([[Determiner + Adjective + Noun] [Verb + Determiner + Noun]]) and structure 2 ([[Determiner + Noun] [Verb + Preposition + Determiner + Noun]]), were recorded (by mimicking real-word French sentences) with disambiguating prosodic groupings matching the two major constituents. French-learning 20- and 24-month-olds were familiarized with either structure 1 or structure 2. All infants were tested with noun-use trials (e.g., *Le crale* “the crale-Noun”) versus verb-use trials (*Tu crales* “You crale-Verb”). Structure-2-familiarized infants, but not structure-1-familiarized infants, discriminated the test trials, demonstrating that prosody alone guides verb categorization. Noun categorization requires determiners, as shown in earlier work [S. Massicotte-Laforge and R. Shi, *J. Acoust. Soc. Am.* **138**(4), EL441–EL446 (2015)]. © 2020 Acoustical Society of America

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## 1. Introduction

Syntactic acquisition in children involves multiple tasks, such as assigning words to grammatical categories (e.g., noun, verb), finding larger phrasal categories (e.g., NP, VP, PP), discovering relations among syntactic categories, etc. How infants achieve these tasks has been a major question for researchers. According to one model,<sup>1–3</sup> infants can use prosody and functional items (i.e., a small set of highly frequent words such as determiners and auxiliaries, and affixes such as tense endings) to break into the system and acquire syntactic structures. Functional items have distinct prosodic and distributional properties relative to lexical words (nouns, verbs, adjective, adverbs) in input speech.<sup>3</sup> The distinction is perceived by infants from birth<sup>4</sup> and allows 8-month-olds to find the head direction of their native language (e.g., head-initial vs head-final).<sup>5</sup> By 8 months infants begin to extract specific functional items in their native language,<sup>6,7</sup> and use these items to segment lexical words.<sup>8,9</sup> From age 1 year, infants use functional items to perform detailed syntactic analyses, including categorizing lexical words<sup>10–12</sup> and finding non-adjacent grammatical dependencies.<sup>13–15</sup> Infants can use function words exclusively for grammatical categorization even when no other cues (e.g., phrasal prosody) were helpful.<sup>11,12</sup>

Phrasal prosody plays a direct role in syntactic acquisition. Researchers have shown that natural language contains prosodic structures.<sup>16</sup> Prosodic phrase boundaries, which are marked by final lengthening, distinct pitch, and pause, often coincide with the edges of syntactic phrases. Infants below 1 year of age can use such cues to segment speech stream into clause- and phrase-size chunks.<sup>17,18</sup> Recent studies show that the use of phrasal prosody yields correct syntactic interpretations in preschoolers<sup>19</sup> and toddlers.<sup>20–22</sup> For example, upon hearing the beginning of the sentences [*The baby flies*][...] or [*The baby*][*flies* ...], where *flies* was a noun in the former and a verb in the latter, preschoolers correctly predicted the intended grammatical categories based on the prosodic grouping cues.<sup>19</sup>

In a prior study<sup>20</sup> we tested infants’ syntactic knowledge using sentences in which all lexical words were French-like pseudo words, thus eliminating possible semantic effects. The only real words were the first and fifth words (French determiners). The familiarization sentences were strings that would have been ambiguous syntactically, e.g., *Ton felli mige vure la gosine*. “Your felli mige vure the gosine,” either with the structure [[Det Adj N]<sub>NP</sub> [V Det N]<sub>VP</sub>]<sub>S</sub>, or with [[Det N]<sub>NP</sub> [V Prep Det N]<sub>VP</sub>]<sub>S</sub>. However, the two structures could be distinguished by prosodic groupings. We produced the sentences with two prosodic phrases corresponding to the two major syntactic phrases for these structures, differing only in the boundary locations (e.g., Structure 1: [*Ton*<sub>Det</sub> *felli*<sub>Adj</sub> *mige*<sub>N</sub>] [*vur*<sub>V</sub> *la*<sub>Det</sub> *gosine*<sub>N</sub>]; Structure 2: [*Ton*<sub>Det</sub> *felli*<sub>N</sub>] [*mige*<sub>V</sub> *vur*<sub>Prep</sub> *la*<sub>Det</sub> *gosine*<sub>N</sub>]). We familiarized one group of French-learning 20-month-olds with structure-1 sentences, and another with structure-2 sentences. Test stimuli for both groups were target words (i.e., the third word taken from familiarization)

Table 1. Stimuli and design of Massicotte-Laforge and Shi (2015). Note that structures 1 and 2 for each sentence are phonemically identical. All lexical words are non-words. The French function words are *un* (“a”), *ton* (“your”), *des* (“some”), *la* (“the”), *le* (“the”), and *tu* (“you”).

Familiarization	
Structure-1 Group [[Det Adj N] <sub>NP</sub> [V Det N] <sub>VP</sub> ] <sub>S</sub>	Structure-2 Group [[Det N] <sub>NP</sub> [V Prep Det N] <sub>VP</sub> ] <sub>S</sub>
[[Ton/Des/Un felli mige] <sub>NP</sub> [vur la gosine] <sub>VP</sub> ] <sub>S</sub>	[[Ton/Des/Un felli] <sub>NP</sub> [mige vur la gosine] <sub>VP</sub> ] <sub>S</sub>
[[Ton/Des/Un felli crale] <sub>NP</sub> [vur la gosine] <sub>VP</sub> ] <sub>S</sub>	[[Ton/Des/Un felli] <sub>NP</sub> [crale vur la gosine] <sub>VP</sub> ] <sub>S</sub>
Test	
Grammatical (noun use: Det+N): <i>Le mige</i> <i>Le crale</i>	Grammatical (verb use: Pron+V): <i>Tu miges</i> <i>Tu crales</i>
Ungrammatical (verb use: Pron+V): <i>Tu miges</i> <i>Tu crales</i>	Ungrammatical (noun use: Det+N): <i>Le mige</i> <i>Le crale</i>

appearing in two types of trials: with a different determiner (i.e., used as a noun, e.g., *le mige* “the mige”) vs with a subject pronoun (i.e., used as a verb, e.g., *tu miges* “you mige”). The noun-use trials were grammatical and the verb-use trials ungrammatical for the structure-1 familiarization group, but vice versa for the structure-2 group. That is, the grammaticality of the test trials was defined by whether the category uses of *mige(s)/crale(s)* in the test trials were the same as their category in the familiarization sentences. The stimuli and design of that study are in Table 1. We found that both groups discriminated the test trials. Crucially, both groups listened longer to ungrammatical trials (i.e., longer to verb-use trials for structure-1 group, and reversely, longer to noun-use trials for structure-2 group), after hearing the respective familiarized structures. The results showed that infants correctly categorized the target words, possibly using both phrasal prosody and function words.

Following that study,<sup>20</sup> we asked if prosody alone can guide infants to interpret syntactic structures and assign grammatical categories to novel words. In this new study we replaced the French determiners in the familiarization sentences of our previous study<sup>20</sup> with pseudo words. These sentences thus contained all nonsense words, and the only remaining cue was the phrasal prosody distinguishing the two intended structures. The test stimuli were those in the previous study. Using the same test stimuli of that study enabled us to make clear predictions about the results of the test trials in the present study (see the end of Sec. 2). This new experiment, along with the previous one, enabled us to better understand the roles of prosody and functional items in infants’ early syntactic analysis and grammatical categorization. We hypothesized that if prosody alone was sufficient for infants’ grammatical interpretation, our new study should yield identical response patterns as in the previous study. If, however, functional items are required, we should observe no discrimination of test trials in the present study. Given that grammatical knowledge between 1.5 and 2 years of age develops significantly, we recruited two age groups of toddlers to test if they performed differently in our task.

## 2. Method

Participants were 80 Canadian-French-learning infants, 40 20-month-olds (range: 20 months to 21 months 26 days, mean age: 633 days; 21 girls) and 40 24-month-olds (range: 24 months to 25 months 27 days, mean age: 757 days; 26 girls). Twenty-three other infants were tested, but their data were excluded due to fussiness.

Familiarization stimuli were pseudo determiners (*guin* /gẽl/, *ti* /ti/; both CV syllables) and pseudo lexical words (*felli*, *mige*, *crale*, *vur*, *gosine*), all of which conformed to the phonology of French. These words formed sentences containing all non-words (*Guin felli mige vur ti gosine*. *Guin felli crale vur ti gosine*.). Crucially, the first and fifth words of the previous study<sup>20</sup> (e.g., *Ton<sub>Det</sub> felli mige vur la<sub>Det</sub> gosine*) (see Table 1), i.e., French determiners, were replaced by the pseudo determiners *guin* and *ti* in the present experiment (see Table 3). The same Quebec-French speaker who produced the stimuli of our previous study recorded multiple tokens of the sentences of the present study. As before, she simulated real French sentences that had the two distinct structures (structure 1: [[Det Adj N]<sub>NP</sub> [V Det N]<sub>VP</sub>]<sub>S</sub>; structure 2: [[Det N]<sub>NP</sub> [V Prep Det N]<sub>VP</sub>]<sub>S</sub>). For example, she read a structure-1 elicitation sentence containing all French words (e.g., *Ton petit chat mord le ruban*. “Your little cat bites the ribbon.”), followed by an all-non-word sentence

(*Guin felli migelcrale vur ti gosine.*). Likewise, structure-2 sentences in French (e.g., *Ton cheval dort dans le désert.* “Your horse sleeps in the desert.”) served to elicit the production of the all-non-word structure-2 sentences (*Guin felli migelcrale vur ti gosine.*). We asked her to mimic the intonation pattern of real-word sentences on the matched pseudo-word sentences, and to produce each non-word with the same prosody of the corresponding real word in matched sentences. The final selected stimuli (for familiarization trials) were three tokens of the *mige* sentence and three tokens of the *crale* sentence in structure-1 prosody, as well as three tokens of the *mige* sentence and three tokens of the *crale* sentence in structure-2 prosody.

This method of stimulus construction ensured that the same strings were produced with different prosody. The prosodic phrase boundaries coincided with the major syntactic phrases (subject NP, VP) in these sentences. Final lengthening and raised pitch at the end of the subject NP with a pause before the VP were expected cues. The all-non-word strings (six tokens in structure 1, six in structure 2) showed the expected acoustic cues (see the measures in Table 2).

The stimuli for test trials were the recordings of those in our previous study:<sup>20</sup> the non-words *mige* and *crale* appearing in noun-use utterances (i.e., *le mige* “the mige”; *le crale* “the crale”) and in verb-use utterances (i.e., *tu miges* “you mige”; *tu crales* “you crale” (see Table 3). There were three tokens for each test utterance, and the acoustic patterns of *mige(s)* and *crale(s)* in noun use versus verb use were comparable (see acoustic measures in our previous study<sup>20</sup>).

Visual stimuli were the same as in our previous study.<sup>20</sup> Specifically, we created the animation of a cartoon character, who “spoke” the speech stimuli, with head and body motions. We synchronized his mouth openings/closures with our speech. A zooming star with bird singing served as the attention-getter, and the pre-trial stimuli were an animation of moving balloons with water bubble sound.

The procedure was identical to those of the previous study.<sup>20</sup> In a preferential looking task the child sat on the parent’s lap about one meter in front of an LCD screen in an acoustic chamber. Auditory stimuli were played in loudspeakers next to the screen. The parent heard masking music through headphones. The experiment began with a pre-trial (presenting balloon animations and bubble sound) to acquaint the infant with the equipment. Then in familiarization and test trials the cartoon character appeared on the screen and spoke the speech stimuli described above (see also Table 3). Each familiarization and test trial started (with the character appearing and speaking) when the child looked at the screen, and a trial ended (with the disappearance of the character) if the child looked away from the screen for two seconds or more, or when the maximum trial length elapsed. The maximum length was 22.3 s for each structure-1 familiarization trial, and 23 s for each structure-2 familiarization trial. The slight length difference was due to the inherently longer duration of the structure-2 sentences in our speaker’s productions. The maximum length of each test trial was 21.2 s. The ISI was 1 s for all trials. The attention-getter appeared between trials. A camera filmed the baby and sent live video to the adjacent room, where a researcher, blind to all stimuli, watched the video through a closed-circuit TV and pressed down a computer key whenever the baby looked at the screen. The experiment was run by a computer program, which simultaneously recorded all looks.

The design was also the same as in our previous study.<sup>20</sup> Infants were divided into two familiarization groups: one group heard the all-non-word sentences intended in structure-1 prosody, and the other group heard the strings intended in structure-2 prosody. The three tokens of the two familiarization sentences (i.e., 3 × 2 *migelcrale* sentences) for each group were presented randomly, with the restriction that the same sentence did not occur consecutively more than twice in any trial. Familiarization trials repeated until the baby reached the pre-set criteria for

Table 2. Acoustic properties (measured in PRAAT): mean and standard deviation (in parenthesis) related to the intended subject-NP boundary of the familiarization sentences in the present study. The measurements on word 2 and word 3 tokens were made on the whole word.

	Structure 1 [[Det Adj N] <sub>NP</sub> [V Det N] <sub>VP</sub> s	Structure 2 [[Det N] <sub>NP</sub> [V Prep Det N] <sub>VP</sub> s	Independent <i>t</i> -tests (2-tailed)
Word 3: duration (s)	0.57 (0.02)	0.50 (0.05)	<i>t</i> (10) = 3.58; <i>p</i> = 0.005
Word 3: mean pitch (Hz)	324.23 (23.49)	292.33 (16.63)	<i>t</i> (10) = 2.71; <i>p</i> = 0.022
Word 3: mean intensity (dB)	62.81 (1.00)	76.67 (0.96)	<i>t</i> (10) = -24.50; <i>p</i> = 0.00
Pause duration after Word 3 (s)	0.33 (0.03)	0 (0)	<i>t</i> (10) = 30.34; <i>p</i> = 0.00
Word 2: duration (s)	0.38 (0.01)	0.45 (0.01)	<i>t</i> (10) = -11.35; <i>p</i> = 0.00
Word 2: mean pitch (Hz)	184.92 (10.47)	265.59 (18.29)	<i>t</i> (10) = -9.38; <i>p</i> = 0.00
Word 2: mean intensity (dB)	60.07 (1.18)	71.90 (1.89)	<i>t</i> (10) = -13.04; <i>p</i> = 0.00
Pause duration after Word 2 (s)	0.02 (0.03)	0.53 (0.05)	<i>t</i> (10) = -21.62; <i>p</i> = 0.00

Table 3. Stimuli and design of the present study. Note that all words in the familiarization phase are non-words. The French function words in the test trials are *le* (“the”), and *tu* (“you”), and the *-s* ending in the non-words *miges* and *crales* is mute. The non-word *guin* is a CV syllable (/gɛ̃/), and its spelling conforms to the French orthographic convention.

Familiarization	
Structure-1 Group [[Det Adj N] <sub>NP</sub> [V Det N] <sub>VP</sub> ] <sub>S</sub>	Structure-2 Group [[Det N] <sub>NP</sub> [V Prep Det N] <sub>VP</sub> ] <sub>S</sub>
[[ <i>Guin felli mige</i> ] <sub>NP</sub> [ <i>vur ti gosine</i> ] <sub>VP</sub> ] <sub>S</sub>	[[ <i>Guin felli</i> ] <sub>NP</sub> [ <i>mige vur ti gosine</i> ] <sub>VP</sub> ] <sub>S</sub>
[[ <i>Guin felli crale</i> ] <sub>NP</sub> [ <i>vur ti gosine</i> ] <sub>VP</sub> ] <sub>S</sub>	[[ <i>Guin felli</i> ] <sub>NP</sub> [ <i>crale vur ti gosine</i> ] <sub>VP</sub> ] <sub>S</sub>
Test	
Grammatical (noun use: Det+N): <i>Le mige</i> <i>Le crale</i>	Grammatical (verb use: Pron+V): <i>Tu miges</i> <i>Tu crales</i>
Ungrammatical (verb use: Pron+V): <i>Tu miges</i> <i>Tu crales</i>	Ungrammatical (noun use: Det+N): <i>Le mige</i> <i>Le crale</i>

the accumulated looking (structure 1: 89 s; structure 2: 92 s; the latter being longer due to the slightly longer sentence durations in structure-2 productions). These criteria, similar to those of our previous study, ensured that the participants would be familiarized with each sentence token about four times. After the familiarization, all infants heard the same test trials, as in our previous study: *mige/crale* in noun use (i.e., *le mige*; *le crale*; “the mige/crale”) and in verb use (i.e., *tu miges*; *tu crales*; “you mige/crale”), presented in alternating trials for a total of eight trials. Stimuli within a test trial were presented randomly, with the restriction that the same utterance (e.g., *le crale*) did not occur consecutively more than twice. The test trials formed two types: grammatical vs ungrammatical, according to the intended categories of *mige/crale* in the production of our familiarization structures. In particular, the noun-use test trials were the grammatical type, and the verb-use trials were ungrammatical type for infants who were familiarized with structure-1 intended prosody. The opposite was the case for the group familiarized with structure-2 prosody, with noun-use trials being ungrammatical and verb-use grammatical. Thus, the use of function words in the test utterances ensured that infants’ categorization of the novel words heard in familiarization could be assessed. It was important that the test trial stimuli and manipulation were identical to those of our previous study, which enabled us to make precise predictions about the results of the present study, as described below. The first test trial was grammatical or ungrammatical, counterbalanced across sub-groups. Table 3 shows the design.

As the familiarization sentences were all non-words, prosody was the only potential cue to the distinct structures. If infants could use prosody alone to interpret the structures and categorize the novel words, they should discriminate grammatical vs ungrammatical test trials and show a novelty preference for ungrammatical trials, as in our previous study.<sup>20</sup> However, if infants required the presence of functional items in familiarization sentences and cannot use prosody alone to interpret the grammatical categories of the novel words in those sentences, they should not discriminate the test trials since the target words (*mige/crale*) used as a noun or verb in test utterances should not matter to them after hearing the familiarization sentences.

### 3. Results

For each child, the mean looking time per trial for grammatical trials and that for ungrammatical trials were calculated, with the first trial of each type dropped, as is usually done in this procedure.<sup>11,23</sup> The looking time was analyzed in a  $2 \times 2 \times 2$  analysis of variance, with trial type (grammatical vs ungrammatical) as the within-subject factor, and familiarization (structure-1 prosody vs structure-2 prosody) and age (20 months vs 24 months) as the between-subject factors. The results showed no trial type  $\times$  age interaction [ $F(1,76) = 0.01$ ,  $p = 0.942$ ], suggesting that the two age groups responded similarly. There was no effect of age [ $F(1,76) = 0.21$ ,  $p = 0.648$ ], nor familiarization [ $F(1,76) = 1.25$ ,  $p = 0.267$ ]. The familiarization  $\times$  age interaction was nearly significant [ $F(1,76) = 3.83$ ,  $p = 0.054$ ], an effect that was not relevant to our hypotheses. The interaction of the three factors was not significant [ $F(1,76) = 0.36$ ,  $p = 0.550$ ]. There was a significant effect of trial type [ $F(1,76) = 7.65$ ,  $p = 0.007$ ].

Crucially, the trial type  $\times$  familiarization interaction was significant,  $F(1,76) = 6.55$ ,  $p = 0.012$ . Followup paired t-tests showed that the structure-1 familiarization group did not

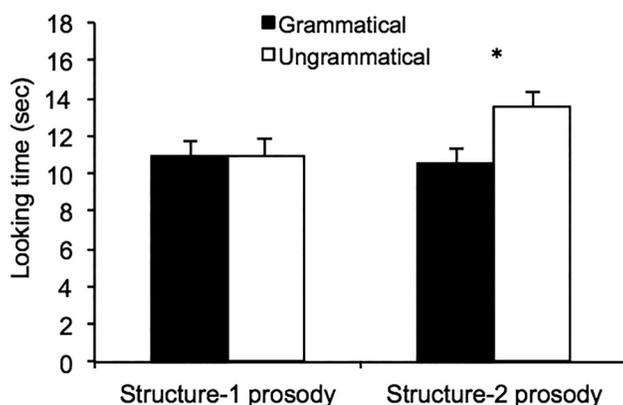


Fig. 1. Looking (listening) times to grammatical versus ungrammatical test trials for infants who were familiarized with structure-1 prosody and those familiarized with structure-2 prosody. The data of 20 months and 24 months are collapsed.

discriminate grammatical vs ungrammatical trials [grammatical:  $M = 10.87$  s,  $SE = 0.81$ ; ungrammatical:  $M = 10.99$  s,  $SE = 0.81$ ;  $t(39) = -0.17$ ,  $p = 0.868$ , 2-tailed]. In contrast, the structure-2 familiarization group discriminated the test trial types [grammatical:  $M = 10.51$  s,  $SE = 0.84$ ; ungrammatical:  $M = 13.55$  s,  $SE = 0.8$ ;  $t(39) = -3.45$ ,  $p = 0.001$ , 2-tailed], with longer looking to ungrammatical trials (novelty preference). See Fig. 1.

#### 4. General discussion

Our results reveal how prosody can support early grammatical acquisition. The test-trial looking pattern of the structure-2 group in the present study was identical to that of the structure-2 group in the previous study: both discriminated the verb-use trials (e.g., *tu migel/crales*) vs noun-use trials (e.g., *le migel/crale*) and both listened longer to ungrammatical trials. Thus, even though the familiarization sentences in the present study contained all pseudo words (e.g., [[*Guin felli*] [*migel crale vur ti gosine*]]), infants interpreted the second prosodic phrase as a cohesive phrase and categorized the first word at the beginning of the prosodic phrase as a verb, indicating that prosody alone was sufficient for this analysis. This analysis was likely based on infants' prior tracking of verb distribution in the input: Verbs in French can occur at the beginning of a prosodic phrase, such as in our familiarization sentences and in imperative utterances (e.g., *Viens ici!* "Come here!"). This contrasts with the distribution of nouns: Nouns in French do not occur at the beginning of a prosodic phrase (except people's names), as they generally require a preceding determiner. Our infants' analysis of nouns differed from their verb analysis.

Specifically, in structure-1 familiarization sentences, word 3 was inside the first prosodic phrase. In our previous study<sup>20</sup> function words (in particular, determiners) were present, and the infants who heard structure 1 (e.g., [[*Ton<sub>Det</sub> felli migel/crale*] [*vur la<sub>Det</sub> gosine*]]) categorized *migel crale* as a noun. However, when determiners were changed to phonologically comparable non-words in the present study (e.g., [[*Guin felli migel/crale*] [*vur ti gosine*]]), infants did not discriminate the test trials. These results suggest that prosody alone was not a sufficient cue for infants to categorize *migel crale*. Infants needed a determiner to categorize a following noun, and this analysis was constrained within the same prosodic grouping, as shown by structure-1 infants in our previous study.

In sum, the results of the present study reveal early syntactic knowledge in toddlers. Our stimuli contained exclusively non-words, requiring an analysis beyond any memorized utterances from prior natural input and beyond the influence of semantics. Infants demonstrated syntactic productivity. They used the prosodic cues to perceptually group words into phrases and categorized novel words. The combined results of structure-1 infants in our previous and present studies show that to analyze certain categories (such as nouns and NP), functional items are required, and that prosody can work conjointly to guide infants. On the other hand, even when facing all novel words, infants can still interpret certain structures and categorize certain words (e.g., VP, verbs) using prosody alone. The fact that both ages in our study, 20- and 24-month-olds, yielded the same results, suggests that the grammatical bootstrapping mechanisms remain constant for these ages. Our findings support the functor-prosody bootstrapping model,<sup>1-3</sup> showing how the two types of information work to bootstrap early syntactic acquisition.

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