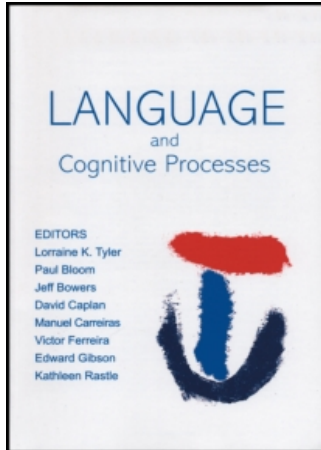


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Phrasal prosody disambiguates syntax

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Two experiments tested whether phonological phrase boundary cues, as produced by naïve speakers, constrain syntactic analysis in French. Pairs of homophones belonging to different syntactic categories (verb and adjective) were inserted within locally ambiguous sentences that differed in their prosodic structure (e.g., [les pommes dures] ... – *hard apples* ... – versus [les pommes] [durent ...] – *apples last* ... – where brackets indicate phonological phrase boundaries). In Experiment 1 six speakers, unaware of the ambiguities, recorded the sentences. Acoustical analyses showed that they all produced reliable prosodic cues (phrase-final lengthening and pitch rise). Experiment 2 tested whether listeners exploited these prosodic cues to constrain syntactic analysis. They listened to the sentences beginnings (cut after the ambiguous

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word) and completed them in writing. Their assignments of the target words to their correct syntactic categories were better than chance. We discuss these results in light of the on-going debate about the production of disambiguating prosody by speakers who are unaware of the ambiguities.

Several sentence comprehension studies have established that phrasal prosody can disambiguate syntactic structure (Beach, 1991; Kjelgaard & Speer, 1999; Marslen-Wilson, Tyler, Warren, Grenier, & Lee, 1992; Nagel, Shapiro, Tuller, & Nawy, 1996; Schafer, Speer, Warren, & White, 2000; Schepman & Rodway, 2000; Stirling & Wales, 1996). Listeners are able to exploit major intonation boundaries (typically intonational phrase boundaries) to parse syntactically ambiguous sentences. The role of intermediate prosodic boundaries (or phonological phrase boundaries) is more controversial. Kjelgaard & Speer (1999) and Schafer (1997) proposed that both intonational and phonological phrase boundaries affect syntactic interpretation. In contrast, Marcus & Hindle (1990) and Price, Ostendorf, Shattuck-Hufnagel, & Fong (1991) suggest that only intonational phrase boundaries have an effect on syntactic analysis. In the present study, we evaluated the influence of phonological phrase boundaries on syntactic ambiguity resolution.

In order to test the influence of prosody on syntactic parsing, researchers initially used either synthesised stimuli or sentences recorded by expert speakers who were aware of the syntactic ambiguities. However, whether non-expert speakers, who are not aware of the ambiguities, produce disambiguating cues is still very much debated. Some authors propose that only expert speakers produce disambiguating prosodic cues (Allbritton, McKoon, & Ratcliff, 1996; Fox Tree & Meijer, 2000; Snedeker & Trueswell, 2003), whereas others postulate that even naïve speakers spontaneously produce prosodic cues that are helpful for listeners (Kraljic & Brennan, 2005; Schafer et al., 2000; Schafer, Speer, & Warren, 2005; Schepman & Rodway, 2000).

For instance, Allbritton et al. (1996) used ambiguous sentences, such as 'They rose early in May', and had them read by both expert and non-expert speakers (actors vs. students). They found that only expert speakers produced informative prosodic cues, when they were aware of the aim of the experiment and were told to intentionally pronounce the sentences with one precise meaning (see also Fox Tree and Meijer, 2000, for similar results). On the other hand, Kraljic and Brennan (2005) triggered the production of ambiguous sentences during a cooperative game-playing task. In the sentence 'Put the dog in the basket on the star', the noun phrase 'in the basket' can either be attached as a modifier to the noun 'dog', or as a goal (it modifies the verb 'put'). They found that speakers spontaneously produced clearly disambiguating prosodic cues, that allowed listeners to correctly infer

the meaning of the ambiguous sentences, whether or not they were aware of the ambiguity. Kraljic and Brennan (2005) thus conclude that prosodic cues are a by-product of planning and articulating utterances.

One possible hypothesis to account for these divergent results focuses on the production task: cooperative game-playing would trigger prosodic disambiguation (as in Kraljic & Brennan, 2005) while reading would not (as in Allbritton et al., 1996). However, Snedeker and Trueswell (2003) also used a cooperative game-playing task and found that participants produced informative prosodic cues only when they were aware of the ambiguity (using ambiguous sentences such as 'Tap the frog with the flower').

An alternative hypothesis rests on the prosodic structure of the stimuli used in the different experiments. Even though prosodic structure reflects syntactic structure, the prosody-syntax congruency is not exact (Nespor & Vogel, 1986; Selkirk, 1982; Shattuck-Hufnagel & Turk, 1996). A prosodic boundary always signals a syntactic boundary, however the converse is not true; many syntactic boundaries are not marked prosodically. The actual realisation of a prosodic boundary in a sentence depends on several factors, such as the syntactic structure, but also the length of the resulting prosodic constituents, with overly long and overly short constituents being disfavoured (see for instance, Delais-Roussarie, 1995; Ferreira, 1993; Gee & Grosjean, 1983; Shattuck-Hufnagel & Turk, 1996; Vaissière, 1997). A phonological phrase typically consists of one or two content words together with the function words associated to them, and typically contains between 3 and 7 syllables (for instance, Delais-Roussarie, 1995, measured 3.8 syllables on average per phonological phrase, in French). For these reasons, it seems that sentences used in Allbritton et al. (1996) would be preferentially produced as one intonational phrase only (e.g., '[They rose early in May]'). Segmenting these sentences into two prosodic units (two intonational phrases or two phonological phrases) seems less felicitous: it would lead to the production of one very short prosodic unit, containing two syllables only (as in '[They rose] [early in May]' or '[They rose early] [in May]'). In Snedeker and Trueswell (2003), the resulting prosodic constituents for the 'modifier attachment' sentences should be '[Tap] [the frog with the flower]', where the first phonological phrase is too short (one syllable only), and therefore hard to produce naturally. In contrast, in Kraljic and Brennan's (2005) ambiguous sentences, the prosodic structures resulting from both readings were equally felicitous ('[Put the dog] [in the basket on the star]' and '[Put the dog in the basket] [on the star]'). As a result, these authors observed adequate disambiguation even by naïve speakers.

To validate this hypothesis, we devised locally ambiguous sentences such that the production of a disambiguating prosodic boundary should be felicitous. The syntactic ambiguity rested on the fact that two homophones can belong to different syntactic categories. For instance, in French, the word /dyr/ can be either a verb or an adjective, as in the following sentences (where brackets mark phonological phrase boundaries):

1. Verb sentence: [J'ai vraiment l'impression] [que les pommes] [DURENT plus longtemps] [que les bananes] (*I really have the impression that apples LAST longer than bananas*)
2. Adjective sentence: [J'ai vraiment l'impression] [que les pommes DURES] [font de meilleures tartes] [que les golden] (*I really have the impression that HARD apples make better pies than golden apples*)

In these sentences, the first words (up to the ambiguous word) have the same pronunciation, but the ambiguous word is a verb in the former sentence and an adjective in the latter one. These sentences differ in their syntactic structure and therefore in their prosodic structure. While there is a phonological phrase boundary placed before the ambiguous word in the first sentence, the phrase boundary follows the ambiguous word in the second sentence. Notice that the prosodic units around the ambiguous word always contain at least three syllables. This length was such that we expected the production of a prosodic boundary to be felicitous, even for uninformed speakers. In addition, the critical boundary occurs between the subject noun phrase and the verb phrase, a position that should be particularly well-marked according to most theories of prosodic phonology (see for instance, Nespor & Vogel, 1986; Shattuck-Hufnagel & Turk, 1996). Experiment 1 tests whether speakers who are naïve to the intent of the experiment produce different prosodic structures on such pairs of locally ambiguous sentences.

EXPERIMENT 1: PRODUCTION TASK

Method

Participants. Six native speakers of French took part in this production experiment. They did not know the aim of the experiment. At the end of the recording session, none of them had noticed that many sentences were locally ambiguous.

Material. Twenty-two adjective/verb homophones were chosen. For each homophone, an adjective and a verb sentence were created (see

Appendix1).¹ For instance, for the word /dyr/, we used the adjective sentence ‘... les pommes dures font de meilleures tartes ...’ (... *hard apples make better pies* ...) and the verb sentence ‘... les pommes durent plus longtemps ...’ (... *apples last longer* ...). To make sure that the speakers did not become aware of the syntactic ambiguity when reading these sentences, control unambiguous sentences were interspersed with the ambiguous sentences.

Procedure. Sentences were presented in writing, and speakers had to read them. Before pronouncing each sentence, speakers were asked to read it silently in their head, to ensure a fluent production. Speakers were told to read with a lively voice and a good articulation. Each speaker was recorded individually in a sound-proofed room. All sentences were digitised at a sampling rate of 16 KHz.

Results and discussion

We measured the duration, the pitch and the energy of the segments around the phonological phrase boundaries. There were two possible phonological phrase boundary positions: just before the ambiguous word (this boundary is present in verb sentences but not in adjective sentences), and just after the ambiguous word (in adjective sentences but not in verb sentences).

The analysis of duration revealed significant phrase-final lengthening. There was no pause in the acoustic signal, either before or after the ambiguous word. Before the first phonological phrase boundary, we obtained a significant rhyme lengthening of 18% (142 to 168 ms, $t(21) = 5.24$, $p < .001$): e.g., /ɔm/ was longer in ‘... [que les pommes] [durent ...]’ than in ‘... [que les pommes dures] ...’. Before the second phonological phrase boundary, rhyme lengthening was 31% (179 to 234 ms, $t(21) = 7.2$, $p < .001$): /yr/ was longer in ‘... [que les pommes dures] ...’ than in ‘... [que les pommes] [durent ...]’. This is congruent with the literature (e.g., Delais-Roussarie, 1995).

Pitch contours also differed significantly between verb and adjective sentences. Before the first phonological phrase boundary, the pitch contour was ascending at the end of the phrase (rise of 13 Hz between ‘les’ and ‘pommes’ in the verb sentence ‘... [que les pommes] [durent ...]’), significantly different from 0, $t(21) = 2.1$, $p = .05$. When the same vowels were in the middle of a phrase, the pitch contour was significantly descending

¹ Ten French adults were asked to estimate the frequency and the plausibility of each target word in ambiguous sentences, using a scale from 1 (not frequent or not plausible at all) to 7 (very frequent or very plausible). The average frequency and plausibility of verb and adjective targets were balanced: [frequency: 4.8 for verbs vs. 5.1 for adjectives, $t(21) < 1$; plausibility: 5.0 for verbs vs. 5.3 for adjectives, $t(21) = 1.4$, $p = .1$].

(− 19 Hz between ‘les’ and ‘pommes’ in the adjective sentence ‘... [que les pommes dures] ...’), $t(21) = 4.2$, $p < .001$). These pitch contours were significantly different, + 13 vs. − 19 Hz, $t(19) = 5.3$, $p < .001$. For the second boundary position, we also obtained an ascending pitch contour in phrase-final position, + 32 Hz between ‘pommes’ and ‘dures’ in the adjective sentence, significantly different from 0, $t(21) = 5$, $p < .001$, compared with a flat contour in the other sentence (− 4 Hz between ‘pommes’ and ‘durent’ in the verb sentence), not significantly different from 0, $t(21) < 1$. These pitch contours were significantly different, + 32 vs. − 4 Hz, $t(21) = 4.6$, $p < .001$. A pitch rise at the end of a phonological phrase has already been described in French (Di Cristo, 2000; Welby, 2006). An analysis of the energy (root-mean-square of the individual segments) revealed no differences between adjective and verb sentences.

Both the phrase-final lengthening and the pitch rise were significant for each of the speakers individually. Phonological phrase boundaries were thus clearly marked by speakers who were unaware of the ambiguities. Thus when the ambiguous word is processed by listeners, its phonemic content gives no cue as to its grammatical category, but the prosodic context does. Are these prosodic differences salient enough for French listeners to assign a verb or an adjective interpretation to the ambiguous words?

EXPERIMENT 2: COMPLETION TASK

We conducted a completion task to investigate whether the prosodic cues produced by the speakers were exploited by listeners to infer the syntactic category of the ambiguous words. In this experiment, sentences were cut just after the end of the ambiguous word and auditorily presented to participants who had to complete them freely in writing.

Method

Participants. Sixty native speakers of French took part in this experiment, ten in each speaker condition.

Material. We used the ambiguous sentences recorded by the non-expert speakers during the production task (44 experimental sentences for 22 ambiguous items). Ambiguous sentences were cut just after the end of the ambiguous word, at a zero-crossing of the amplitude signal (for instance, ‘J’ai vraiment l’impression que les pommes durent...’/I really have the impression that apples last...). In addition, ten unambiguous distractor sentences were cut anywhere in a sentence at a word boundary (for instance, ‘j’écoute une radio...’/I listen to a radio...). For each speaker, we created two blocks of sentences so that each member of a given pair appeared in a

different block. Each block contained eleven verb sentences, eleven adjective sentences and five distractor sentences. Half of the participants from each speaker group listened to block 1 and the other half listened to block 2.

Procedure. Each participant was tested individually in a quiet room. Printed instructions informed participants that they were to listen to sentence beginnings and that they had to complete them in writing. A trial began with the auditory presentation of a sentence beginning; participants could listen to it as many times as they wished (by pressing the space bar). They then wrote a whole sentence on a response sheet. They pressed a key to obtain the next trial. The auditory stimuli were stored at a sampling rate of 16 kHz and presented through a ProAudioSpectrum Pro 16-bit soundboard. Before the experiment began, participants performed a 2-items training, with non-ambiguous sentences. The whole procedure was controlled by the Expe program (Pallier, Dupoux, & Jeannin, 1997).

Results and discussion

The sentence completions given by participants were coded as to whether the ambiguous word was interpreted as an adjective or as a verb.² Four per cent of the responses were discarded because the target word could not be unambiguously interpreted as an adjective or a verb (52 responses out of 1200).

Figure 1 presents the mean number of adjective and verb responses to experimental sentences, collapsed across all speakers. Two ANOVAs were conducted on the mean number of adjective responses³, one with participants and one with items as random factors. The by-subject analysis included one within-subject factor, Sentence Type (adjective vs. verb sentences), and two between-subjects factors, Speaker (from Speaker 1 to Speaker 6) and Counterbalancing (block 1 vs. 2). The by-item analysis included two within-item factors, Speaker and Sentence Type.

The analyses revealed a significant main effect of Sentence Type, $F_1(1, 48) = 198$, $p < .001$; $F_2(1, 19) = 124$, $p < .001$. It reflected the fact that participants gave more adjective responses to adjective sentences than to verb sentences (7.7 vs. 3.1), and thus that they gave more verb responses to verb sentences than to adjective sentences (6.1 vs. 2.2).

² Two items were excluded from the analysis because they led to a large response bias (88% of adjective responses, whatever the sentence they heard, for item 21 'violet - violait'/purple - violated; 97% of verb responses for item 22 'cool - coulent'/cool - sank). The analyses were run on 20 ambiguous items (the same results were obtained when these two items were kept in the analysis).

³ Since adjective and verb responses were complementary (with the exception of the discarded responses), we used only the mean number of adjective responses in the statistical analyses.

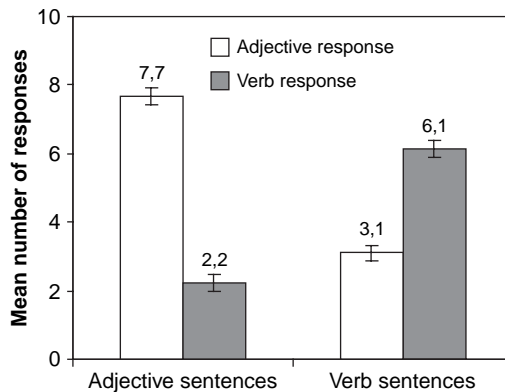


Figure 1. Mean number of adjective and verb responses given to adjective and verb sentences (out of 10 possible responses for each sentence type). Results are collapsed across all naïve speakers. Error bars represent standard errors of the means.

We also observed a main effect of Speaker significant only in the subjects analysis, $F_1(5, 48) = 3, p = .02$; $F_2(5, 95) = 1.8, p = .1$. The interaction between Speaker and Sentence Type was significant by item only, $F_1(5, 48) = 2, p = .1$; $F_2(5, 95) = 2.5, p = .04$, indicating that there was some variability in the responses given for each speaker. However, in spite of some variation in the effect size between speakers, the main effect of Sentence Type was significant for each speaker: for all six speakers, $F_1(1, 8)$ comprised between 13.5 and 47.6, $p < .001$, and $F_2(1, 19)$ comprised between 6.5 and 82, $p < .02$.

French listeners were thus able to correctly interpret two sentence beginnings that only differed in their syntactic and prosodic structures. They assigned different syntactic categories to the ambiguous words, depending on their prosodic context only: they gave more adjective than verb responses to adjective sentences, and more verb than adjective responses to verb sentences.

GENERAL DISCUSSION

The experiments described in this paper suggest that French adults exploit phonological phrase boundary cues to resolve local syntactic ambiguities. Even though they were not aware of the syntactic ambiguities, non-expert speakers did produce helpful prosodic cues, salient enough to allow listeners to correctly assign its syntactic category to an ambiguous target. Phonological phrase boundaries are thus spontaneously produced and guide the syntactic analysis of spoken sentences.

Another important finding is that the disambiguating effect of prosody was observed for every speaker. This result contributes to the on-going debate on the spontaneous production of informative prosodic cues: some authors have proposed that only expert speakers or speakers aware of the ambiguities could produce disambiguating prosodic cues (see for instance, Allbritton et al., 1996), while others have found that even naïve speakers produced informative prosodic cues (see for instance, Kraljic & Brennan, 2005). Our results support the conclusions developed by Kraljic and Brennan, who proposed that prosodic cues are a by-product of planning and articulating sentences. In agreement with this finding, our study showed that uninformed speakers spontaneously produced prosodic cues in a reading task. These prosodic cues were salient enough to help listeners to correctly infer the intended meaning of ambiguous sentences. As we postulated, the divergent results on the spontaneous production of prosodic cues seem to be due to the prosodic structure of the stimuli used in these experiments: contrary to Allbritton et al.'s stimuli, our experimental sentences were sufficiently long to make the production of a phonological phrase boundary felicitous (resulting in prosodic constituents of adequate length, with 3 to 7 syllables in each phonological phrase). The position of the phonological phrase boundary therefore depended on the syntactic structure of the experimental sentences (it was always placed between the subject noun phrase and the verb phrase, that is, before the ambiguous word in verb sentences, and after the ambiguous word in adjective sentences).

To conclude, both intonational phrases and phonological phrases can be used by adults in order to guide the syntactic parsing of spoken sentences. It has been argued that these prosodic cues could be useful for infants who are acquiring their maternal language. Since intonational and phonological phrase boundaries always correspond to syntactic boundaries, perceiving these prosodic units should help babies to parse the sentences they hear into syntactic constituents (Morgan, 1986). Since intonational phrases typically correspond to whole clauses, perceiving them would tell infants where clauses begin and end; however, these prosodic boundaries would not provide any information about their internal syntactic structure. In contrast, phonological phrases typically contain only one or two content words together with some function words. Thus, many sentences that an infant is likely to hear can be divided into two or more phonological phrases. As a result, the ability to exploit phonological phrase boundaries could be very useful in the course of language acquisition. Experimental evidence shows that both adults and infants can use phonological phrase boundaries to constrain lexical access (Christophe, Peperkamp, Pallier, Block, & Mehler, 2004; Gout, Christophe & Morgan, 2004; Millotte, 2005). Our results suggest that phonological phrase boundaries guide syntactic analysis in French adults. Thus, it seems reasonable to assume that these prosodic units may help infants to perform

a syntactic analysis of spoken sentences, and thus facilitate lexical and syntactic acquisition (Christophe, Millotte, Bernal & Lidz, in press).

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APPENDIX 1

Experimental materials for the production experiment. For each ambiguous item, written in capitals, two ambiguous sentences were created: a verb and an adjective one. They were cut right after the ambiguous word for the completion experiment

<i>Item</i>	<i>Sentence</i>
1	Je trouve que la fumée DANSE joliment en s'échappant du feu de bois.
1	Je trouve que la fumée DENSE qui s'échappe de ce bâtiment laisse imaginer le pire.
2	J'ai vraiment l'impression que les pommes DURENT plus longtemps que les bananes.
2	J'ai vraiment l'impression que les pommes DURES font de meilleures tartes que les golden.
3	La jeune femme LACE les souliers de son petit garçon.
3	La jeune femme LASSE lit un livre en attendant de reprendre des forces.
4	Je crois que cet homme LACHE son boulot parce qu'il est trop stressant.
4	Je crois que cet homme LACHE refuse de voir la vérité en face.
5	J'ai appris que cet homme LOUCHE depuis qu'il a eu un accident de voiture.
5	J'ai appris que cet homme LOUCHE doit comparaître devant la justice.

Appendix (*Continued*)

<i>Item</i>	<i>Sentence</i>
6	Le petit chien MORD la laisse qui le retient dans l'espoir de se libérer.
6	Le petit chien MORT sera enterré demain dans le jardin de ses maîtres.
7	Le petit tambourin ROMPT l'harmonie de la musique.
7	Le petit tambourin ROND a une très bonne sonorité.
8	Elle trouve que les enfants SALENT beaucoup trop leur repas.
8	Elle trouve que les enfants SALES font la honte de leurs parents.
9	Ce politicien INTEGRE les minorités dans son projet de développement urbain.
9	Ce politicien INTEGRE sera certainement élu aux prochaines législatives.
10	Ce grand écrivain CELEBRE la naissance de Victor Hugo avec son nouveau livre.
10	Ce grand écrivain CELEBRE fera une dédicace demain dans une grande librairie.
11	Manger cette tartelette COMPLETE délicieusement ce repas.
11	Manger cette tartelette COMPLETE ne me va pas car je n'ai plus faim.
12	Ces petites lumières DIFFUSENT une agréable sensation de calme.
12	Ces petites lumières DIFFUSES ne fatiguent pas les yeux.
13	Ce petit clown DISTRAIT les enfants malades dans les hôpitaux.
13	Ce petit clown DISTRAIT n'a pas vu qu'il avait oublié son nez rouge.
14	Ce président ILLUSTRÉ la réussite sociale et professionnelle.
14	Ce président ILLUSTRÉ lit très peu de romans contemporains.
15	Cette belle femme CAPTIVE l'attention du public.
15	Cette belle femme CAPTIVE craint pour sa vie.
16	J'ai appris que les adolescents MUAIENT de plus en plus précocement.
16	J'ai appris que les adolescents MUETS désiraient souvent devenir interprètes en langue des signes.
17	Je trouve que mes amies PERCENT rapidement dans le milieu du mannequinat.
17	Je trouve que mes amies PERSES reçoivent une éducation trop stricte.
18	Sa petite amie TAILLE des rosiers dans le jardin.
18	Sa petite amie THAI découvre Paris pour la première fois.
19	On sait que les hommes PUREMENT s'échapper de ce camp de concentration.
19	On sait que les hommes PURS sont très rares dans le milieu de la politique.
20	Je vous dis que ce numéro PERD toujours à la roulette.
20	Je vous dis que ce numéro PAIR terminera le tirage du loto de ce soir.
21	Il pense que ce grand tableau VIOLAIT délibérément les principes des Impressionnistes.
21	Il pense que ce grand tableau VIOLET définit parfaitement l'idéal de l'art contemporain.
22	Il a peur que ses amis COULENT pendant la tempête.
22	Il a peur que ses amis COOL puissent gâcher son repas d'affaires.