

# *Bootstrapping Lexical and Syntactic Acquisition*

**Anne Christophe<sup>1,2</sup>, Séverine Millotte<sup>1,3</sup>,  
Savita Bernal<sup>1</sup>, Jeffrey Lidz<sup>4</sup>**

<sup>1</sup> *Laboratoire de Sciences Cognitives et Psycholinguistique, EHESS / CNRS / DEC-ENS, Paris*

<sup>2</sup> *Maternité Port-Royal, AP-HP, Faculté de Médecine Paris Descartes*

<sup>3</sup> *Laboratoire de Psycholinguistique Expérimentale, Genève*

<sup>4</sup> *Cognitive Neuroscience of Language Laboratory, Department of Linguistics, University of Maryland, U.S.A.*

## **Key words**

*function words*

*language acquisition*

*phrasal prosody*

## **Abstract**

This paper focuses on how phrasal prosody and function words may interact during early language acquisition. Experimental results show that infants have access to intermediate prosodic phrases (phonological phrases) during the first year of life, and use these to constrain lexical segmentation. These same intermediate prosodic phrases are used by adults to constrain on-line syntactic analysis. In addition, by two years of age infants can exploit function words to infer the syntactic category of unknown content words (nouns vs. verbs) and guess their plausible meaning (object vs. action). We speculate on how infants may build a partial syntactic structure by relying on both phonological phrase boundaries and function words, and present adult results that test the plausibility of this hypothesis. These results are tied together within a model of the architecture of the first stages of language processing, and their acquisition.

## **1 Introduction**

Infants acquiring language have to learn about the lexicon, the phonology, and the syntax of their native language. For each of these domains, being able to rely on knowledge from the other domains would simplify the learner's task. For instance, since syntactic structure spells out the relationships between words in a sentence, it

---

*Acknowledgments:* The work presented in this paper was supported by a grant from the French ministry of Research to the first author (ACI n° JC6059), by two grants from the Direction Générale de l'Armement to the second author (PhD and post doctoral fellowships), by a PhD grant from the French Ministry of Research to the third author, by a CNRS Poste Rouge to the fourth author (in 2004), by a grant from the National Institute of Health (R03-DC006829) by a grant from the Agence Nationale de la Recherche ("Acquisition précoce du lexique et de la syntaxe," n° ANR-05-BLAN-0065-01) and by the European Commission FP6 Neurocom project.

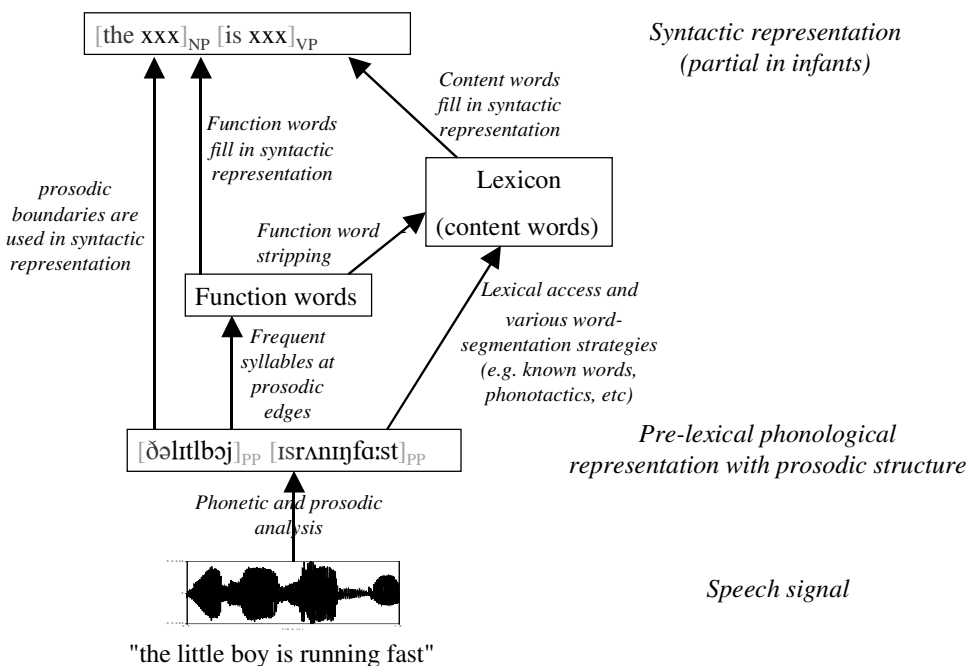
*Address for correspondence.* Anne Christophe, LSCP, ENS, 29, rue d'Ulm, 75005 Paris, FRANCE; phone: (33) 01 44 32 26 18; fax: (33) 01 44 32 26 30; e-mail: <anne.christophe@ens.fr>.

makes sense to assume that infants need to have access to words and their meanings in order to learn about syntax. Conversely, learning about the meaning of words would be greatly facilitated if infants had access to some aspects of syntactic structure (Gillette, Gleitman, Gleitman, & Lederer, 1999; Gleitman, 1990). These potential circularities can partially be solved if infants can learn some aspects of the structure of their language through a surface analysis of the speech input they are exposed to. Morgan and Demuth (1996) introduce the term *phonological bootstrapping* to express the idea that a purely phonological analysis of speech may give infants some information about the structure of their language.

In this paper, we focus on the very beginning of language acquisition, and consider processes that may happen during the first two years of life. More specifically, we discuss how infants may start building a lexicon, and how they may start acquiring rudiments of syntax, that is, building the skeleton of a syntactic tree. In particular, we examine the role of two sources of information to which very young infants may plausibly have access: phrasal prosody and function words. The model in Figure 1 summarizes our hypotheses about the architecture of the speech processing system and its acquisition.

**Figure 1**

A model of speech processing and early language acquisition



One central feature of this processing model is the existence of a prelexical phonological representation containing information both on the phonetic content of the utterance and on its prosodic structure (see Figure 1). This prelexical representation

is computed from the speech signal and used for lexical access. Thus, one prediction of the model is that lexical access occurs within the domain of units defined by phrasal prosody, such as *phonological phrases*: The first section of this paper reviews experimental data showing that both infants and adults rely on phonological phrase boundaries to constrain on-line lexical access. Phrasal prosody, the rhythm and melody of speech, has long been known to be processed very early on by infants (see e.g., Mehler, Jusczyk, Lambertz, Halsted, Bertoni, & Amiel-Tison, 1988), and has often been assumed to provide them with information about some aspects of their mother tongue (see e.g., Christophe, Nespors, Guasti, & van Ooyen, 2003; Gleitman & Wanner, 1982; Morgan, 1986).

A second crucial aspect of the model is the special role played by function words (e.g., determiners, auxiliaries, prepositions, etc.). They are represented within a special lexicon, that is built and accessed from the prelexical representation (paying special attention to prosodic edges) and that directly informs syntactic processing. Infants may be able to discover function words quite early in their acquisition of language because they are extremely frequent syllables that typically occur at prosodic edges (beginning or end depending on the language). The second section reviews the literature on infants' knowledge of function words, and presents experimental data showing that 2-year-olds are able to exploit function words to infer the syntactic category of unknown content words (and therefore constrain their meaning).

The top part of the model features syntactic analysis. We assume that it is fed by three types of information: the content word lexicon (trivially), the function word lexicon, and the prosodic structure (hence the direct arrow between the prelexical representation and syntactic processing). In the third section, we present experimental evidence showing that phonological phrase boundaries are directly used to constrain syntactic analysis, in adults. We also present evidence that even in the absence of information from the content word lexicon (using *jabberwocky*), function words and phrasal prosody allow adults to perform a first-pass syntactic analysis. This situation may well mimic infants' speech processing at a stage of their development where they already have fair knowledge of both the phrasal prosody and function words of their native language, but are still faced with many unknown content words.

One last feature of the model is worth mentioning, the "function-word-stripping" process, suggesting that recognition of a function word facilitates access to the immediately neighboring content word. This procedure was first proposed in Christophe, Guasti, Nespors, Dupoux, & van Ooyen (1997) and has since then been confirmed both in adults (Christophe, Welby, Bernal, & Millotte, 2005) and in infants (Hallé, Durand, & de Boysson-Bardies, this issue; Shi & LePage, 2008). Thus, Hallé and colleagues (this issue) showed that 11-month-old French infants recognized known words when they were presented in the context of an appropriate function word (i.e., an article, as in *les chaussures* 'the shoes'), but not when they were presented in the context of a nonsense function word (e.g., *mã chaussures*, where /mã/ is a nonsense word). Shi and LePage (2008) showed that French-speaking 8-month-olds familiarized with an "article + noun" string (e.g., *des preuves*, 'some evidence') then chose to listen longer to the isolated noun (*preuves*, 'evidence'), in contrast to when they were familiarized with a "nonsense item + noun" string (e.g., *ké preuves*, where /ké/ is a nonsense item).

## 2 Phonological phrases constrain on-line lexical access in both infants and adults

The first main feature of the model presented in Figure 1 is the prelexical *phonological representation with prosodic structure*. Phrasal prosody is the pitch modulation and rhythmic variation of speech utterances. The two major prosodic units are intonational phrases and phonological phrases (Nespor & Vogel, 1986). Phonological phrases typically contain one or two content words together with the function words that are associated with them. For instance, the sentence “the little boy is running fast” contains two phonological phrases, as in [the little boy] [is running fast].<sup>1</sup> Phonological phrases tend to contain between four and seven syllables, are typically marked by phrase-final lengthening and phrase-initial strengthening, and usually consist of one intonation contour with a potential pitch discontinuity at the boundary (see Christophe, Gout, Peperkamp, & Morgan, 2003; Shattuck-Hufnagel & Turk, 1996, for reviews).

If this prelexical phonological representation exists and is the basis for lexical access (as depicted on the model by the arrow between the prelexical representation and the content word lexicon), then we predict that whenever a prosodic boundary occurs in the prelexical representation, it corresponds to a word boundary. In other words, lexical access should operate within the domain of phonological phrases, and lexical candidates that straddle a phonological phrase boundary should never get activated. To test this hypothesis, we presented adults with sentences containing local lexical ambiguities, in French (Christophe, Peperkamp, Pallier, Block, & Mehler, 2004). We observed delayed lexical access when a local lexical ambiguity occurred within a phonological phrase (consistently with the literature, see e.g., McQueen, Norris, & Cutler, 1994). Thus, the string of words ‘[un *chat grincheux*]’ (‘a grumpy cat’), containing the potential competitor word *chagrin* (‘sorrow’), was processed more slowly than ‘[un chat drogué]’ that contains no potential competitor (since no French word starts with *chad*).

In contrast, when the lexical competitor straddled a phonological phrase boundary, there was no delay in lexical recognition. For instance, the processing of ‘[son grand *chat*] [*grimpe* aux arbres]’ (‘his big cat was climbing trees’) that contains the potential competitor word *chagrin*, was not delayed relative to an unambiguous control. These results suggest that lexical access occurs within the domain of phonological phrases in adults. The result that prosodic structure influences lexical access

<sup>1</sup> In that example, the prosodic break corresponds to the main syntactic break, between the subject Noun Phrase and the Verb Phrase. This is not necessarily the case: For instance, in [He was eating] [an enormous apple], the prosodic break falls within the Verb Phrase (between the Verb and its complement) and the major syntactic break (between the subject pronoun ‘he’ and the Verb Phrase) is not marked prosodically. The prosodic structure is thus clearly not identical to the syntactic structure, and prosodic units do not systematically correspond to syntactic constituents (e.g., [he was eating] is not a syntactic constituent in the above sentence). However, whenever a prosodic boundary is encountered in the signal, it does correspond to a syntactic boundary. It is in that sense that infants and adults may use the prosodic structure to make inferences about syntactic structure.

had also been observed in other languages, with different experimental techniques (e.g., Davis, Marslen-Wilson, & Gaskell, 2002, for English; Salverda, Dahan, & McQueen, 2003; Shatzman & McQueen, 2006a; and Shatzman & McQueen, 2006b, for Dutch).

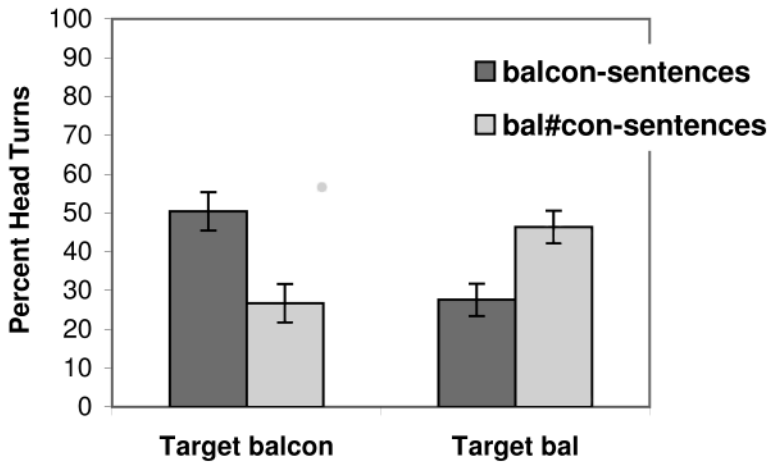
How about infants? Previous research has already shown that even newborn infants are able to discriminate bisyllabic strings that differ only in the presence or absence of a phonological phrase boundary (Christophe, Dupoux, Bertoni, & Mehler, 1994; Christophe, Mehler, & Sebastián-Gallés, 2001), and that by nine months of age, infants react to the disruption of phonological phrases (Gerken, Jusczyk, & Mandel, 1994; Jusczyk, Kemler-Nelson, Hirsh-Pasek, Kennedy, Woodward, & Piwoz, 1992). This suggests that phonological phrases are perceived by infants in their first year of life. More directly, we exploited a variant of the conditioned head-turning technique that is equivalent to the word-monitoring task used in adults (Gout, Christophe, & Morgan, 2004). Infants were trained to turn their head for a given word, for example, *paper*. A few days later, they came back and were exposed to whole sentences, some of which really contained the target word *paper*, as in [The college] [with the biggest **paper** forms] [is best], while others contain both syllables of the target word *paper*, separated by a phonological phrase boundary, as in [The butler] [with the highest **pay**] [**per**forms the most]. With this experimental technique, we observed that American 10- and 13-month-olds responded significantly more often to sentences containing *paper* than to sentences containing the two syllables *pay*]/*per* separated by a phonological phrase boundary. A control group of infants trained to turn their head for the monosyllabic word *pay* showed the reverse pattern (acoustic analyses of the stimuli showed that the *pay* and *per* syllables in both sentence types differed only in their prosodic characteristics, duration, pitch, and intensity). These results show that American infants as young as 10 months of age do exploit phonological phrase boundaries to constrain lexical access: they do not attempt to recognize a word that straddles a phonological phrase boundary (see also Johnson, in press).

This experiment was replicated with French infants and sentences. We used a target word such as *balcon* (balcony). Test sentences either contained the target word *balcon*, such as [Ce grand **balcon**] [venait d'être détruit] ('this big balcony had only just been destroyed'), or contained both syllables of *balcon* separated by a phonological phrase boundary, as in [Ce grand **bal**] [**con**sacrera leur union] ('this great ball will consecrate their union'). Just as with American infants, we observed that French 16-month-olds trained to turn their head for *balcon* responded more often to *balcon*-sentences than to *bal*]/*con*-sentences, while infants trained to turn their head for the monosyllabic word *bal* showed the reverse pattern<sup>2</sup> (see Figure 2).

<sup>2</sup> French infants succeed in the word-detection task later than American infants. They find it hard to find words in the middle of long sentences before the age of 13–14 months (which makes it hard to test their ability to exploit phonological phrase boundaries per se). This delay of French infants in word-finding tasks has also been observed with other experimental techniques (Gout, 2001) and in other laboratories (Nazzi, Iakimova, Bertoni, Frédonie, & Alcantara, 2006).

**Figure 2**

Results of a conditioned head-turning experiment with 36 French 16-month-olds (adapted from Millotte, 2005)



These results show that both adults and infants access their lexicon from a prelexical representation that contains some information about prosodic structure. In other words, prosodic structure is computed on-line as the speech signal unfolds, and lexical access occurs within the domain of phonological phrases (as represented in the model in Figure 1). It so happens that phonological phrases occur in all of the world's languages, and are marked with similar cues in all the languages that have been studied so far. Thus, phrase-final lengthening has been observed in many unrelated languages (e.g., Barbosa, 2002 for Brazilian Portuguese; de Pijper & Sanderman, 1994, for Dutch; Fisher & Tokura, 1996, for Japanese; Rietveld, 1980, for French; Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992, for English) as well as phrase-initial strengthening (e.g., Cho & Keating, 2001 for Korean; Fougeron, 2001 for French; Keating, Cho, Fougeron, & Hsu, 2003 for Korean, Taiwanese, French and English). It is thus very possible that relying on phonological phrase boundaries to constrain lexical access and syntactic processing is a universal procedure that is used in all languages.<sup>3</sup>

<sup>3</sup> Note however that even if the cues used to mark phonological phrases are universal, infants may still have to learn a lot about the phonology of their native language before they can exploit them. For instance, duration is a strong cue to phrasal prosody; however duration is also used to convey differences between phonemes, in some languages. Thus, when a given segment is lengthened, infants have to find ways to figure out whether this is due to its position within the prosodic structure (e.g., unit-final), or whether it is an intrinsic feature of that segment (e.g., it is a long vowel or consonant).

### 3 Using function words to infer words' syntactic categories

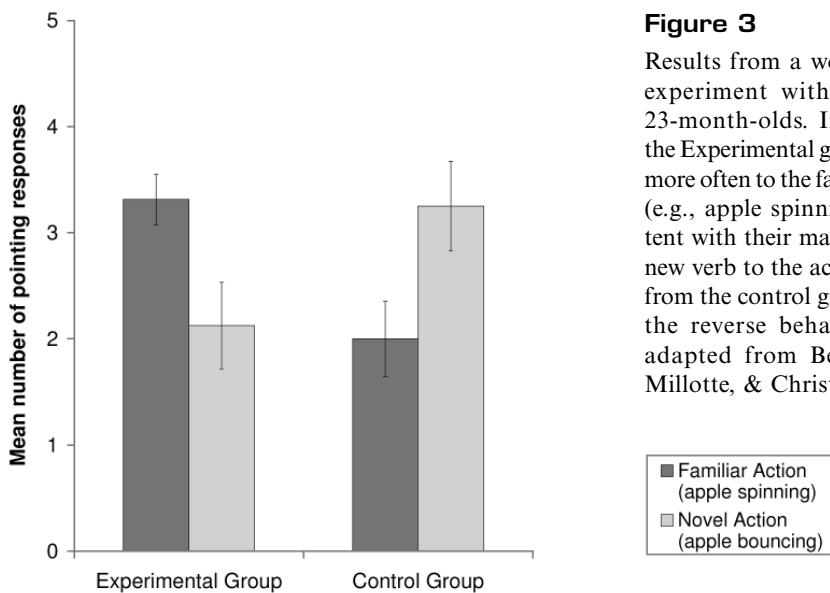
The second crucial feature of the processing model presented in Figure 1 is the special role of function words. Function words and morphemes are extremely frequent items, often short (monosyllabic), which tend to occur at the borders of prosodic units (Shi, Morgan, & Allopenna, 1998). Infants could thus compile a list of the syllables that occur at the beginnings and ends of prosodic units, store the most frequent ones in a separate list, and subsequently identify these syllables as closed-class items when encountered at the borders of a prosodic unit. In favor of this hypothesis, several experiments showed that infants around their first birthday already possess some knowledge of the function words of their language (Hallé et al., this issue; Shady, 1996; Shafer, Shucard, Shucard, & Gerken, 1998; Shi, Werker, & Cutler, 2006).

Identifying a list of functional items would not be sufficient for infants to start doing even a rough syntactic analysis: To that end, infants would need, in addition, to identify categories of function words, such as determiners (signaling nouns) and pronouns (signaling verbs). A recent experiment by Höhle, Weissenborn, and colleagues suggests that German infants around 16 months of age may already be able to identify the category determiners (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004). In this experiment, infants familiarized with a nonsense word in the context of a determiner (e.g., *das Pronk*, 'the pronk') listened longer to sentences where this nonsense word occupied the position of a verb, than to sentences where it appeared as a noun (thus showing a significant novelty preference). The same effect was not obtained for nonsense verbs. In another recent experiment, Kedar, Casasola and Lust (2006) showed that 18- and 24-month-old American infants were better at identifying a known noun depending on whether it was preceded by a correct function word (*the*) or an inappropriate one (*and*, as in "Look at *and* ball!", see also Gerken & McIntosh, 1993; Zangl & Fernald, 2007).

These results suggest that infants within their second year of life are already figuring out what the categories of functional items are in their language. The next step for them is to exploit the function words to infer the syntactic categories of neighboring content words. Recent computational work shows that an uninformed analysis of child-directed speech can yield remarkably good content word categorization by relying on function words (Chemla, Mintz, Bernal, & Christophe, in press; Mintz, 2003). To experimentally test infants' ability to categorize content words, we exploited the fact that nouns tend to map to objects, while verbs tend to map to actions. We used a word-learning task in which 23-month-old French infants were presented with one object (e.g., an apple) undergoing an action (e.g., spinning). Infants in the Verb condition were taught a novel verb, within sentences that contained only function words and attention-getters, for example, "*Regarde, elle dase!*" ('Look, it is **dazing**'). In a similar situation, adults would infer that the new word, '*dase*', is a verb and refers to the action. Infants' comprehension was tested by showing them two pictures of the now-familiar object (e.g., the apple), one with an action matching that of the familiarization phase (e.g., *spinning*), and the other with a novel action (e.g.,

*bouncing*). Infants were asked to point in response to a question containing the novel word (“*Montre-moi celle qui dase!*” ‘Show me the one that’s dazzling’).

The results show that 23-month-olds who were taught a new verb, point more often to the familiar action (e.g., *apple spinning*) than to the new one (*apple bouncing*) (see Figure 3). Even though this behavior is consistent with our hypothesis that they interpreted the novel word as a verb and therefore inferred that it referred to the action, an alternative interpretation cannot be ruled out. In particular, infants may have ignored the syntactic structure information, and may have mapped the new word to *spinning apple*. Or, they may have mapped it to *apple*, and when given the choice between two apples in test, they may have chosen the spinning one on the grounds that it was more likely to be “the same one as before.” To invalidate this alternative interpretation, we ran a control group of infants: They were taught a novel noun on the same visual scenes, for example, “*Regarde la dase!*” (‘Look at the daz’). Crucially, the sentences used in the Noun and the Verb condition differed minimally, and only by their function words (*elle* vs. *la* in the example given). Infants in the Noun group were asked to point to the “dase” during test (“*Montre-moi la dase!*” ‘Show me the daz!’). In a similar situation, adults would infer that the new word, “dase” refers to the object, and therefore the question is stupid (two identical objects are presented, both are “dase”). However, if infants in the experimental group chose the spinning apple because it was more likely to be “the same one as before,” then infants from the control group should exhibit the exact same behavior. In sharp contrast, we observed that infants from the control group pointed significantly more often to the novel action than to the familiar one. The interaction between the type of action (familiar/novel) and the experimental condition (experimental/control) was highly significant. The difference in behavior between groups of infants can only come from their processing of the linguistic stimuli during the familiarization phase.



**Figure 3**

Results from a word-learning experiment with 32 French 23-month-olds. Infants from the Experimental group pointed more often to the familiar action (e.g., apple spinning), consistent with their mapping of the new verb to the action. Infants from the control group showed the reverse behavior (figure adapted from Bernal, Lidz, Millotte, & Christophe, 2007)



These results show that 23-month-old infants are able to use function words to perform a syntactic analysis of short sentences, and infer the syntactic category of unknown content words. In addition, they exploit this knowledge to constrain the possible meanings of these new words (in our case, verb = action — previous work had already shown that infants were able to map new nouns to objects, see e.g., Waxman & Booth, 2001).

## 4 Syntactic analysis is supported by phrasal prosody and function words

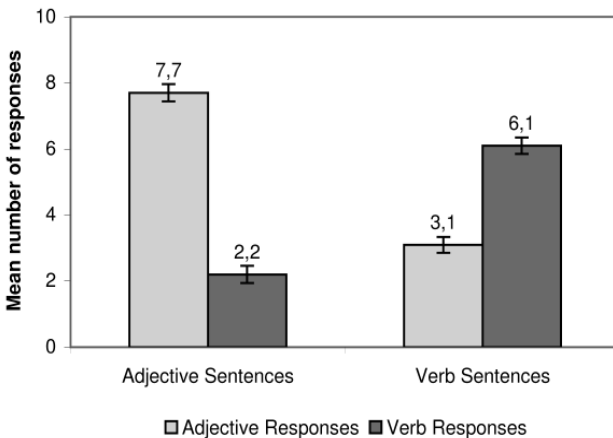
As we mentioned in the introduction, phonological phrase boundaries always coincide with the boundaries of syntactic constituents. As a result, it would make sense for both infants and adults to exploit phonological phrase boundaries to constrain their on-line syntactic analysis. To test this hypothesis, we created temporarily ambiguous sentences in French, exploiting the fact that two homophones can belong to different syntactic categories (e.g., a verb and an adjective), as in:

Adjective sentence: “[le petit chien **mort**] ...” — “[the little **dead** dog] ...’

Verb sentence: “[le petit chien] [**mord** ... ]” — “[the little dog] [**bites** ... ]’

These sentences were cut just after the ambiguous word and presented to French adults in a completion task, in which participants listened to the beginnings of ambiguous sentences and completed them in writing. We observed that French adults distinguished between two sentence beginnings that differed only syntactically and prosodically (Millotte, Wales, & Christophe, 2007). Before they had access to the disambiguating information, adults gave more adjective responses to adjective sentences than to verb sentences, and vice-versa for verb responses (see Figure 4). These results were replicated with an on-line word detection task in which adults had to respond to words specified with their syntactic category (see next experiment for a more detailed description of the task, Millotte, René, Wales, & Christophe, in press).

These results demonstrate that adults exploit phonological phrase boundaries to constrain their on-line syntactic analysis. They lend support to our hypothesis that



**Figure 4**

Results from a completion task in which participants listened to ambiguous sentence beginnings, cut just after the end of the ambiguous word. Subjects gave adjective interpretations of the ambiguous words when listening to the beginning of an adjective sentence, and verb interpretations when listening to verb sentences (figure adapted from Millotte et al., 2007)

information about phrasal prosody directly informs syntactic processing (represented on the model in Figure 1 by the direct arrow between the prelexical representation and syntactic processing). The model puts forward the hypothesis that infants may compute a preliminary syntactic structure by relying both on prosodic boundaries and function words: prosodic boundaries would give syntactic constituent boundaries, while function words would allow infants to label these constituents. To spell out the example from the model, in the sentence [*The little boy*] [*is running fast*], brackets are given by phrasal prosody. The first unit would be identified as a Noun Phrase because it starts with the determiner *the*, while the second unit would be identified as a Verb Phrase because it starts with the auxiliary *is*. Infants might thus hear this sentence as [*The XXX*]<sub>NP</sub> [*is XXX*]<sub>VP</sub>, where brackets are given by prosody, and labels by the function words *the* and *is*.

To test the plausibility of this hypothesis, we presented adult participants with *jabberwocky* sentences, where function words and prosodic information were preserved, but all content words were replaced by nonwords (Millotte, Wales, Dupoux, & Christophe, 2006). In that way, we simulated the situation of an 18-month-old infant, who may have access to prosodic boundaries and function words, but does not know many content words yet. We created two experimental conditions, one where the target word was immediately preceded by a function word that gave its category (determiner for nouns, pronoun for verbs), and another one where the target word was not immediately preceded by a function word, and a more complex analysis was needed. Instances of experimental sentences are presented below (where *pardale* is the target word, the French gloss and its English translation are provided below each example):

“*Adjacent function word*” condition:

Verb sentence: [Elle **pardale**] [tru les sbimes] [de grabifouner]  
[Elle **promet**] [toutes les semaines] [de téléphoner]

*She promises every week to phone*

Noun sentence: [Un **pardale**] [ga tachin proquire]  
[Un **cadeau**] [fait toujours plaisir]

*A gift always gives pleasure*

“*Function word and Prosody*” condition:

Verb sentence: [Un gouminet] [**pardale** tigou] [d’aigo soujer]  
[Un étudiant] [**promet** toujours] [d’être sérieux]

*A student always promises to be serious*

Noun sentence: [Un gouminet **pardale**] [agoche mon atrulon]  
[Un incroyable **cadeau**] [attire mon attention]

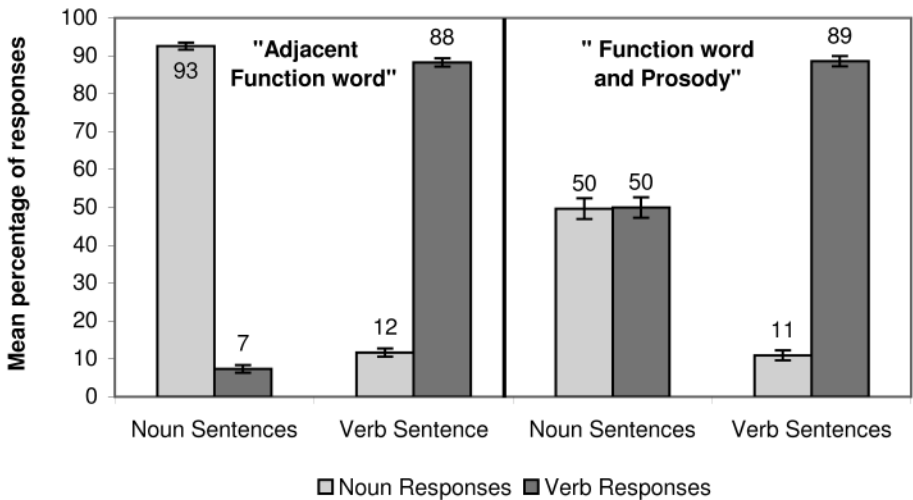
*An incredible gift draws my attention*

French adults performed an abstract word detection task, in which targets were specified with their syntactic category. Thus, verb targets were presented in infinitive form (e.g., *pardaler* ‘to pardale’) and participants were told that they had to respond

to the word whatever its surface form (e.g., past, future, singular, or plural subject). Noun targets were specified as “article + noun” (e.g., *un pirdale*, ‘a pirdale’). Whenever participants were presented with a verb target, they had to respond to sentences containing verb targets, and refrain from responding to sentences containing noun targets (and vice-versa for the detection of a noun target).

**Figure 5**

Results from an abstract word detection experiment with Jabberwocky sentences: Subjects correctly identified the syntactic category of an unknown content word that was immediately preceded by a function word (left-hand half of the figure); in contrast, when there was an intervening content nonword, subjects succeeded only in the verb condition, when the to-be-categorized nonword was immediately preceded by a phonological phrase boundary (figure adapted from Millotte et al., 2006)



The results, presented in Figure 5, indicate that participants were perfectly able to use the presence of a function word to infer the syntactic category of the following nonsense content word (“adjacent function word” condition). In more than 90% of the cases, a nonword preceded by an article was interpreted as a noun, whereas it was considered to be a verb when preceded by a pronoun (this was true even though the crucial function word was not systematically positioned sentence-initially, or even phonological-phrase-initially). In the second experimental condition, “function word and prosody,” performance was excellent for verb sentences (90% correct responses), where a prosodic boundary was placed just before the target word. In contrast, performance in noun sentences was at chance (50%), which may in part be due to the fact that the relevant information, the prosodic boundary, occurred after the target word rather than before it.

Thus, in this experiment, function words and prosodic boundaries allowed listeners to start building a syntactic structure for spoken sentences, even in the absence of any information about the content words themselves (neither their meaning nor their syntactic category could be retrieved from the lexicon). French adults used

phonological phrase boundaries to define syntactic boundaries; they used function words to label these syntactic constituents (noun phrase, verb phrase) and infer the syntactic category of target words. Young infants in their second year of life, who do not yet know many content words, but may well have access to function words and prosodic boundaries, may thus also be able to perform this kind of syntactic analysis.

## **5 Conclusion**

To summarize, we propose that infants could bootstrap their lexical and syntactic acquisition by paying attention to two specific sources of information that can be available early on, without much knowledge of their native language: phrasal prosody and function words. We reviewed experimental results showing that both infants and adults exploit prosodic boundary information on-line to constrain lexical access (Part 1, Christophe et al., 2004; Gout et al., 2004; Millotte, 2005; Salverda et al., 2003; Shatzman & McQueen, 2006a). Regarding function words, we reviewed experimental data showing both that young infants already have some knowledge of the functional items of their native language around one year of age (Hallé et al., this issue; Shady, 1996; Shafer et al., 1998; Shi, 2005), and that they start to exploit them to infer something about the syntactic category of adjoining content words and their meaning in their second year of life (Part 2, Bernal et al., 2007; see also Fisher, Klingler, & Song, 2006; Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004).

Finally, we propose that both infants and adults could perform a first-pass syntactic analysis of incoming speech by putting together these two pieces of information, function words and phrasal prosody: Prosodic boundaries would give syntactic constituent boundaries, while function words would help label these constituents. This hypothesis was supported by the results of adult experiments using either locally ambiguous or jabberwocky sentences (see Part 3, Millotte 2006, submitted; Millotte et al., in press; Millotte et al., 2007). In adults, this first-pass syntactic analysis may allow listeners to make on-line guesses as to the syntactic category of upcoming content words, and therefore accelerate lexical access and reduce ambiguity. In infants, this first-pass analysis may be all they initially have to constrain their acquisition of the meaning of unknown lexical items. In fact, infants of about 18 months of age may well be in a situation similar to that of adults listening to jabberwocky sentences: They may already be able to perform an adequate analysis of phrasal prosody, may know a lot about the (most frequent) function words of their language, but would not yet know many of its content words. Future work should explicitly test how well infants in their second year of life are able to integrate function words and phrasal prosody, as well as extend the existing results to more typologically-varied languages.

*manuscript received: 05. 07. 2006*

*manuscript accepted: 01. 02. 2007*

---

## References

- BARBOSA, P. A. (2002). Integrating gestural temporal constraints in a model of speech rhythm production. In S. Hawkins & N. NGuyen (Eds.), *Proceedings of the ISCA workshop on Temporal Integration in the Perception of Speech* (p. 54). Cambridge: Cambridge University Printing Service.
- BERNAL, S., LIDZ, J., MILLOTTE, S., & CHRISTOPHE, A. (2007). Syntax constrains the acquisition of verb meaning. *Language Learning and Development*, **3**, 325–341.
- CHEMLA, E., MINTZ, T. H., BERNAL, S., & CHRISTOPHE, A. (in press). Categorizing words using “Frequent Frames”: What cross-linguistic analyses reveal about distributional acquisition strategies. *Developmental Science*.
- CHO, T., & KEATING, P. (2001). Articulatory strengthening at the onset of prosodic domains in Korean. *Journal of Phonetics*, **28**, 155–190.
- CHRISTOPHE, A., DUPOUX, E., BERTONCINI, J., & MEHLER, J. (1994). Do infants perceive word boundaries? An empirical study of the bootstrapping of lexical acquisition. *Journal of the Acoustical Society of America*, **95**, 1570–1580.
- CHRISTOPHE, A., GOUT, A., PEPPERKAMP, S., & MORGAN, J. L. (2003). Discovering words in the continuous speech stream: The role of prosody. *Journal of Phonetics*, **31**, 585–598.
- CHRISTOPHE, A., GUASTI, M. T., NESPOR, M., DUPOUX, E., & van OUYEN, B. (1997). Reflections on phonological bootstrapping: Its role for lexical and syntactic acquisition. *Language and Cognitive Processes*, **12**, 585–612.
- CHRISTOPHE, A., MEHLER, J., & SEBASTIÁN-GALLÉS, N. (2001). Perception of prosodic boundary correlates by newborn infants. *Infancy*, **2**, 385–394.
- CHRISTOPHE, A., NESPOR, M., GUASTI, M. T., & van OUYEN, B. (2003). Prosodic structure and syntactic acquisition: The case of the head-complement parameter. *Developmental Science*, **6**(2), 213–222.
- CHRISTOPHE, A., PEPPERKAMP, S., PALLIER, C., BLOCK, E., & MEHLER, J. (2004). Phonological phrase boundaries constrain lexical access: I. Adult data. *Journal of Memory and Language*, **51**, 523–547.
- CHRISTOPHE, A., WELBY, P., BERNAL, S., & MILLOTTE, S. (2005). *French adults interpret an initial rise as a word beginning*. Paper presented at the Architectures and Mechanisms for Language Processing, Gand.
- DAVIS, M. H., MARSLÉN-WILSON, W. D., & GASKELL, M. G. (2002). Leading up the lexical garden-path: Segmentation and ambiguity in spoken word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, **28**, 218–244.
- De PIJPER, J. R., & SANDERMAN, A. A. (1994). On the perceptual strength of prosodic boundaries and its relation to suprasegmental cues. *Journal of the Acoustical Society of America*, **96**, 2037–2047.
- FISHER, C., KLINGLER, S. L., & SONG, H.-J. (2006). What does syntax say about space? Two-year-olds use sentence structure to learn new prepositions. *Cognition*, **101**, B19–B29.
- FISHER, C., & TOKURA, H. (1996). Prosody in speech to infants: Direct and indirect acoustic cues to syntactic structure. In J. L. Morgan & K. Demuth (Eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition* (pp. 343–363). Mahwah, NJ: Lawrence Erlbaum Associates.
- FOUGERON, C. (2001). Articulatory properties of initial segments in several prosodic constituents in French. *Journal of Phonetics*, **29**, 109–135.
- GERKEN, L., JUSCZYK, P. W., & MANDEL, D. R. (1994). When prosody fails to cue syntactic structure: 9-month-olds’ sensitivity to phonological versus syntactic phrases. *Cognition*, **51**, 237–265.
- GERKEN, L., & McINTOSH, B. (1993). Interplay of function morphemes and prosody in early language. *Developmental Psychology*, **29**, 448–457.

- GILLETTE, J., GLEITMAN, H., GLEITMAN, L., & LEDERER, A. (1999). Human simulations of vocabulary learning. *Cognition*, **73**, 165–176.
- GLEITMAN, L. (1990). The structural sources of verb meanings. *Language Acquisition*, **1**, 3–55.
- GLEITMAN, L., & WANNER, E. (1982). The state of the state of the art. In E. Wanner & L. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 3–48). Cambridge U.K.: Cambridge University Press.
- GOUT, A. (2001). *Etapes précoces de l'acquisition du lexique*. Unpublished PhD thesis, Ecole des Hautes Etudes en Sciences Sociales, Paris.
- GOUT, A., CHRISTOPHE, A., & MORGAN, J. (2004). Phonological phrase boundaries constrain lexical access: II. Infant data. *Journal of Memory and Language*, **51**, 548–567.
- HALLÉ, P., DURAND, C., & de BOYSSON-BARDIES, B. (2008). Do 11-month-old French infants process articles? *Language and Speech*, **51**, 23–44.
- HÖHLE, B., WEISSENORN, J., KIEFFER, D., SCHULZ, A., & SCHMITZ, M. (2004). Functional elements in infants' speech processing: The role of determiners in the syntactic categorization of lexical elements. *Infancy*, **5**, 341–353.
- JOHNSON, E. K. (in press). Infants use prosodically conditioned acoustic-phonetic cues to extract words from speech. *Journal of the Acoustical Society of America*.
- JUSCZYK, P. W., KEMLER-NELSON, D. G., HIRSH-PASEK, K., KENNEDY, L., WOODWARD, A., & PIWOZ, J. (1992). Perception of acoustic correlates of major phrasal units by young infants. *Cognitive Psychology*, **24**, 252–293.
- KEATING, P., CHO, T., FOUGERON, C., & HSU, C.-S. (2003). Domain-initial articulatory strengthening in four languages. In J. Local, R. Ogden, & R. Temple (Eds.), *Papers in Laboratory Phonology, VI: Phonetic Interpretation* (pp. 143–161). Cambridge: Cambridge University Press.
- KEDAR, Y., CASASOLA, M., & LUST, B. (2006). Getting there faster: 18- and 24-month-old infants' use of function words to determine reference. *Child Development*, **77**, 325–338.
- MCQUEEN, J. M., NORRIS, D., & CUTLER, A. (1994). Competition in spoken word recognition: Spotting words in other words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**, 621–638.
- MEHLER, J., JUSCZYK, P. W., LAMBERTZ, G., HALSTED, G., BERTONCINI, J., & AMIEL-TISON, C. (1988). A precursor of language acquisition in young infants. *Cognition*, **29**, 143–178.
- MILLOTTE, S. (2005). *Le rôle de la prosodie dans le traitement syntaxique adulte et l'acquisition de la syntaxe*. Unpublished PhD thesis, Ecole des Hautes Etudes en Sciences Sociales, Paris.
- MILLOTTE, S., WALES, R., DUPOUX, E., & CHRISTOPHE, A. (2006). Can prosodic cues and function words guide syntactic processing and acquisition? In R. Hoffmann & H. Mixdorff (Eds.), *Speech prosody: 3rd International Conference*. Dresden: Dresden TUD Press.
- MILLOTTE, S., RENÉ, A., WALES, R., & CHRISTOPHE, A. (in press). Phonological phrase boundaries constrain on-line syntactic analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.
- MILLOTTE, S., WALES, R., & CHRISTOPHE, A. (2007). Phrasal prosody disambiguates syntax. *Language and Cognitive Processes*, **22**, 898–909.
- MINTZ, T. H. (2003). Frequent frames as a cue for grammatical categories in child-directed speech. *Cognition*, **90**, 91–117.
- MORGAN, J. L. (1986). *From simple input to complex grammar*. Cambridge MA: MIT Press.
- MORGAN, J. L., & DEMUTH, K. (1996). Signal to syntax: An overview. In J. L. Morgan & K. Demuth (Eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition* (pp. 1–22). Mahwah, NJ: Lawrence Erlbaum Associates.
- NAZZI, T., IAKIMOVA, G., BERTONCINI, J., FREDONIE, S., & ALCANTARA, C. (2006). Early segmentation of fluent speech by infants acquiring French: Emerging evidence for crosslinguistic differences. *Journal of Memory and Language*, **54**, 283–299.

- NESPOR, M., & VOGEL, I. (1986). *Prosodic phonology*. Dordrecht: Foris.
- RIETVELD, A. C. M. (1980). Word boundaries in the French language. *Language and Speech*, **23**, 289–296.
- SALVERDA, A. P., DAHAN, D., & McQUEEN, J. (2003). The role of prosodic boundaries in the resolution of lexical embedding in speech comprehension. *Cognition*, **90**, 51–89.
- SHADY, M. (1996). *Infant's sensitivity to function morphemes*. Unpublished PhD Thesis, State University of New York, Buffalo.
- SHAFER, V. L., SHUCARD, D. W., SHUCARD, J. L., & GERKEN, L. (1998). An electrophysiological study of infants' sensitivity to the sound patterns of English speech. *Journal of Speech, Language and Hearing Research*, **41**, 874–886.
- SHATTUCK-HUFNAGEL, S., & TURK., A. E. (1996). A prosody tutorial for investigators of auditory sentence processing. *Journal of Psycholinguistic Research*, **25**, 193–247.
- SHATZMAN, K. B., & McQUEEN, J. M. (2006a). Prosodic knowledge affects the recognition of newly acquired words. *Psychological Science*, **17**(5), 372–377.
- SHATZMAN, K. B., & McQUEEN, J. M. (2006b). Segment duration as a cue to word boundaries in spoken-word recognition. *Perception and Psychophysics*, **68**, 1–16.
- SHI, R. (2005). *Perception of function words in preverbal infants*. Paper presented at the 10th International Congress for the Study of Child Language, Berlin, Germany.
- SHI, R., & LEPAGE, M. (2008). The effect of functional morphemes on word segmentation in preverbal infants. *Developmental Science*, **11**, 407–413.
- SHI, R., MORGAN, J. L., & ALLOPENNA, P. (1998). Phonological and acoustic bases for earliest grammatical category assignment: A cross-linguistic perspective. *Journal of Child Language*, **25**, 169–201.
- SHI, R., WERKER, J., & CUTLER, A. (2006). Recognition and representation of function words in English-learning infants. *Infancy*, **10**, 187–198.
- WAXMAN, S. R., & BOOTH, A. E. (2001). Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. *Cognitive Psychology*, **43**, 217–242.
- WIGHTMAN, C. W., SHATTUCK-HUFNAGEL, S., OSTENDORF, M., & PRICE, P. J. (1992). Segmental durations in the vicinity of prosodic phrase boundaries. *Journal of the Acoustical Society of America*, **91**, 1707–1717.
- ZANGL, R., & FERNALD, A. (2007). Increasing flexibility in children's online processing of grammatical and nonce determiners in fluent speech. *Language Learning and Development*, **3**, 199–231.