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CHAPTER 2

# Early perception of phrasal prosody and its role in syntactic and lexical acquisition

Alex de Carvalho[1], Isabelle Dautriche[2], Séverine Millotte[3] & Anne Christophe[1]

[1]Laboratoire de Sciences Cognitives et Psycholinguistique (ENS, EHESS, CNRS), Département d'Études Cognitives (École Normale Supérieure – PSL Research University) / [2]Centre for Language Evolution, School of Philosophy, Psychology and Language Sciences, University of Edimburgh / [3]Laboratoire d'Étude de l'Apprentissage et du Développement, CNRS UMR 5022, UB, Université Bourgogne Franche-Comté

This chapter will review empirical findings on the perception of phrasal prosody in very young infants, and how it develops in first language acquisition. The ability to process phrasal prosody impacts learning of important aspects of language, specifically word segmentation and syntactic parsing. We will see that infants are able to perceive crucial aspects of phrasal prosody before the end of their first year of life, and that a few months later they are able to exploit the prosodic structure of an utterance to constrain its syntactic analysis, and therefore, to infer the meaning of unknown words.

## Introduction

Infants acquiring language face the challenging task of having to learn by extracting information directly from the speech stream. Given the complexity of this spoken input, it is impressive that around the age of two or three years, toddlers already show a deep knowledge about aspects of the phonology, semantics and syntax of their native language. How were they able to build this knowledge during the first steps of language acquisition? In this chapter we will review empirical findings on the perception and use of a potential cue that is directly accessible from the speech stream: phrasal prosody. Phrasal prosody reflects the organization of sentences into prosodic constituents above the word level, and it is conveyed by variations in pitch, duration, and energy, of speech sounds over the course of an utterance.

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In all the languages of the world, the words and syllables composing the speech stream are not produced in a monotonous way. Rather, speech is characterized by rhythmic and intonational variations over the course of an utterance: its prosody. The prosody of a language can be described at different levels (i.e., syllables, words, phrases, and whole utterances) and impacts linguistic interpretations in various ways. For example, prosodic information can be used to convey lexical meaning at the word level through variations in stress pattern or lexical tone (e.g. 'beBE' and 'BEbe' are two different words in Spanish, differing only in their stress patterns). Prosody is also used to mark whether a sentence is declarative or interrogative (e.g. Zhou, Crain, & Zhan, 2012) and it conveys useful discourse information such as information structure (e.g. focus, new vs. old information; Hirschberg & Pierrehumbert, 1986; Pierrehumbert & Hirschberg, 1990). Prosody can also be used to change the interpretation of an utterance (e.g. irony, disbelief, etc.), and it can even reflect the emotional state of the speaker (Armstrong, Andreu, Esteve-Gibert, & Prieto, 2016; Jun, 2005, 2014; Ladd, 2008). As for phrasal prosody, the prosodic structure of an utterance can be described hierarchically, in the sense that utterances contain one or more intonational phrases, intonational phrases contain one or more phonological phrases, and phonological phrases contain one or more prosodic words, which in turn contain syllables (e.g. Nespor & Vogel, 1986). In this chapter, we will focus on the role of phrasal prosody on speech segmentation and parsing, and its impact on syntactic and lexical acquisition.

Our interest in this topic stems from the fact that the prosodic boundaries at the phrasal level (i.e., phonological and intonational phrases) always coincide with the boundaries between syntactic constituents in a sentence (Nespor & Vogel, 1986). Thus, the prosody of an utterance can reflect aspects of the syntactic structure of a sentence and provide important cues for parsing (e.g., Morgan & Demuth, 1996; Nespor & Vogel, 1986). For example, a sentence like: "The little boys run really fast", tends to be produced as: [the little boys] [run really fast] (brackets indicate phonological phrases), where the three words "the little boys" are grouped into one single prosodic unit, corresponding to the noun phrase in this sentence, and "run really fast" are grouped into a second prosodic unit, corresponding to the verb phrase. Although it is not the case that all syntactic constituent boundaries are marked by a prosodic boundary, whenever a prosodic boundary is perceived in the speech stream, it always coincides with a syntactic constituent boundary (Nespor & Vogel, 1986). As a result, salient prosodically-conditioned acoustic information such as phrase-final lengthening, pitch variations, and pauses, may allow listeners to identify prosodic boundaries which in turn might be useful to segment the continuous speech stream into relevant units, such as words and syntactic constituents. In other words, phrasal pros-

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ody might be particularly important for young listeners, who still do not know much about their native language, because it could represent an important tool to parse sentences into meaningful constituents and to identify some of the syntactic constituents of a sentence even before infants have acquired an extensive vocabulary (Christophe, Millotte, Bernal, & Lidz, 2008; Morgan, 1986; Morgan & Demuth, 1996). In this chapter we will review empirical findings supporting this hypothesis.

The first section will show that infants are sensitive to prosodic information from birth onwards and that this cue can help them to learn important aspects of their native language. The second section will present empirical findings showing that infants can rely on phrasal prosody to segment the speech stream into words and constrain lexical access. Finally, in the third section we will present recent findings suggesting that infants can exploit the relationship between the prosodic and syntactic structures of sentences to constrain their syntactic analysis – which in turn would allow them to constrain the acquisition of word meanings.

## Early perception of prosodic cues

Considerable work has shown that infants have extensive experience with prosody from their first days of life (Christophe, Mehler, & Sebastián-Gallés, 2001; Decasper & Spence, 1986; Mehler et al., 1988; Nazzi, Bertoncini, & Mehler, 1998; Shi, Werker, & Morgan, 1999). An important study conducted by Mehler et al. (1988) showed that four-day-old infants are already sensitive to prosodic information when listening to sentences. Testing French newborns with French and Russian, and American infants with English and Italian, the authors observed that infants showed a preference for listening to their native language over a foreign one. Given that a few days after birth, infants have received very little postnatal language input, it is possible that prenatal exposure plays a role in this early preference for native speech (e.g., Decasper & Spence, 1986). Indeed, some prosodic characteristics from the speech stream, such as rhythm, stress and intonation, pass through the skin and uterus to the fetus (Decasper & Spence, 1986). To test whether newborns' preference arises from an early knowledge of the prosodic characteristics of their native language, Mehler et al. (1988) tested another group of French and American infants using low-pass filtered speech samples, where the prosodic information remained intact while phonetic information was stripped away. Their results showed that French newborns preferred to listen to low-pass filtered French speech over filtered Russian speech and American infants showed the same pattern for filtered English vs. filtered Italian speech. These results suggest that from birth onwards, infants are already sensitive to

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prosodic information, which helps them to distinguish their native language from a foreign language.

In a subsequent study, Nazzi et al. (1998), used low-pass filtered sentences in foreign languages to test infants' sensitivity to prosody to distinguish between non-native languages. They showed that French newborns were also able to discriminate foreign languages based on their prosodic patterns. For example, French newborns were able to discriminate stress-timed English from mora-timed Japanese, but failed to discriminate between English and Dutch because these languages share the same rhythmic properties (both stress-timed languages). Taken together, these results show not only that infants can use prosodic cues to discriminate their native language from a foreign one but also that they can use prosody to categorize languages based on their rhythmic and intonational properties.

Subsequent studies provided further evidence about the role played by prosody during the first steps of language acquisition, showing in particular that infants use it to segment the continuous speech stream into chunks. One of the earliest infant studies on continuous speech perception showed that 7-month-old infants are able to rely on prosodic information to recognize clauses in the speech stream: Hirsh-Pasek, Kemler Nelson, Jusczyk, Cassidy, Druss, and Kennedy (1987) showed that 7-to-10-month-olds are sensitive to the coherence of intonational phrases in the speech stream. Inserting a one-second pause either at clause boundaries or at within-clause locations in the speech stream, the authors observed that infants prefer to listen to speech containing pauses at clause boundaries (i.e., "*Cinderella lived in a great big house*-PAUSE-*but it was sort of dark*-PAUSE-…") than within clauses (i.e., "*Cinderella lived in a great big house, but it was*-PAUSE-*sort of dark because she had*-PAUSE-…"; see also Männel & Friederici, 2009, for similar results at 5 months with EEG and Teixidó, François, Bosch, and Männel, this volume, for a review of the role of prosody in early speech segmentation). Subsequent studies showed that infants are sensitive to smaller prosodic units, phonological phrases, that may correspond to noun phrases or parts of verb phrases in a sentence, from about the age of 6 months (e.g. Gerken, Jusczyk, & Mandel, 1994; Johnson & Seidl, 2008; Soderstrom, Seidl, Kemler-Nelson, & Jusczyk, 2003). Moreover, infants show better memory for units from the speech stream that correspond to whole prosodic units than for chunks of speech that span prosodic boundaries (Mandel, Jusczyk, & Nelson, 1994; Nazzi, Iakimova, Bertoncini, Frédonie, & Alcantara, 2006). This shows that infants are not only sensitive to prosodic grouping information, but that they recognize the prosodic well-formedness of speech chunks, and find it harder to process chunks of speech that are not well-formed prosodically.

It is important to note that some of the cues that mark prosodic units are the same in all the world's languages, especially for larger prosodic units such as intonational phrases. These tend to be followed by a silent pause, systematically exhibit

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final lengthening, and often show marked pitch excursions (e.g., a decline, or a rise for questions; note that these boundary cues are also found in other domains such as musical phrases). However, other cues may vary between languages, so that infants need to learn some language-specific properties before they can exploit those cues efficiently, which may explain why sensitivity to smaller prosodic units such as phonological phrases arises later during development. For instance, the pitch contours typical of smaller prosodic units such as phonological phrases vary between languages, which means that children need experience with their native language before they can exploit these cues as reliable boundary markers in their language. For instance, experimental work suggests that while younger infants (even across different languages) tend to rely on strong and universal prosodic markers, such as pauses, older infants can make use of more subtle prosodic cues such as pitch contours and lengthening even in the absence of pauses (Johnson & Seidl, 2008; Seidl, 2007; Wellmann, Holzgrefe, Truckenbrodt, Wartenburger, & Höhle, 2012).

Prosody has also been proposed to help infants discover the word order of their native language. In fact, many languages differ with respect to the position of the verb and its object in a sentence, or more generally, the respective position of heads and complements. Either complements tend to follow their heads, or they tend to precede them. This organization, in turn, can impact the order of function words (highly frequent functional morphemes, such as articles, auxiliaries, etc…) with respect to content words (much less frequent lexical items, such as nouns, verbs, adjectives, etc…) in a sentence. For example, in VO (Verb-Object) languages such as English and French, function words typically appear before content words and at the beginning of phrases (e.g., *Le bateau* 'The boat'; *de Paris* 'from Paris' – head-initial languages), while in OV languages like Turkish and Japanese, function words tend to appear after content words and at the end of phrases (e.g., *Tokyo kara* 'Tokyo from' – head-final languages; Dryer, 1992). In addition, the head-direction of a language also determines which element will be more prosodically prominent within phonological phrases: The first one in head-final languages (typically marked with higher pitch), and the last one in head-initial languages (typically marked with lengthening; Nespor, Shukla, van der Vijver, Avesani, Schrandolf, & Donati, 2008). Thus, infants could use both the prosodic cues and the relative position of frequent and infrequent elements to infer the basic word order of their native language (Bernard & Gervain, 2012; Christophe, Nespor, Guasti, & Van Ooyen, 2003; Gervain, Mehler, Horie, Mazuka, & Nespor, 2008; Gervain & Werker, 2013; Höhle, Weissenborn, Schmitz, & Ischebeck, 2001). For instance, Christophe et al. (2003) showed that 2-month-old infants were able to distinguish between two languages that have very similar phonology, but differ in their head-direction: French (head-initial) versus Turkish (head-final) suggesting that this kind of prosodic information might be used by young listeners to obtain information about

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the word order in their native language. Additionally, Gervain and colleagues (2008) showed that 8-month-olds are already sensitive to the typical position in which frequent and infrequent elements appear in their native language in order to infer the position of function and content words (e.g., Italian: VO, frequent-infrequent; or Japanese: OV, infrequent-frequent). Thus, in an artificial grammar experiment, when exposed to an unsegmented string of syllables in which some syllables were highly frequent (i.e., playing the role of function words) and others infrequent (i.e. playing the role of content words), infants segment this continuous signal such that the position of the frequent elements respects the typical order of function and content words in their native language (Italian infants prefer to have the frequent elements in initial position, and Japanese infants in final position).

Interestingly however, in the case of bilingual infants acquiring both VO and OV languages, frequency alone does not provide enough information about word order since both frequent-final and frequent-initial phrases occur in their input. Researchers have proposed that prosodic information could cue word order in this case. For instance, in a recent experiment, Gervain and Werker (2013) showed that bilingual 7-month-olds acquiring simultaneously an OV and a VO language exploit prosodic information to determine the relative order of frequent and infrequent elements in an unsegmented string of syllables. When familiarized with strings of syllables consistent with an OV prosodic pattern (with high-low-high-low pitch alternations), infants preferred to listen to chunks of syllables with the frequent elements at the end; in contrast, when familiarized with strings of syllables consistent with a VO prosodic pattern (short-long-short-long), they showed the reverse preference. These studies suggest that prosody, together with frequency information, impacts word order acquisition. Taken together, the studies reviewed in this section show that prosody is indeed an important source of information, directly accessible from the speech stream, which may promote early language learning in a variety of ways.

## Using phrasal prosody to segment the speech stream into words

Discovering the words composing their language is one of the challenging tasks faced by language learners. During their development, infants have to extract the word-forms from the continuous speech stream, and associate the extracted word-forms with a possible meaning. However, given that in fluent speech there are no pauses between two consecutive words, how can infants segment the speech stream into words? Several studies have shown that infants can use a variety of cues to discover word boundaries; although none of them is sufficient on its own, together they may allow infants to discover many words in their input

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(see Thorson, this volume). Word segmentation cues that have been proposed and studied include phonotactic constraints (e.g., Jusczyk, 1997), words heard in isolation (e.g., Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Lew-Williams, Pelucchi, & Saffran, 2011), the statistical structure of the input (e.g., transitional probabilities; e.g., Saffran, Aslin, & Newport, 1996), word-level prosodic information such as typical word stress pattern (e.g., Cutler & Butterfield, 1992; Echols, 1993; Echols & Newport, 1992; Jusczyk, Houston, & Newsome, 1999; see Bhatara, Boll-Avetisyan, Höhle, & Nazzi, this volume, for a detailed review), as well as phrasal prosody (e.g., Gout, Christophe, & Morgan, 2004; Johnson, 2008; Shukla, Nespor, & Mehler, 2007; Shukla, White, & Aslin, 2011).

Turning our attention toward the role of phrasal prosody on segmentation into words, several studies have shown that infants are able to perceive prosodic phrase boundaries and exploit them to find the boundaries between words from 6 months onwards (Gout et al. , 2004; Johnson, 2008; Millotte et al., 2010; Shukla et al., 2011). Since prosodic units such as phonological phrases are constructed by grouping words together, whenever a prosodic boundary is perceived, it has to correspond to a word boundary (Nespor & Vogel, 1986). Thus, sensitivity to phrasal prosody might provide cues to speech segmentation and, therefore, constrain lexical search. Of course, since most prosodic units contain more than one word, many word boundaries will not be marked by phrasal prosody – word segmentation within phonological phrases will have to rely on some other cues mentioned above. As an illustration of the impact of prosodic boundaries on word segmentation (1), the sentences below both contain the two syllables *pay* and *per*, however, only the first one contains the word *paper*:

(1) a. [The college] [with the biggest *paper* forms] [is best]
b. [The butler] [with the highest *pay*] [*per*forms the most]

In the second sentence, the prosodic boundary between the syllable 'pay' and the syllable 'per' should block lexical access to the word *paper*: indeed, it has been shown with adult listeners that prosodic boundaries constrain lexical access (Christophe, Peperkamp, Pallier, Block, & Mehler, 2004; Endress & Hauser, 2010; Warner, Otake, & Arai, 2010). To test infants' ability to use phrasal prosody to segment the speech stream into words, Gout et al. (2004) used the above sentences (1) in a conditioned head-turn procedure. In a first session, they trained American 10-month-olds to turn their heads toward a puppet whenever they heard the word *paper* (for instance). Then, during a test phase infants were exposed to full sentences, such as (a) and (b). Their results showed that infants trained to respond to the word *paper* turned their head more often when listening to *paper*-sentences (a) than to *pay#per*-sentences (b). In contrast, infants trained to respond to the target word *pay* turned equally often for both types of sentences

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(since the syllable *pay* was present in both sentences, the target word *pay* might have been noticed in both sentences). This results show that 10-month-old American infants can use phrasal prosody to segment the speech stream into words and, therefore, to constrain their lexical access. Further studies showed similar results with French 16-month-olds (Millotte et al., 2010) and other experiments in English confirmed these results, showing that 12-month-olds can use phrasal prosody to constrain lexical access within strings of nonsense syllables differing in their prosodic structure (Johnson, 2008). Moreover, Shukla et al. (2011) showed that 6-month-olds were able to better associate a visual referent to a novel word aligned with a prosodic phrase boundary, than to a novel word that straddled a prosodic boundary. This suggests that infants are sensitive to the fact that words are aligned with prosodic phrase boundaries, and exploit this information to facilitate word learning. Taken together these results highlight the importance of phrasal prosody for segmenting the speech stream into words and constraining lexical access and lexical acquisition.

## The role of phrasal prosody for syntactic parsing in children

The empirical studies presented above show that phrasal prosody has an important role in infant speech perception, allowing them to discriminate between languages, infer aspects of the word order of their language, and segment the speech stream into words and clauses. Since the prosodic structure of an utterance partially reflects the syntactic structure of a sentence (Nespor & Vogel, 1986), the *prosodic bootstrapping* hypothesis proposes that phrasal prosody could also help infants to discover the syntactic structure of sentences (e.g., Morgan, 1986; Morgan & Demuth, 1996). As mentioned above, the relationship between prosodic structure and syntactic structure is such that prosodic boundaries are aligned with syntactic constituent boundaries. Thus, prosodic information such as phrase-final lengthening, pitch variation and pauses can help listeners to identify prosodic boundaries, and therefore to find some syntactic constituent boundaries. Taking it into account, prosodic information might facilitate on-line sentence processing in adults, and might provide a way for infants to identify some of the syntactic constituents of an utterance even before they have acquired an extensive vocabulary.

Supporting this hypothesis, many studies have shown that adults integrate phrasal prosody online to recover the syntactic structure of sentences (Kjelgaard & Speer, 1999; Michelas & D'Imperio, 2015; Millotte, René, Wales, & Christophe, 2008; Millotte, Wales, & Christophe, 2007; Snedeker & Trueswell, 2003; Weber, Grice, & Crocker, 2006). Given the extensive literature we reviewed in this chapter showing that infants have an early access to phrasal prosody, and are able to exploit

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it for lexical segmentation, one would naturally expect that infants might also be able to use phrasal prosody, as adults do, to constrain syntactic analysis. However several studies investigating whether preschoolers can exploit phrasal prosody to constrain their syntactic analysis have found that children have difficulties using prosody for syntactic ambiguity resolution in English (Snedeker & Trueswell, 2001, 2003; Vogel & Raimy, 2002) and in Korean (Choi & Mazuka, 2003). Most of these studies in English used sentences with a prepositional phrase attachment ambiguity, such as "Can you touch the frog with the feather?", in which the prepositional phrase "with the feather" can be interpreted either as an instrument of the verb "touch" or as a modifier of the noun "frog". In such sentences, the default prosodic structure is the same for the two possible interpretations (i.e. [Can you touch] [the frog] [with the feather] – Snedeker & Yuan, 2008), but speakers who are aware of the ambiguity can intentionally disambiguate by exaggerating one of the prosodic breaks, in order to favor one interpretation over the other, i.e. "[Can you touch the frog] [with the feather]?" for the instrument interpretation, vs. "[Can you touch] [the frog with the feather]?" for the modifier interpretation (Snedeker & Trueswell, 2003). Snedeker and Trueswell (2001) found that children failed to use this kind of prosodic information when interpreting this kind of sentences. In a subsequent experiment, which controlled for children's perseveration biases, Snedeker and Yuan (2008) observed that children succeeded in this task, when they were presented with only one kind of sentences: either modifier-only, or instrument-only. However, when they were presented with both instrument and modifier sentences across the experiment, as in the previous study, children failed to use prosody to constrain their syntactic interpretations (Snedeker & Yuan, 2008). Children's difficulty using prosody in this kind of sentences might be due to the fact that the disambiguating prosodic breaks they needed to use are not part of the normal prosodic structure of these sentences, but these cues are only produced when the speaker is consciously trying to disambiguate (Snedeker & Trueswell, 2003). Thus, children may have had difficulties using this kind of optional prosodic information.

To avoid this problem of optional prosodic disambiguation, de Carvalho and colleagues exploited locally ambiguous sentences featuring noun/verb homophones, in which the default prosodic structure differed between conditions (de Carvalho, Dautriche, & Christophe, 2016, for French; and de Carvalho, Lidz, Tieu, Bleam, & Christophe, 2016, for English). For example, the word "watch" is a verb in the sentence: [Mommies] [**watch** TV every night], but it is a noun in the sentence: [Mommy's **watch**] [ticks very noisily]. Here, brackets indicate prosodic units, which reflect the syntactic structure of each sentence. Crucially, in both cases, there is a prosodic break (marked by phrase-final lengthening and pitch change) between the subject Noun Phrase and the Verb Phrase: this break falls after the critical word when it is used as a noun, and before it when it is used as a verb.

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American and French 4-year-olds presented with the beginning of these ambiguous sentences (e.g., "Mommies watch …") interpreted the ambiguous target word as a noun or as a verb depending on the prosodic structure in which it was embedded, as shown by the words they used to complete the sentences in a sentence completion task (de Carvalho, Dautriche, & Christophe, 2016; de Carvalho, Lidz, Tieu, Bleam, & Christophe, 2016). These results show that preschoolers can use prosodic boundaries to infer the presence of a syntactic constituent boundary, and in turn use that information to figure out the syntactic category of an ambiguous word. The discrepancy between these recent findings and the previous literature showing children's failure to use prosody to constrain syntactic analysis, rests on the disambiguating prosodic information used. In the recent studies, the prosodic boundary between the noun phrase and the verb phrase is part of the normal prosodic structure of sentences, and it is present even in non-ambiguous sentences (e.g. [the little frog] [eats a lot of food]).

The important question then is when do children become able to use phrasal prosody to constrain their syntactic analysis? Given that infants were shown to be sensitive to prosodic boundaries very early during development (e.g. Gerken et al., 1994; Gout et al., 2004; Johnson, 2008; Soderstrom et al., 2003), it is possible that not only preschoolers but even younger children would be able to exploit phrasal prosody to constrain syntactic analysis. De Carvalho, Dautriche, Lin, and Christophe (2017) tested two-year-old French toddlers with the sentences featuring noun/verb homophones described above (e.g., 'ferme' in French can be used as a noun in: [*la petite* ***ferme***] [*est très jolie*] – [the small **farm**] [is very nice] or as a verb in: [*la petite*] [***ferme*** *la boîte à poupée*] – [the little girl] [**closes** the toy box]). To test toddlers' ability to use prosody to disambiguate these sentences, they were presented with two images displayed side-by-side on a TV screen: one associated with the noun interpretation of the target word (e.g., a farm) and the other one with the verb interpretation (e.g., a little girl closing something). At the same time, toddlers listened to the sentence beginnings pronounced in a noun-prosody or a verb-prosody condition. Crucially, the end of the sentences was replaced with babble noise, such that only prosodic information could be used to disambiguate. The results, depicted in Figure 1, show that toddlers in the noun prosody condition switched their gaze toward the noun image around the end of the ambiguous word, while toddlers in the verb prosody condition looked more toward the verb image. Taking into account saccade preparation time (e.g., + / – 300ms: Allopenna, Magnuson, & Tanenhaus, 1998), this suggests that toddlers computed the syntactic category of the critical word online, before the word offset.

These results show that two-year-olds, upon hearing the first words of a sentence, exploit its prosodic structure to group words into constituents, and exploit this constituent structure in their on-line syntactic analysis of spoken sentences.

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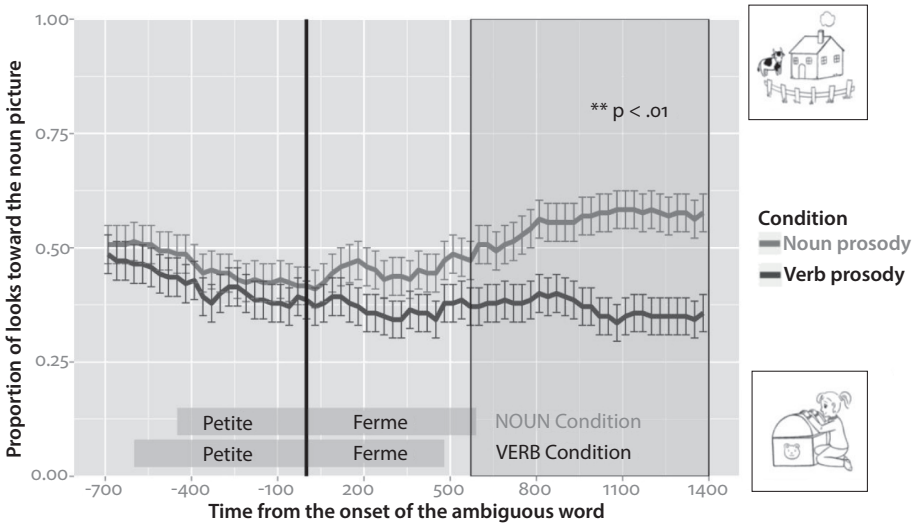


**Figure 1.** Proportion of looks toward the noun image, time-locked to the onset of the ambiguous word (vertical black line), for the noun prosody condition (light gray curve) and the verb prosody condition (dark gray curve). Error bars represent the standard error of the mean. A nonparametric cluster-based permutation test (Maris & Oostenveld, 2007) revealed a significant difference between the noun prosody and the verb prosody conditions, starting 600 ms after the onset of the ambiguous target word (gray time-window). Figure adapted from de Carvalho et al. (2017).

The ability to exploit information from the speech to access the syntactic structure of sentences can be extremely useful for infants during language acquisition. As proposed by Gleitman (1990), having access to the syntactic structure of sentences can help infants to discover the meaning of novel words (the *syntactic bootstrapping* hypothesis). For example, in a very recent study, He and Lidz (2017) showed that 18-month-olds listening to a sentence like "*Look, it's a doke*!" were able to infer that the novel word '*doke*' referred to an object (i.e., a penguin), but when they were listening to sentences like "*Look! It's pratching*!", they inferred that '*pratching*' referred to an action (i.e., a spinning action). In this case, the critical word, '*doke*' or '*pratch*', was preceded and/or followed by disambiguating function morphemes (*a, it's… -ing*). However, in everyday life, not all content words are immediately preceded by function words, as shown in the earlier examples with noun/verb homophones (e.g., *bears* can be either a noun or a verb, in: "The giant bears…"). In such cases, a representation in terms of syntactic constituent could be very useful. For example, *bears* is a noun in: [The giant bears]$_{NP}$ [are very hungry], and a verb in: [The giant]$_{NP}$[bears$_{v}$ a heavy load]$_{VP}$). But can infants exploit prosodic boundaries together with function words to constrain their syntactic

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analysis of sentences containing novel words? If so, can they use this information to determine the syntactic nature of these novel words and therefore constrain their meaning?

To investigate this question, de Carvalho, He, Lidz, and Christophe (2015) used two novel words in French (e.g., *bamoule* and *doripe*) to construct minimal pairs of sentences that differed only in their prosodic structures. For instance, the novel word *bamoule* was used as a noun in the sentence: [*Regarde la petite bamoule*]! – [*Look at the little bamoule*]!, where all the words in this sentence were grouped together into a single prosodic unit, and the novel word *doripe* was used as a verb in the sentence: [*Regarde*]! [*la petite*] [*doripe*]! – [*Look*]! [*The little one*] [*is doriping*]!, where all the words in the sentence were spread into three different prosodic units (square brackets indicate prosodic phrase boundaries). Crucially, note that when *doripe* was used as a verb there was a prosodic boundary preceding it (i.e., the boundary between the noun phrase and the verb phrase) but, when *bamoule* was used as a noun, it was embedded in a single prosodic unit together with the other words of the sentence, corresponding to the verb 'look' and the following noun phrase.

In a Habituation-Switch paradigm (e.g., Werker, Cohen, Lloyd, & Casasola, 1998), 18-month-old monolingual French-learning infants were first habituated[1] to two video stimuli showing a penguin doing two different intransitive actions (e.g., spinning, cartwheeling), one in each video. During the presentation of one of the videos (e.g., a penguin spinning), infants heard sentences in the Noun-prosody condition (e.g., [*Regarde la petite* ***bamoule***!] – Look at the little **bamoule**!, where *bamoule* was a noun, naming an object, here the penguin), and during the presentation of the other video (e.g., a penguin cartwheeling), they heard sentences in the Verb-prosody condition (e.g., [*Regarde*],[*la petite*][***doripe***!] – Look, the little$_{(one)}$ is **doriping**, where *doripe* was a verb, naming an action, here cartwheeling). Then, to test whether infants were able to correctly interpret these sentences, during the test phase, the audio tracks of the two videos were switched. Half of the participants were exposed to the Noun-Switch-condition, that is, they heard the noun sentence with 'bamoule' while seeing the cartwheeling video, and half were exposed to the Verb-Switch-condition, that is, they heard the verb sentence with "doripe" while seeing the spinning video. If infants have learned, like adults would, that "bamoule" meant "penguin" and "doripe" meant "cartwheeling", they should be surprised in the Verb-Switch condition (look longer to the

1. The habituation criterion was reached when an infant's average looking time during any block of 3 consecutive trials dropped to less than 65% of the average looking time for the most-attended block (i.e. the 3-trial block that had the longest total looking time to the video stimuli).

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video), because they are listening to the "doripe" sentence while the penguin is "spinning" instead of "cartwheeling". However in the Noun-Switch condition infants should not be surprised when listening to the sentence with "bamoule", since there is still a penguin present in the video, even if it is now doing a different action.

The results of this experiment, presented in Figure 2, showed that infants' looking time toward the videos was significantly longer in the Verb-Switch condition than in the Noun-Switch condition, during the test phase. These results fit with the idea that the action change was inconsistent with their interpretation of the novel verb, while it didn't matter for their interpretation of the novel noun (a penguin was present in both videos). Thus, we observe that, from 18 months of age, infants can exploit prosodic structure to group words into constituents, and calculate the syntactic structure of sentences, which can then help them to infer the probable meaning of novel words: mapping nouns to objects and verbs to actions. Note that since both noun and verb sentences in this experiment were composed of exactly the same words in the same order (*regarde-la-petite-bamoule/doripe*), a simple analysis in terms of which words is preceding *bamoule* or *doripe* was not enough to determine the syntactic category of the novel words, since they are the same in both conditions. Remarkably, in this situation, toddlers were then able to integrate information coming from phrasal

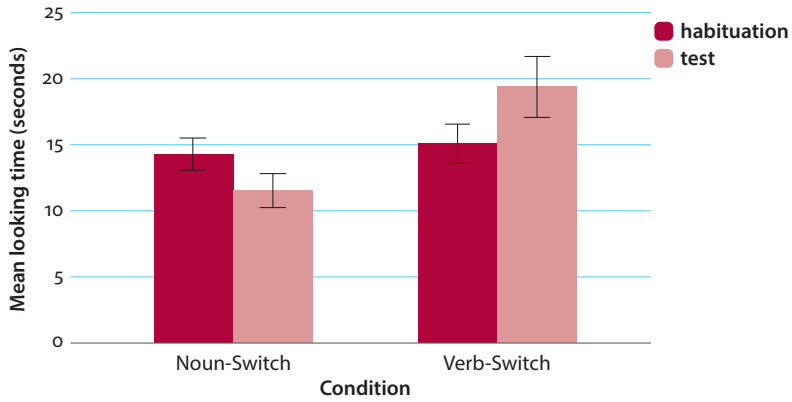


**Figure 2.** Mean looking time in seconds toward the videos during the last two trials of the habituation phase (in dark red) and during the two trials of the test phase (in light red) for participants assigned to the Noun-Switch Condition (on the left; $N = 24$) and to the Verb-Switch Condition (on the right; $N = 24$). Error bars represent the standard error of the mean. Each trial has a maximal duration of 50 seconds. There was a significant interaction between Condition and Phase (habituation/test). Figure adapted from de Carvalho et al. (2015).

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prosody (that delimits syntactic constituents), together with the function words (to label these syntactic constituents), in order to access the syntactic category of unknown words. In other words, putting together phrasal prosody and function words allows infants to construct a first-pass syntactic structure, which may be extremely important to constrain the acquisition of word meanings (a *syntactic skeleton*, Christophe et al., 2008).

Other recent studies using an artificial language (Hawthorne & Gerken, 2014; Hawthorne, Mazuka, & Gerken, 2015) or jabberwocky sentences (Massicotte-Laforge & Shi, 2015) have confirmed the idea that phrasal prosody may help infants organize sentences into syntactic constituents even when they do not know most of the words. For example, Hawthorne and Gerken (2014) tested the syntactic organization of sentences composed exclusively of non-words. For instance, when familiarized with non-word sentences exhibiting the prosodic pattern of two syntactic constituents, such as "[*bup div kagî*] [*feb zaf vot*]", 19-month-olds then preferred to listen to sentences like [*feb zaf vot*] [*bup div kagî*] – where the order of the two constituents is changed – than to sentences like [*zaf vot bup*] [*div kagî feb*] in which words are moved around irrespective of the constituent structure (whereas in natural languages, only words that are grouped in the same constituent can 'move' together – Hawthorne & Gerken, 2014). Hawthorne et al. (2015) extended these findings to strings of nonwords with non-native prosody. Testing English- and Japanese- acquiring 19-month-olds with sentences from an artificial language with a non-native prosodic contour (i.e., English infants with Japanese prosody and Japanese infants with English prosody), the authors demonstrated that both groups were able to use phrasal prosody to parse the speech into cohesive and re-orderable syntactic constituent-like units. This finding suggests that the cues that marked syntactic constituents boundaries in these experiments (e.g., pauses, pitch variation and phrase-final lenghthining cues) are important prosodic cues that toddlers can exploit even in non-native prosody. More generally, since phrasal prosody is found in all languages (e.g., Shattuck-Hufnagel & Turk, 1996) one would expect infants to be able to use phrasal prosody to identify word and syntactic boundaries in any language of the world.

## Conclusions

This chapter provided an extensive review of empirical findings on the perception of phrasal prosody during the first steps of language acquisition. We showed that infants are sensitive to prosodic information from birth. Before their first birthday they can use phrasal prosody to segment continuous speech into words and they

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can also exploit prosodic information together with other cues (i.e., the position of function words relative to content words) to infer the typical word order in their language. A few months later, they readily exploit the prosodic structure of an utterance to access some of its syntactic constituents. Together with function words, this allows young children to build a partial syntactic representation, which can in some cases help them to assign a syntactic category to a novel word (e.g. noun vs. verb). Taken together, these results demonstrate the important role played by phrasal prosody during the first steps of language acquisition.

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