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Phonological phrase boundaries constrain lexical access I. Adult data☆

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Abstract

We tested the effect of local lexical ambiguities while manipulating the type of prosodic boundary at which the ambiguity occurred, using French sentences and participants. We observed delayed lexical access when a local lexical ambiguity occurred within a phonological phrase (consistent with previous research; e.g., '[un *chat grin*cheux],' containing the potential competitor word '*chagrin*,' was processed more slowly than '[un chat drogué]' that contains no potential competitor). In contrast, when the lexical competitor straddled a phonological phrase boundary, there was no delay in lexical recognition (e.g., '[son grand *chat*] [*grim*pait...],' potential competitor '*chagrin*,' was not delayed relative to the non-ambiguous control). These results were observed with two different on-line tasks, word-monitoring and phoneme-monitoring. They suggest that lexical access occurs within the domain of phonological phrases. We discuss the implications of these results for models of lexical access.

Keywords: On-line lexical access; Segmentation into words; Prosodic boundary cues; French language

The well-known lack of salient acoustic word boundary cues has led psycholinguists to propose lexical access mechanisms that do not rely on a preliminary segmentation of the speech signal into word-sized units: rather, word segmentation is conceived as a by-product of word identification (see, e.g., Cutler, 1990). For instance, the TRACE model of word recognition (McClelland & Elman, 1986) implements multiple activation of word candidates together with competition between overlapping candidates. At any point in time, all the words compatible with the currently available phonemic information are activated; overlapping candidates that share one or several phonemes inhibit one another (see also Frauenfelder & Peeters, 1990; Norris, 1994). These two processes ensure that each phoneme is ultimately assigned to one and only one word. Whenever a string of phonemes

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allows for several segmentations (e.g., "catalog" vs "cat a log"), syntactic and/or semantic processes have to be involved in the disambiguation. We will refer to this type of strategy as a 'lexical segmentation strategy' (irrespective of the exact way in which it is implemented). Experimental evidence suggests that the lexical segmentation strategy is actually exploited by adults (see, e.g., McQueen, Cutler, Briscoe, & Norris, 1995; McQueen, Norris, & Cutler, 1994; Norris, McQueen, & Cutler, 1995). For instance, when participants have to spot a word in a non-sense string of syllables, McQueen et al. (1994) observed that "mess" was more readily detected in "nomess" (no overlapping candidate) than in "domess," that matches the beginning of "domestic" (overlapping competing candidate).

In parallel with this lexical segmentation strategy, researchers have also studied various non-lexical segmentation cues that are available independently of lexical knowledge, such as phonotactics, allophony, coarticulation, and stress (e.g., Cutler & Butterfield, 1992; Mattys, 2004; McQueen, 1998; McQueen, Otake, & Cutler, 2001; Norris, McQueen, Cutler, & Butterfield, 1997; Suomi, McQueen, & Cutler, 1997). Some recent models have begun to explore the possibility to incorporate both pre-lexical and lexical information in the word-finding process; for instance, in the Shortlist model, stress-based word boundary cues influence the level of activation of potential lexical candidates (Norris et al., 1997).

Typically, the domain within which segmentation strategies (whether lexical or pre-lexical) operate has been left unspecified, and one may think that they apply to whole utterances. In this paper, we examine the possibility that segmentation strategies operate within smaller domains. More specifically, we propose that listeners spontaneously perceive continuous speech as being organized into prosodic units, such as intonational phrases, phonological phrases, and prosodic words.[1] The largest of these units, the intonational phrase, usually consists of a whole clause or sentence, and is very often marked by a pause at the end, together with significant final lengthening (Delais-Roussarie, 1995; Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992; among others) and pitch declination (Cruttenden, 1986) followed by pitch resetting upon crossing the boundary (e.g., de Pijper & Sanderman, 1994). It seems reasonable to assume that pauses are interpreted as word boundaries, and therefore that multiple activation of lexical candidates applies within an intonational phrase but not across an intonational phrase boundary (in addition, there is experimental evidence that intonational phrase boundaries constrain on-line syntactic analysis, see, e.g., Kjelgaard & Speer, 1999; Schepman & Rodway, 2000; Warren, Grabe, & Nolan, 1995).

We therefore focus on prosodic units smaller that the intonational phrase, namely phonological phrases and prosodic words (Nespor & Vogel, 1986). A prosodic word contains only one lexical head, potentially grouped with some functional elements. A phonological phrase consists of one or more prosodic words (e.g., [the little dog] [was running fast]).[2] From a phonetic point of view, a phonological phrase typically contains between 4 and 7 syllables and is characterized by pre-boundary lengthening (Delais-Roussarie, 1995; Wightman et al., 1992) and the fact that there is one melodic contour per phonological phrase (Hayes & Lahiri, 1991 for Bengali; Pasdeloup, 1990 for French). It also exhibits greater initial strengthening (such that the first phoneme of a phonological phrase is typically more strongly articulated and potentially longer, see Fougeron & Keating, 1997; Keating, Cho, Fougeron, & Hsu, 2003), as well as reduced coarticulation between phonemes that span the boundary (see, e.g., Byrd, Kaun, Narayanan, & Saltzman, 2000; Hardcastle, 1985; Holst & Nolan, 1995).

On-line studies of lexical access in auditory sentences have typically not manipulated the type of prosodic boundary involved. They often exploited sentences with a local lexical ambiguity (e.g., 'two lips' vs 'tulips') and relied on the cross-modal priming technique (Swinney, 1981; Zwitserlood, 1989). For instance, Gow and Gordon (1995) observed priming for a semantic associate of 'tulips' visually presented just after the syllable 'lips' in a sentence containing 'two lips' (see also Shillcock,

[1] A wide variety of vocabulary is found in the literature, though most authors agree in postulating two levels above the prosodic word, corresponding to phonological phrases and intonational phrases, see Shattuck-Hufnagel and Turk (1996) for an excellent review. For instance, phonological phrases (or at least, what appears to be equivalents to them) have been referred to as major phrases (Ladd, 1986; Selkirk, 1984), intermediate intonational phrases (Beckman & Pierrehumbert, 1986), minor phrases (Dirksen, 1992), accentual groups (Verluyten, 1982), and so on. In this paper we stick to the phonological phrase definition of Nespor and Vogel (1986), and pick out uncontroversial examples of these intermediate units.

[2] There is a tension between a purely formal definition of phonological phrases (solely in terms of a derivation from the syntactic structure of the sentence), and a phonetic definition which would rely on measurements of what speakers actually produce, and typically refers to aspects such as the length of prosodic units (e.g., Gee & Grosjean, 1983). Thus, it seems intuitive that an unusually long phonological phrase, such as [the extraordinarily virulent anti-protectionist deputy], should be broken up into smaller units, and this is what has been reported (e.g., Delais-Roussarie, 1995). It is not clear up to now whether two kinds of prosodic units, "formal" and "surface," should be postulated, or whether only one representation taking into account both syntactic and rhythmic constraints will account for the data.

1990; Tabossi, Burani, & Scott, 1995). Such results suggest that any acoustic/prosodic information about the presence of a boundary between 'two' and 'lips' was either not perceived or not used on-line to block activation of 'tulips.' In Gow and Gordon's experiment, the material featured a wide variety of prosodic boundaries, ranging from a word boundary within a prosodic word such as "a claim" versus "acclaim," to an intonational phrase boundary, as in: "When the first runners *pass tell* them their times" versus "When the first runner's *pastel* shorts came into view someone made a crack." Examination of their experimental materials shows that about 65% of sentences featured a phonological phrase or intonational phrase boundary. Thus, in this experiment the priming effect could either be observed for all sentences irrespective of the boundary involved, or it could be restricted to the 35% of sentences with a smaller boundary (either prosodic word boundary or word boundary). In order to specifically study the influence of prosodic boundaries, they should be explicitly manipulated within the experiment.

One difficulty with the cross-modal priming task is that it relies on the assumption that priming reflects the *automatic* activation of the embedded target word. Thus, if a semantic associate of the embedded word (e.g., FLOWER for the sentence '…two lips…') is presented visually right at the end of the embedded word, priming is expected if and only if the target word was indeed spontaneously activated. The problem with this assumption is that immediate conscious priming has been argued to reflect not only spontaneous activation processes, but also post-access strategies (Holender, 1986; Kouider & Dupoux, 2001; Seidenberg, Waters, Sanders, & Langer, 1984). As a result, the observation that a word embedded in other words primes one of its semantic associates does not guarantee that this word was spontaneously activated.

To avoid this problem, one could show that priming occurs in some conditions but not others (assuming that post-access strategies should apply equally throughout the experiment). Davis, Marslen-Wilson, and Gaskell (2002) did precisely that, and observed that the amount of priming depended on the experimental conditions, within the same experiment. With locally ambiguous sentences such as '…cap tucked…' vs '…captain…,' they observed more cross-modal repetition priming of 'captain' when participants heard 'captain'-sentences than 'cap tucked'-sentences (and vice versa for 'cap' targets), even when the carrier sentences were cut just after 'cap.' This experiment thus showed that the acoustic/prosodic information distinguishing the two types of sentences was sufficient to influence cross-modal repetition priming. Since there is no reason why post-access strategies would differ depending on the prosodic characteristics of the stimuli, it seems reasonable to conclude that the results reflect at least in part on-line lexical activation. Interestingly, in all sentences the ambiguity always occurred between a subject noun and a verb, spanning a phonological phrase boundary. This experiment thus showed that the prosodic information marking phonological phrase boundaries is exploited to disambiguate local lexical ambiguities (in addition, the authors were careful not to produce this prosodic boundary in an exaggerated way, suggesting that this experiment may even under-estimate the usefulness of phonological phrase boundaries).

In this paper we compare prosodic word boundaries and phonological phrase boundaries, using two different experimental techniques to study on-line lexical access in spoken sentences. First, we use a word-monitoring task (Experiments 1 and 2). We then confirm the observed results with a task that relies on the comparison between two versions of the phoneme detection task (Experiments 3 and 4, see Christophe, Guasti, Nespor, Dupoux, & van Ooyen, 1997).

Experiment 1: Word-monitoring: Local ambiguity effect within a phonological phrase

To study lexical segmentation on-line, we exploited the fact that lexical access should be slowed down for sentences that contain a local lexical ambiguity, that is, when more than one lexical parse is temporarily available. For instance, the first sentence from the example below (in French) contains a local lexical ambiguity within a phonological phrase (square brackets mark phonological phrases):

[Le livre] [racontait l'histoire] [d'un grand *chat grin*cheux] [qui avait mordu un facteur]. (*chagrin*)
("The book told the story of a big grumpy cat who had bitten a mailman" // "sorrow")
[Le livre] [racontait l'histoire] [d'un grand *chat dro*gué] [qui dormait tout le temps]. (**chad*)
("The book told the story of a big doped cat who was sleeping all the time")

Up to the syllable "*grin*," participants cannot decide whether they heard the French word "*chat*" followed by a word starting with "*grin*," or whether they heard the French word "*chagrin*"—at least not on the basis of the segmental information. In contrast, the second sentence contains no such lexical ambiguity, since no word in French starts with the string of phonemes "*chad*." The participants' task was to respond to the target word "*chat*" ("cat") as fast as possible. If the ending of "*chat*" is not clearly marked through acoustic/prosodic means, we expect the identification of "*chat*" to be slowed down in the presence of an overlapping competitor ("*chagrin*"). The non-ambiguous sentence served as a baseline and provided us with an estimate of how fast the word "*chat*" was responded to in the absence of any competitor (since there are no words in French starting with "chad..."). A main effect of local ambiguity would thus show that the boundary between two prosodic words within a phonological phrase is not reliable enough to allow participants to clearly identify the end of the preceding word (in French).

Method

Participants

Twenty native speakers of French took part in this experiment.

Materials

Thirty-six pairs of experimental sentences were constructed, so that one member of each pair contained a noun phrase that was locally ambiguous, e.g., "un *chat grin*cheux," where "chagrin" is also a word in French (meaning, respectively, "a grumpy cat" and "sorrow"). The second sentence of each pair contained a noun phrase that was completely non-ambiguous, e.g., "un chat drogué" (meaning "a doped cat") where no French word starts with "chad." All noun phrases had the form "determiner noun adjective" which is the default ordering in French (with an optional prenominal adjective). The noun phrases always formed one single phonological phrase, while noun and adjective belonged to two separate prosodic words. The local ambiguity therefore occurred at a prosodic word boundary, within a phonological phrase. The target word was always a monosyllabic noun; the following adjective was necessarily different, and was matched between conditions in number of syllables and frequency (ambiguous vs non-ambiguous, mean frequency: 5.5 vs 4.3, $t(71) < 1$, frequencies taken from the database Lexique, see New, Pallier, Ferrand, & Matos, 2001; http://www.lexique.org). In addition, for each pair of sentences, a third sentence was constructed that contained the competitor word making up the local lexical ambiguity (e.g: 'chagrin'). Sentences from a triplet were identical up to the crucial noun phrase, and their syntactic and prosodic structures were matched after it, as in the example above.

We checked that the competitor word was plausible within the sentences (if the competitor word was highly implausible in some sentences, then it might receive reduced activation[3]). To do so, a group of 10 native French participants read all experimental sentences and judged their overall plausibility on a 0 (completely implausible) to 7 (highly plausible) scale. Sentences containing the competitor word were found to be plausible overall (mean rating: 5.9, standard error 0.2) receiving slightly higher ratings than the other two types of sentences (ambiguous: mean 5.5, st. error 0.3; non-ambiguous: mean 5.4, st. error 0.2). Acoustic measures of the target words showed that they did not differ across conditions (mean duration, ambiguous: 180.4 ms, non-ambiguous, 180.5 ms, $t(36) < 1$).

We also computed diphone statistics to estimate whether the diphone spanning the word boundary (e.g., /ag/ in 'chat grincheux') was more likely to occur within a word or at a word boundary (if these diphone statistics differ between the ambiguous and the non-ambiguous condition, this may affect mean reaction times to these conditions independently of the fact that they are ambiguous or not).[4] To do so, we computed the probability of occurrence of each diphone within words (sum of the frequencies of all words containing this diphone, divided by the sum of the frequencies of all words in the lexicon). We also estimated the probability of occurrence of the diphone at a word boundary as the product of the probability of a word ending in the first member of the diphone and of the probability of a word beginning with the second member of the diphone (e.g., $p(/ag/)_{\text{word boundary}} = p(\text{word ending in /a/}) \times p(\text{word beginning by /g/})$). We observed that overall, the within and between-word probabilities were roughly equivalent (within-word: 0.34%, between-words: 0.39%). However, for ambiguous sentences the within-word probability exceeded the between-word probability, whereas the reverse was true for non-ambiguous sentences (between-word minus within-word probabilities: ambiguous, −0.17%, st. error 0.08%; non-ambiguous, 0.26%, st. error 0.05%, $t(35) = 4.5$, $p < .001$). Phonotactic probabilities may thus contribute to faster reaction times to the target in non-ambiguous sentences relative to ambiguous sentences.

In addition to the 72 experimental sentences, there were 28 distractor sentences that contained the target word, and 50 sentences that did not contain the target word. Of these 50 sentences, 20 did not contain any word resembling the target word. In the remaining 30 sentences, one word contained a syllable that was homophonous to the target word (e.g., target CHAT, foil: "un éCHAfaudage," "a scaffolding"; this syllable was not word-initial in 27 instances, and word-initial in only 3 instances). Target words occurred at the beginning, in the middle or at the end of sentences.

A native French speaker, who was naive as to the aims of the experiment, read all sentences with a natural intonation at a rather fast speech rate. Two blocks of sentences were constructed so that each member of a given pair appeared in a different block. Half the participants had Block A first and then Block B, and the reverse was true for the other half of the participants (this design allowed us to perform an analysis restricted to results from the first block, in which each participant

[3] We thank James McQueen for pointing this out to us.

[4] We thank Sven Mattys for this suggestion.

heard only one member of each pair). Within each block the order of presentation of trials was random and different for each subject.

Procedure

Each participant was tested individually in a quiet room. The target word was displayed in the center of the screen (e.g., "CHAT"), for 1 s. The screen was left blank for another second, then one sentence was played. The trial ended 2 s after the end of the auditory presentation, and a new trial began immediately. Response times were measured from the onset of target words. Speed and accuracy were emphasized. The auditory stimuli were stored at a sampling rate of 16 kHz and were presented directly through an OROS AU22 16-bit D/A board at 64 kHz (four times oversampled) followed with lowpass filtering at 20 kHz. Before the experiment began, participants received 15 practice trials. During practice, the computer provided on-line feedback as to the correctness and speed of the responses. The whole experimental procedure was controlled by the Expe program, a flexible programming language for psycholinguistic experiments (Pallier, Dupoux, & Jeannin, 1997; http://www.lscp.net/expe).

Results

Reaction times over or below 2 standard deviations from the mean per participant and per condition were replaced by the cutoff value. The false alarm rate was 5% for sentences that contained a syllable homophonous to the target word, and 1.5% for sentences that contained no word similar to the target word. Results are displayed in Fig. 1.

Two ANOVAs were conducted on the reaction time and error data, one with participants and one with items as random factor. The by-subjects ANOVA included one within-subject factor, Ambiguity, and one between-subjects counterbalancing factor, Order (whether participants had Block A first and Block B second or vice versa). The by-items ANOVA included the within-item factor Ambiguity. The reaction time analysis revealed a significant main effect of Ambiguity (effect size: 36.5 ms, $F_1(1, 18) = 18.6$, $p < .001$, $F_2(1, 35) = 10.2$, $p < .01$, $\min F'(1, 53) = 6.6$, $p < .02$). The Order factor had no main effect and did not interact with Ambiguity (all $F < 1$). The same analyses on the error data (misses) revealed no significant effects. The same analyses restricted to the first block of the experiment, when each subject had heard only one member of each pair of experimental sentences, revealed a significant ambiguity effect, of the same size as in the overall analysis (indicating that the ambiguity effect was not created by some conscious strategy of participants, if they noticed that sentences occurred in pairs when listening to the second block of the experiment).

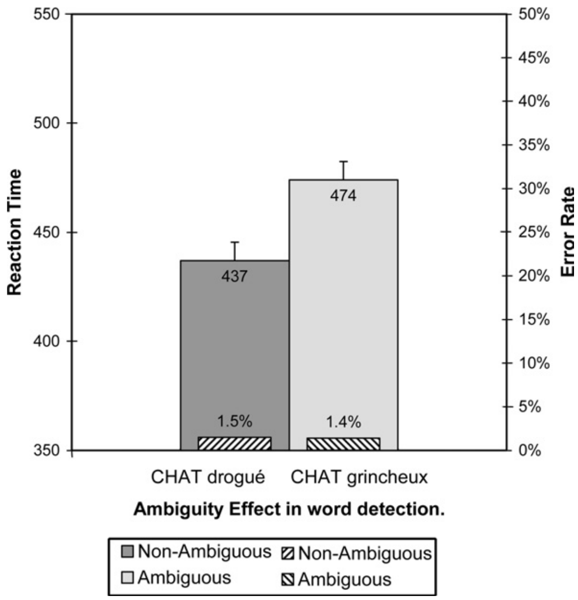

Fig. 1. Mean reaction times and error rates (misses) for word-monitoring in Experiment 1. Sentences either featured a local lexical ambiguity (light-gray bars) or were completely unambiguous. Participants were slowed down for locally ambiguous sentences. Error bars represent one standard error of the difference.

Discussion

In this experiment, we observed a significant local ambiguity effect. Specifically, we observed that participants responded more slowly to the target word "chat" in a context in which it had a competitor ("chagrin"), than when it had no competitor ("chat drogué"). This in turn suggests that the acoustic/prosodic cues at prosodic word boundaries were not sufficiently reliable for participants to firmly establish the end of the target word "chat" and the beginning of the next word (this does not mean that prosodic word boundary cues were completely useless, see Salverda, Dahan, & McQueen, 2003; we will come back to this point in the discussion of Experiment 3). Instead, participants had to keep open the possibility that the syllable "cha" was the beginning of a longer word, which led to a delay in lexical recognition when a competing candidate was congruent with the segmental information in the speech signal.

It is also possible that the significant difference between conditions is due at least in part to the difference between diphone probabilities (see Materials). Since the diphones spanning the word boundary were less likely to occur within a word in the non-ambiguous condition (and the converse in the ambiguous condition) this may have speeded up participants' responses to the monosyllabic target in the non-ambiguous condition relative to the ambiguous condition (see, e.g., McQueen, 1998; Vitevitch & Luce, 1999; for evidence that phonotactic probabilities are used on-line to constrain lexical access). If the phonotactic difference between conditions contributed to the ambiguity effect, we should expect a positive correlation between the size of the ambiguity effect, and the size of the difference in diphone probabilities (for each item pair). We failed to observe such a correlation ($r^2 = .024$, $t(34) < 1$). In the next experiment, we will investigate whether the presence of a phonological phrase boundary modulates the size of the ambiguity effect.

Experiment 2: Word-monitoring: Local ambiguity effects within and across phonological phrases

This experiment used the same basic design as Experiment 1, but introduced one more experimental factor: the boundary between the two words that created the local ambiguity was either a prosodic word boundary (as in Experiment 1), or a phonological phrase boundary. The prosodic word boundary was always realized as a boundary between noun and adjective in a noun phrase of the type "determiner noun adjective" (as in Experiment 1). The phonological phrase boundary was always realized as the boundary between a multi-word subject Noun Phrase and the following Verb Phrase (we chose this situation because it is a very clear case in which restructuring between adjacent phonological phrases is impossible). The following example illustrates the conditions of the experiment (target word: "chat," phonological phrases are indicated with square brackets):

Prosodic word boundary condition:
[Le livre] [racontait l'histoire] [d'un *chat grin*cheux] [qui avait mordu] [un facteur] (*chagrin*)
("The book told the story of a grumpy cat who had bitten a postman" // "sorrow")
[Le livre] [racontait l'histoire] [d'un *chat dro*gué] [qui dormait tout le temps] (**chad*)
("The book told the story of a doped cat that slept all day long").

Phonological phrase boundary condition:
[D'après ma sœur], [le gros *chat*] [*grim*pait aux arbres] (*chagrin*)
("According to my sister, the big cat climbed the trees" // "sorrow")
[D'après ma sœur], [le gros *chat*] [*dre*ssait l'oreille] (**chad*)
("According to my sister, the big cat pricked up his ears").

Given the results observed in Experiment 1, we expected to find an ambiguity effect in the prosodic word boundary condition. As regards the phonological phrase boundary condition, three different patterns of results could be obtained. First, it could be that prosodic boundary cues are not exploited on-line during lexical access, in which case we should observe an ambiguity effect of equal amplitude in the phonological phrase and in the prosodic word boundary conditions. Second, phonological phrase boundary cues could be so strong as to allow participants to know very quickly and with certainty that a word boundary occurred: in this case, they would close all pending lexical candidates at the boundary, and open a new set of lexical candidates starting at the first syllable after the boundary. We would then expect to observe no ambiguity effect in the phonological phrase boundary condition, and an interaction between Ambiguity and Prosodic Boundary Type. Finally, we might observe an intermediate result, with a weaker ambiguity effect in the phonological phrase boundary than in the prosodic word boundary condition: this would indicate that participants were able to exploit phonological phrase boundary cues, but that these cues were not reliable enough to allow them to fully prevent the activation of the lexical candidates that span the boundary.

Method

Participants

Thirty native speakers of French took part in this experiment. They were paid a small fee for their participation. Seven additional participants were excluded from the analyses because they made more than 45% false alarms in the hardest-to-reject category (that is, 5 or more false alarms out of 9 sentences; e.g., target "CHAT," foil "un CHApeau"). Another pair of participants had very slow reaction times compared to the others and were excluded from the analyses.

Materials

Thirty-two pairs of experimental sentences were constructed, such that within each pair, one sentence contained a local ambiguity (e.g., "*chat grin*cheux," where "*chagrin*" is also a word in French), while the other one was entirely unambiguous (e.g., "*chat dro*gué," where no word in French starts with the string of phonemes "*chad*..."). The target was always a monosyllabic noun. Half of the experimental sentence pairs were such that there was a phonological phrase boundary between the target noun and the following word ("Phonological Phrase Boundary condition"), always instantiated as the boundary between a multi-word subject Noun Phrase and a Verb Phrase. The other half of sentence pairs only had a prosodic word boundary, since the target noun was always followed by an adjective within the same phonological phrase ("Prosodic Word Boundary condition"). For each pair of sentences, a third sentence containing the competitor word (e.g., 'chagrin') was constructed as well. Matched sentences were completely identical until the target noun, and the end of the sentences had similar syntactic and prosodic structures.

As for Experiment 1, a group of 10 participants read all experimental sentences and judged their plausibility on a 0 to 7 scale: Sentences containing competitor words were judged plausible overall (Prosodic Word Boundary: mean 6.1, st. error 0.27; Phonological Phrase condition: mean 6.0, st. error 0.18) receiving slightly higher ratings than ambiguous and non-ambiguous sentences (Prosodic Word Boundary: ambiguous, 5.8, st. error 0.25; non-ambiguous 6.0, st. error 0.22; Phonological Phrase Boundary: ambiguous, 5.7, st. error 0.29; non-ambiguous 5.4, st. error 0.33). Target nouns did not differ in duration across conditions (ambiguous: 234 ms, non-ambiguous: 228 ms, $t(31) < 1$). The word following the target was necessarily different across conditions, and was matched in number of syllables and frequency (Prosodic Word Boundary: mean frequency of the following adjective 5.4 vs 6.6, $t(31) < 1$ in the ambiguous and non-ambiguous conditions; Phonological Phrase boundary: mean frequency of the following verb 7.6 vs 10.2, $t(30) < 1$). As in Experiment 1, we computed diphone statistics to compare the probability of occurrence of the diphone spanning the word boundary within a word and between-words. We observed that overall, the between-word probabilities were slightly greater than within-word probabilities (within-word: 0.36%, between-words: 0.41%). As in Experiment 1, the within-word probability exceeded the between-word probability for ambiguous sentences, whereas the reverse was true for non-ambiguous sentences (between-word minus within-word probabilities: ambiguous, −0.11%; non-ambiguous, 0.26%; $t(31) = 3.6$, $p < .01$). Importantly, there was no interaction with the Prosodic Boundary factor ($F(1, 30) = 2.1$, $p > .15$). Diphone statistics may thus contribute to an overall ambiguity effect, but cannot modulate the size of the ambiguity effect for each Prosodic condition. Full examples of experimental sentences are listed above.

In addition to the 64 experimental sentences, there were 32 distractor sentences to which participants should not respond. In all of these distractor sentences, one word had a syllable that was homophonous to the target word. In half of the sentences (16) the homophonous syllable was not word-initial (e.g., target "CHAT," foil "un éCHAfaudage"). In the remaining 16 distractor sentences the homophonous syllable was word-initial. In seven of these 16 sentences the carrier word was in a position that could not be occupied by a noun (e.g., an adjective, such as in "un uniforme CHAmarré," "a multicolored uniform"). In the remaining nine sentences, the carrier word was itself a noun (as in "un CHApeau," "a hat"). Results from Experiment 1 suggested that this last category was hardest to reject; however, Experiment 1 contained only three such items and it was not possible to run a formal analysis.

A native French speaker, different from the one who recorded stimuli for Experiment 1 and naive as to the aims of the experiment, read all sentences naturally at a rather fast speech rate. Two blocks of sentences were constructed so that each member of a given pair appeared in a different block. Half the participants had Block A first and then Block B, and the reverse was true for the other half of the participants. Within each block of the experiment, the order of presentation of trials was semi-random and different for each participant, with the constraints that there were never more than five sentences in a row that contained the target, and that no target was repeated over two consecutive trials.

Procedure

Each participant was tested individually in a quiet room. A trial began with the visual presentation of the target word (e.g., "CHAT"), for 1.5 s. The screen was left blank for another second, then a sentence was played. The trial ended 2.5 s after the participant's response or the end of the auditory presentation (whichever came first) and a new trial began immediately. Response times were measured from the onset of target words. Speed and accuracy were emphasized. The auditory stimuli were stored at a sampling rate of 16 kHz and were presented directly through a ProAudioSpectrum Pro 16-bit soundboard. Before the experiment began, participants received eight practice trials. The whole experimental procedure was controlled by the Expe program (Pallier et al., 1997).

Results

Item 13 from the Prosodic Word Boundary condition yielded many errors and a very slow mean reaction time compared with other items, and was therefore excluded from the analysis (20% misses and 1100 ms mean reaction time in the Ambiguous condition; analyses without excluding this item gave the same results). Reaction times over or below 2 standard deviations from the mean per participant were replaced by the cutoff value for each Boundary condition (means and standard deviations were computed on 32 values each). The false alarm rate was 9.3% overall: cases in which the syllable homophonous to the target word was not word-initial were easily rejected (1.5% false alarms), as well as cases in which the homophonous syllable was word-initial, but the carrier word was in a position that could not be occupied by a noun (3.3% false alarms). In contrast, cases in which the homophonous syllable was word-initial, and the carrier word was also a noun, were much harder to reject (27.8% false alarms). This suggests that participants exploit their on-going syntactic processing of the sentence when making their response, since they find it easier to reject a word-initial syllable when it is not in a position suitable for a noun. Mean reaction time and error rates per condition are displayed in Fig. 2. One may note that mean reaction times were somewhat

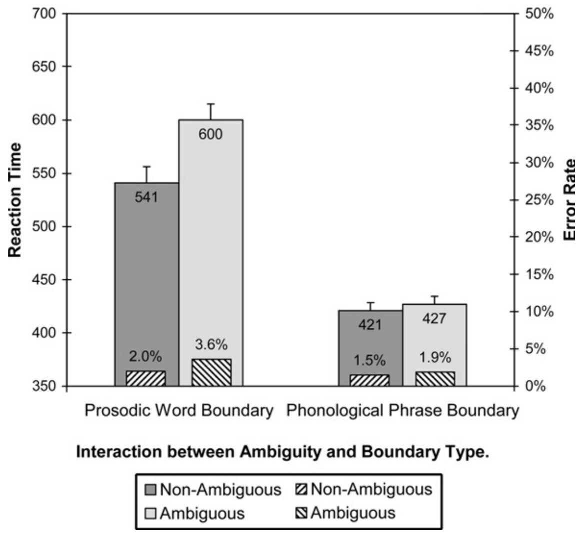

Fig. 2. Mean reaction times and error rates (misses) for word-monitoring in Experiment 2. Sentences either had a local lexical ambiguity (light-gray bars) or were completely unambiguous (dark-gray bars). In addition, this ambiguity either spanned a phonological phrase boundary (right-hand bars) or happened within a phonological phrase (spanning a prosodic word boundary only, left-hand bars). Results showed an effect of ambiguity restricted to the prosodic word boundary condition. Error bars represent one standard error of the difference (Non-Ambiguous–Ambiguous).

slower in the prosodic word condition of Experiment 2 than in Experiment 1, which is probably due to the increase in hard-to-reject foils.

Two ANOVAs were conducted on the reaction time and error data, one with participants and one with items as random factor. The by-subjects ANOVA included one between-subject counterbalancing factor (Order: whether participants started with Block 1 or with Block 2), and two within-subject factors, Ambiguity (non-ambiguous vs ambiguous) and Boundary Type (prosodic word vs phonological phrase). The by-items ANOVA included the between-item factor Boundary Type and the within-item factor Ambiguity. The reaction time analysis revealed a significant main effect of Ambiguity (32.6 ms, $F_1(1,28) = 19.9$, $p < .001$, $F_2(1,29) = 6.3$, $p < .02$, $\min F'(1,46) = 4.8$, $p < .04$), as well as a main effect of Boundary Type (147 ms, $F_1(1,28) = 266$, $p < .001$, $F_2(1,29) = 17.8$, $p < .001$, $\min F'(1,33) = 16.7$, $p < .001$); there was also a significant interaction between Ambiguity and Boundary Type ($F_1(1,28) = 9.8$, $p < .01$, $F_2(1,29) = 4.7$, $p < .05$, $\min F'(1,51) = 3.1$, $p = .08$). This interaction stemmed from the fact that there was a significant Ambiguity effect in the Prosodic Word Boundary condition (59.5 ms, $F_1(1,28) = 18.1$, $p < .001$, $F_2(1,14) = 7.0$, $p < .02$, $\min F'(1,25) = 5.1$, $p < .04$), while there was no Ambiguity effect in the Phonological Phrase Boundary condition (5.6 ms, $F_1 < 1$, $F_2 < 1$). The counterbalancing Order factor showed no main effect ($F_1 < 1$), but it interacted with the Ambiguity factor ($F_1(1,28) = 6.2$, $p < .02$), with one group of participants showing more ambiguity effect than the other. No other interaction reached significance. The same analyses on the error data (misses) revealed no significant effects whatsoever, but the tendencies were in the same direction as the reaction time data, indicating that the reaction time data were not due to a speed–accuracy trade-off (see Fig. 2). Analyses restricted to the first block of the experiment, when participants had heard only one sentence from each pair, revealed the same effects as the overall analyses.

Discussion

This experiment yielded two main results: First, there was a significant interaction between the ambiguity effect and the type of boundary at which the ambiguity occurred. We thus replicated Experiment 1, in that reaction times were significantly longer whenever an embedded bisyllabic word competed with the target monosyllabic word within the same phonological phrase; in sharp contrast, reaction times were as fast as in the control condition whenever the bisyllabic competitor word straddled a phonological phrase boundary. This suggests that in the phonological phrase boundary condition, the presence of a potential competitor word did not influence access to the monosyllabic target. This may be the result of two mechanisms: either the competitor word received very reduced activation because the prosodic pattern of the critical pair of syllables was inconsistent with a single word (in other words, 'chat#-grin' is not a good match for 'chagrin' because it exhibits lengthening and a pitch discontinuity in the middle of the word); or, the phonological phrase boundary was interpreted as the end of a word, thus boosting the activation of the monosyllabic target, allowing it to quickly overcome any competitor word (in other words, 'hearing' a boundary provides extra activation to all the words that either end or start at that boundary). Thus, according to the first mechanism, the competitor word never gets activated; according to the second, it does receive some activation, but its activation level remains much lower than that of the monosyllabic target. Both mechanisms can equally well account for the present data. In fact, both mechanisms may well be at play simultaneously.

Second, we observed much faster reaction times in the phonological phrase condition relative to the prosodic word condition (150 ms faster). This result further confirmed our conclusion that phonological phrase boundaries were interpreted on-line as word boundaries. Following mechanism 2 outlined above, when participants encountered a phonological phrase boundary, they were able to identify the preceding word very fast. In contrast, within phonological phrases, lexical activation of multiple overlapping lexical candidates resulted in slower detection times. Thus, in non-ambiguous sentences, the selection of the appropriate candidate was unproblematic from a lexical point of view; nevertheless, the selection process took time, as evidenced by the fact that reaction times were much slower in the prosodic word condition than in the phonological phrase condition, even for non-ambiguous sentences. Within phonological phrases, participants had to process several additional segments after the end of a word, before this word was recognized. In contrast, the last word of a phonological phrase was identified rapidly.

In Experiment 1, we noted that the ambiguity effect could have been due, at least in part, to the fact that diphones crossing the boundary were more likely to occur at word boundaries in the non-ambiguous than in the ambiguous condition. The same was true for the experimental sentences of Experiment 2, in both prosodic conditions. Phonotactic probabilities may thus have contributed to an overall ambiguity effect, but cannot explain the absence of an ambiguity effect in the phonological phrase boundary condition relative to the word boundary condition (as in Experiment 1, we looked for a positive correlation between the size of the diphone probability difference and the size of the ambiguity effect; there was in fact a non-significant negative correlation both overall, $r^2 = .036$, $t(29) = -1.0$, and restricted to the word boundary condition, $r^2 = .003$, $t(14) < 1$).

We conducted acoustic/prosodic analyses of the sentences to identify some of the cues that signaled phonological phrase boundaries. We measured the duration, pitch, and energy (root-mean-square) of each of the segments surrounding the prosodic word and phonological phrase boundaries (see Table 1). Segment beginnings and ends were identified on the waveform, using both visual and auditory indices, with the Praat software (http://www.fon.hum.uva.nl/praat/).

For duration, we observed a highly significant phrase-final lengthening, as expected from the literature (see, e.g., Wightman et al., 1992; ‘a’ was 40% longer in “chat] [grimpait..” than in “chat grincheux”). We also observed that the second vowel making up the potential ambiguity (S2-vowel) was longer in the Word Boundary condition (‘in’ in ‘grincheux’) than in the Phonological Phrase Boundary condition (‘in’ in ‘grimpait’); in fact, ‘grincheux’ from the word boundary condition was itself phrase-final (in ‘[un chat grincheux]’) whereas ‘grimpait’ from the phonological phrase boundary condition was phrase-initial (as in ‘…chat] [grimpait…’). It could thus be that phrase-final lengthening spread out from the last syllable of the phrase (‘cheux’ in ‘grincheux’) to previous ones. In confirmation of this interpretation, we observed a highly significant phrase-final lengthening on the last syllable of (phrase-final) adjectives relative to (non-phrase-final) verbs (254 ms for the last syllable of adjectives vs 150 ms for the last syllable of verbs); in addition, we also found that S2-vowel lengthening was mainly due to *bisyllabic* adjectives and verbs (e.g., ‘grincheux]’

Table 1
Mean duration (ms), pitch (Hz), and energy (root-mean-square) of segments in the Phonological Phrase boundary and the Word boundary condition in Experiment 2; S1 is the first syllable involved in the local lexical ambiguity (e.g., ‘cha’ in “chat grincheux”); S2 is the second syllable (e.g., ‘grin’ in the same example)

	Phonological Phrase Boundary		Word Boundary		Difference	*t* Test		% Lengthening
	Mean	St. error	Mean	St. error		t(63)	*p*	
Duration (ms)								
S1-onset (ch)	106.4	5.8	112.2	4.5	−5.8	<1		−5.4%
S1-vowel (a)	111.5	5.6	79.5	2.8	32.0	5.1	$<10^{-5}$	40.2%
S1-coda (-)	55.6	5.1	55.9	3.6	−0.3	$t(29) < 1$		−0.4%
S2-onset (gr)	81.9	4.3	85.9	4.3	−4.0	<1		−4.8%
S2-vowel (in)	65.4	2.7	85.0	3.7	−19.6	4.3	$<10^{-4}$	−30%
S2-coda (-)	63.2	3.6	67.5	4.5	−4.3	$t(13) < 1$		−6.8%
Pitch (Hz)								
S1-vowel (a)	291.1	7.0	247.4	7.1	43.7	4.4	$<10^{-4}$	
S2-vowel (in)	259.0	5.1	287.4	5.9	−28.4	3.6	$<10^{-3}$	
Diff S2V-S1V	−32.1	6.9	40.0	8.2	−72.1	6.7	$<10^{-8}$	
Energy (rms)								
S1-vowel (a)	0.202	0.01	0.192	0.01	0.009	<1		
S1-coda (-)	0.072	0.02	0.084	0.01	−0.012	$t(29) < 1$		
S2-onset (gr)	0.090	0.02	0.092	0.02	−0.002	<1		
S2-vowel (in)	0.190	0.01	0.188	0.01	0.002	<1		

The comparison is between-items.

102 ms vs '[grimpait' 68 ms) in which it was penultimate relative to the following prosodic boundary, as opposed to tri- or quadrisyllabic ones (e.g., 'a' in 'larmoyant]' 73 ms and '[larmoyait' 63 ms) in which this vowel occurred longer before the prosodic boundary. The main result here is therefore the highly consistent phrase-final lengthening (40%) occurring before the point of the local lexical ambiguity.

The pitch analysis yielded a very significant difference between the phonological phrase boundary and the word boundary conditions on both vowels surrounding the boundary. Examination of the data revealed that the pitch contour was most often rising across a word boundary within a phonological phrase (27 out of 32 sentences showed a rising pattern); whereas it was most often falling across a phonological phrase boundary (26 out of 32 sentences showed a falling pattern: this is consistent with the literature, which predicts a rising pitch pattern within sentence-medial phonological phrases in French, see, e.g., Di Cristo, 2000; Welby, 2003). Thus, pitch contour was also a highly consistent cue in the present set of sentences. In addition, it is probable that coarticulation was greater at prosodic word boundaries than at phonological phrase boundaries (see, e.g., Byrd et al., 2000), even though this is harder to measure post hoc on the recorded sentences (studies of coarticulation typically use articulatory measurements). This is another cue that may have favored fast lexical access in the phonological phrase boundary condition. All in all, we observed several highly consistent cues to phonological phrase boundaries in our stimuli. The present experiment was not designed to pit one against the other. Our main result is that naturally produced phonological phrase boundaries, containing all the potential acoustic/prosodic cues signaling prosodic boundaries in French, powerfully constrained lexical access.

To further strengthen this conclusion, we conducted two new experiments aimed at replicating our finding with a different on-line technique. In Experiments 3 and 4, we used an experimental technique that relies on the comparison between two versions of the phoneme detection task. One group of participants has to detect phonemes whatever their position in the sentence; the other group has to detect phonemes only if they are in word-initial position. The rationale behind this comparison is that, whenever word boundaries are a by-product of word recognition, then responding only to word-initial phonemes should require some extra work. Conversely, whenever a word boundary is reliably marked in the acoustic signal (through whatever means, phonotactics, prosody, etc.) then the word-initial phoneme detection task should be performed as fast as the generalized phoneme detection task. Christophe et al. (1997) observed that when the target was at a prosodic word boundary within a phonological phrase (e.g., target /l/ 'un fou Larmoyant') then the word-initial phoneme detection task was significantly harder. Christophe et al. interpreted these results as showing that a prosodic word boundary within a phonological phrase necessitated multiple activation of lexical candidates followed by selection. This interpretation is consistent with the results obtained in Experiments 1 and 2, in which we observed local ambiguity effects within phonological phrases (between two content words). Experiment 3 and 4 rely on this task, comparing locally ambiguous sentences to non-ambiguous ones, just as in Experiments 1 and 2.

Experiment 3: Phoneme detection: Local ambiguity effects within a phonological phrase

Christophe et al. (1997) observed that participants were slowed down in the word-initial phoneme detection task, relative to the generalized phoneme detection task, when the target phoneme was at a prosodic word boundary within a phonological phrase. This result suggests that participants had to activate multiple lexical candidates within phonological phrases (consistent with the results of Experiments 1 and 2). This interpretation predicts that processing time should increase even more in the word-initial task when the selection process is slowed down, namely, for sentences in which there is a local lexical ambiguity, that is, when more than one parse is temporarily available (such as in the examples below, task: detect phoneme /g/).

[C'était son *chat Grin*cheux] [qui le rendait nerveux]. (*chagrin*)
("his grumpy cat made him nervous" / "sorrow")
[C'était son *pas Gra*cieux] [qui trahissait] [sa profession de danseur]. (**pagr*..)
("his graceful walk betrayed that he was a professional dancer ")

A replication of Experiment 1 would result in an interaction between the factors ambiguity and experimental task: we expect the effect of experimental task to be greater for locally ambiguous sentences than for non-ambiguous sentences.

Method

Participants

Sixty-four native speakers of French took part in this experiment, 32 in each version of the experimental task (word-initial vs generalized phoneme detection). In addition, six more participants were tested but their data were excluded because they made more than 12% errors overall (two in the generalized task and four in the word-initial one).

Materials

Twenty-two pairs of experimental sentences were constructed, so that one member of each pair contained a noun phrase that was locally ambiguous, e.g., ''son *chat grin*cheux,'' where ''*chagrin*'' is also a word in French (meaning, respectively, ''his grumpy cat'' and ''sorrow''). The second sentence of each pair contained a noun phrase which was non-ambiguous, e.g., ''son *pas gra*cieux'' (meaning ''his graceful walk'') where no French word starts with ''*pagr*.'' All noun phrases had the form ''determiner noun adjective'' which is the default ordering in French. The noun phrases always formed one single phonological phrase, while noun and adjective belonged to two separate prosodic words. The local ambiguity therefore occurred at a prosodic word boundary, within a phonological phrase. The target phoneme was always the first phoneme of the adjective (/g/ in the example). Nouns were all monosyllabic. Nouns from the ambiguous and non-ambiguous condition were, by necessity, different, but they were carefully matched: they differed only in their first phoneme, and their frequencies were matched overall (to avoid any spurious effect of the preceding noun on the detection of the following phoneme; ambiguous vs non-ambiguous, mean frequency: 377 vs 371, $t(43) < 1$). Target-bearing adjectives started with the same phonemes and were matched in number of syllables and frequency (ambiguous vs non-ambiguous, mean frequency: 5.3 vs 2.7, $t(43) = 1.3$, $p > .2$). As a result of this matching procedure, diphones spanning the word boundary were exactly identical in the ambiguous and the non-ambiguous conditions (nouns ended the same, and adjectives started the same, e.g., 'chat grincheux' and 'pas gracieux' both have the diphone /ag/). In addition, a third sentence containing the competitor word (e.g., 'chagrin') was also constructed for each pair of sentences, and recorded by the speaker at the same time as the experimental sentences. Sentences from a triplet were identical until the crucial noun phrase, and their syntactic and prosodic structures were matched immediately after it (see example above). A group of 10 participants judged the plausibility of all the sentences, as in Experiments 1 and 2. Sentences containing the competitor words received high plausibility ratings (mean 6.2, st. error 0.18), slightly higher than ambiguous and non-ambiguous sentences (ambiguous: mean 6.1, st. error 0.18; non-ambiguous: mean 5.7, st. error 0.19).

In addition, 22 filler sentences were constructed so that the target appeared at the beginning of a noun. Another 44 sentences contained the target at the beginning of a syllable but in the middle of a noun or adjective (e.g., target /p/, ''une raPière aiguisée''; ''a sharp sword''). Participants had to respond to these targets in the generalized version of the task but not in the word-initial one. Finally, 32 sentences did not contain the target at all. The carrier word could appear anywhere in the sentences (beginning, middle, or end). The target phonemes used in the experiment were p, t, k, b, d, g, f, s, v, m, r, and they were all present in all conditions.

A native French speaker, different from the ones who read stimuli for Experiments 1 and 2 and naive as to the aims of the experiment, read the stimuli with a natural intonation at a rather fast speech rate. Eight versions of the experimental list were constructed with different random ordering of the sentences. Two blocks of sentences were constructed so that each member of a given pair appeared in a different block. Half the participants had Block A first and then Block B, and the reverse was true for the other half of the participants. The constraints on experimental list construction were that no target could be repeated over two successive trials, and that there were never more than five sentences in a row that contained the target.

Procedure

Each participant was tested individually in a quiet room. A trial began with the visual presentation of the target phoneme for 1 s. The screen was left blank for another second, then one sentence was played. The trial ended 1.5 s after the end of the auditory presentation, and a new trial began immediately. Response times were measured from the onset of all target phonemes. Speed and accuracy were emphasized. The auditory stimuli were stored at a sampling rate of 16 kHz and were presented directly through an OROS AU22 16-bit D/A board at 64 kHz (four times oversampled) followed with lowpass filtering at 20 kHz. The experimental procedure was controlled by the Expe program (Pallier et al., 1997). Before the experiment began, participants received 10 practice trials. During practice, the computer provided on-line feedback as to both correctness and reaction times of the responses.

Results

Two items generated more than 50% misses in at least one task, and were excluded from further analysis (items 2 and 16). All analyses were conducted on the remaining 20 items. Reaction times below or above 2 standard deviations of the mean by participant and by condition (task by ambiguity, i.e., four conditions) were replaced by the cutoff (means and standard deviations were thus computed on 20 values each). The distractor sentences that did not contain the target phoneme generated 10.9% false alarms in the generalized task, and 1.2% false alarms in the word-initial task. Sentences that contained the phoneme in a non-initial position generated 7.8% false alarms in the word-initial task (participants in the generalized task had to respond to these sentences). Mean reaction times and error rates per condition are displayed in Fig. 3.

Two ANOVAs were conducted on both the reaction time and error data, one with participants as the random

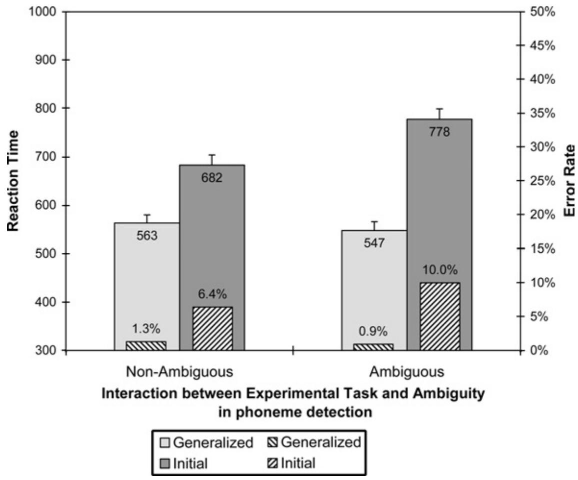

Fig. 3. Mean reaction times and error rates (misses) for the generalized phoneme detection task (light-gray bars) and the word-initial phoneme detection task (dark-gray bars) in Experiment 3. Sentences either featured a local lexical ambiguity (right-hand bars) or were completely unambiguous (left-hand bars). The results show an interaction between Task and Ambiguity, the Task effect being greater for ambiguous than for non-ambiguous sentences. Error bars represent one standard error of the mean.

factor, and one with items as the random factor. The by-subjects ANOVA had two between-subjects factors, Experimental Task (word-initial vs generalized) and Order (counterbalancing factor, starting with Block A vs starting with Block B) and one within-subject factor, Ambiguity (non-ambiguous vs ambiguous). The by-items ANOVA had two within-item factors, Experimental Task and Ambiguity. In the reaction time data, there was a significant main effect of Experimental Task, word-initial responses being slower than generalized responses (effect size 175 ms, $F_1(1,60) = 42$, $p < .001$, $F_2(1,19) = 58$, $p < .001$; $\min F'(1,67) = 24.5$, $p < .001$), as well as a main effect of Ambiguity, ambiguous sentences generating slower responses than non-ambiguous sentences (effect size 40 ms, $F_1(1,60) = 30$, $p < .001$, $F_2(1,19) = 4.6$, $p < .05$; $\min F'(1,26) = 4.0$, $p < .06$). Importantly, there was a significant interaction between Experimental Task and Ambiguity (effect size 111 ms, $F_1(1,60) = 59$, $p < .001$, $F_2(1,19) = 9.5$, $p < .01$; min-$F'(1\,25) = 8.2$, $p < .01$), reflecting the fact that the effect of Experimental Task was much greater for ambiguous sentences (230 ms) than for non-ambiguous sentences (120 ms). This interaction showed that lexical access was delayed in the presence of a local ambiguity, at least within a phonological phrase. The counterbalancing Order factor showed no main effect and did not interact with any other factor (all $F < 1$). The same analyses restricted to the first block of the experiment revealed the same effects as the overall analysis.

The error data showed the same pattern of results, with a significant main effect of Experimental task (effect size 7.1%, $F_1(1,60) = 41.2$, $p < .001$, $F_2(1,19) = 14.8$, $p < .01$; $\min F'(1,34) = 10.9$, $p < .01$), a main effect of Ambiguity significant by subjects only (effect size 1.7%, $F_1(1,60) = 5.5$, $p < .03$, $F_2(1,19) < 1$) and an interaction between Experimental Task and Ambiguity which was significant by subjects only (effect size 4%, $F_1(1,60) = 7.8$, $p < .01$, $F_2(1,19) = 1.1$), but went in the same direction as the reaction time data, indicating that the effect on reaction times was not due to a speed–accuracy trade-off. Again, the counterbalancing Order factor showed no main effect and did not interact with the other factors.[5]

Discussion

This experiment showed that participants were slowed down when they had to detect word-initial phonemes, especially so when a competitor word spanned the prosodic word boundary studied (within a phonological phrase). This result suggests that within phonological phrases, participants rely on multiple activation of possible lexical candidates: when the number of possible parses increases (local ambiguity), participants take longer to figure out which phonemes are word-initial. This result confirms the interpretation given by Christophe et al. (1997) of their finding that participants were slower at detecting word-initial phonemes than at responding to phonemes whatever their position, when the target phoneme occurred at a prosodic word boundary in the middle of a phonological phrase.

[5] In addition to the experimental factors manipulated above, items differed with respect to the competitor word embedded in the ambiguous sentences. In half of the experimental items, the whole competitor word was embedded within the sentence, as for instance the word ''*chagrin*'' in the sentence ''...*chat grin*cheux...''; in the other half of sentences, only the first two syllables of the competing word were present in the sentence, as in ''...*phare ma*jestueux...'' (''stately lighthouse'') that contains the first two syllables of the word ''*pharma*cien'' (''chemist''), where ''*pharma*'' is not a word in French. One would expect ambiguity effects to be stronger when the whole competitor word is embedded in the sentence, than when only its first two syllables are present. To check the influence of this variable, we conducted two additional ANOVAs with the same factors as before and one more within-subject (respectively, between-items) factor, Competitor Word (whole vs part). This ANOVA yielded a three-way interaction between Experimental Task, Ambiguity, and Competitor Word, significant by subjects only (effect size 79 ms, $F_1(1,60) = 7.3$, $p < .01$; $F_2(1,18) = 1.2$), and reflecting the fact that whole embedded words yielded a stronger ambiguity effect (154 ms, $F_1(1,60) = 40$, $p < .001$; $F_2(1,8) = 7.0$, $p < .03$) than part embedded words (75 ms, $F_1(1,60) = 20$, $p < .001$; $F_2(1,10) = 2.9$, $p = .12$). The error data showed the same trends. This analysis indicates that a competitor word that is entirely included in the sentence yields a stronger competition effect than a competitor word that is only partially included.

These data confirm Experiments 1 and 2 and support the conclusion that, at least for French speakers, within a phonological phrase, the boundary between two prosodic words is not sufficiently marked by acoustic means to be completely non-ambiguous, so that one can observe effects of competition between overlapping lexical candidates. One should note that there were some measurable prosodic differences induced by the presence of the word boundary (e.g., between "chat" and "grincheux"). These were measured by comparing the duration, pitch, and energy (root-mean-square) of individual phonemes in experimental sentences (e.g., "…chat grincheux…") and in matched sentences containing the competitor word (e.g., "…chagrin fou…") that were recorded by the speaker at the same time as the experimental sentences (see Table 2).

As expected both from the literature and from previous such measurements (see Christophe, 1993, for a review; Christophe, Dupoux, Bertoncini, & Mehler, 1994; Christophe, Mehler, & Sebastián-Gallés, 2001; Fougeron & Keating, 1997; Quené, 1992) we observed a significant word-initial consonant lengthening (namely, /gr/ was 16% longer in "chat GRincheux" than in "chaGRin fou"), as well as significant word-final vowel lengthening (/a/ was 32% longer in "chAT grincheux" than in "chAgrin fou"), a fact that may be at least partly due to word-final accent in French (in addition the onset of the first syllable was 14% longer when it was a monosyllabic word; this may also be due to the fact that 'cha' was stressed in "chat" but not in "chagrin"). We observed no significant pitch difference, neither did we observe any significant difference in energy. Again, it is plausible that other markers, such as the amount of coarticulation, distinguished between stimuli (although coarticulation differences are difficult to measure post hoc on acoustic stimuli).

It is very plausible that the ambiguity effect we observed would be even greater in the absence of these acoustic/prosodic markers. Thus, Salverda et al. (2003), using an eye-tracking technique, showed that participants were more likely to process a given syllable as a monosyllabic word when it was longer (e.g., 'ham' taken from 'hamster'), and observed significant effects with duration differences of less than 15% (e.g., in their Experiment 3). It is plausible that the prosodic differences from the present experiment, that are of greater amplitude, are also exploited by listeners to inform lexical access. What the present experiment shows is not that acoustic/prosodic markers to prosodic word boundaries are useless, but rather that these markers are not sufficiently reliable to allow unambiguous identification of the word boundary. Some amount of multiple activation, followed by selection between overlapping candidates, was necessary for the retrieval of the word boundary in most cases (enough to yield a statistically significant effect overall).

Now that the double version of the phoneme detection task has been established as being sensitive to multiple lexical activation, we use it in order to investigate the role of phonological phrase boundaries on lexical access.

Experiment 4: Phoneme detection: Local ambiguity effects within and across phonological phrases

The design of this experiment was parallel to the one of Experiment 2. We manipulated two crossed factors,

Table 2
Mean duration (ms), pitch (Hz), and energy (root-mean-square) of segments in the Word boundary (e.g., 'chat grincheux') and the No boundary (e.g., 'chagrin fou') sentences used in Experiment 3; S1 is the first syllable involved in the local lexical ambiguity (e.g., 'cha' in "chat grincheux"); S2 is the second syllable (e.g., 'grin' in the same example)

	Word boundary		No boundary		Difference		*t* Test		% Lengthening
	Mean	St. error	Mean	St. error	Mean	St. error	*t*(21)	*p*	
Duration (ms)									
S1-onset (ch)	98.1	4.3	86.3	3.7	11.8	3.5	3.4	.003	14%
S1-rime (a)	111.5	8.7	84.2	4.3	27.3	6.7	4.1	.001	32%
S2-onset (gr)	85.2	4.8	73.3	4.0	11.9	3.3	3.6	.002	16%
S2-rime (in)	74.5	5.4	75.4	5.9	−1.0	3.9	<1		−1%
Pitch (Hz)									
S1-V (a)	118.2	3.1	115.3	3.1	3.0	3.0	<1		
S2-V (in)	115.0	4.6	116.1	4.3	−1.1	4.8	<1		
Diff S2V-S1V	−3.2	3.4	0.9	3.2	−4.1	3.8	1.1		
Energy (rms)									
S1-onset (ch)	0.132	0.02	0.114	0.02	0.018	0.02	<1		
S1-rime (a)	0.237	0.01	0.231	0.01	0.006	0.02	<1		
S2-onset (gr)	0.139	0.01	0.136	0.01	0.003	0.01	<1		
S2-rime (in)	0.213	0.02	0.194	0.01	0.02	0.02	<1		

The comparison is within-item.

local ambiguity and size of the prosodic boundary, as shown in the example below (target phoneme indicated in capitals):

Prosodic word boundary condition:
[Le livre] [racontait l'histoire] [d'un *chat Grin*cheux] [qui avait mordu] [un facteur] (*chagrin*)
("The book told the story of a grumpy cat who had bitten a postman" // "sorrow")
[Le livre] [racontait l'histoire] [d'un *pou Grin*cheux] [qui détestait le shampooing]. (*poug..)
("The book told the story of a grumpy louse that hated shampoo").

Phonological phrase boundary condition
[Le gigantesque *phare*] [*D*ominait toute la côte] (*fardeau*)
("The enormous lighthouse dominated the whole coast" // "burden")
[Le gigantesque *four*] [*D*ominait toute la cuisine] (*fourd..)
("The enormous oven dominated the whole kitchen").

Participants had to detect the first phoneme of the word just following the boundary (either prosodic word boundary or phonological phrase boundary depending on the condition). We expected the prosodic word condition to replicate Experiment 3: namely, we expected a significant interaction between Experimental Task and Ambiguity, with the effect of experimental task being greater for locally ambiguous sentences. For the phonological phrase boundary condition, a full replication of Experiment 2 would obtain if we found no interaction between Task and Ambiguity.

Method

Participants

Forty-eight native speakers of French took part in this experiment, 24 in each version of the experimental task (word-initial vs generalized phoneme detection). In addition, two more participants were tested but their data were excluded because they made more than 15% errors overall (one in each version of the task).

Materials

A subset of the ambiguous sentences from Experiment 2 was used (those sentences in which the target phoneme occurred before the crucial word could not be included in this experiment). For each locally ambiguous sentence (e.g., "son *chat Grin*cheux"), a new non-ambiguous sentence was constructed so that the carrier word was identical and the preceding noun was different (e.g., "son pou Grincheux," where no French word starts with "poug"; plausibility ratings for these sentences were similar to those for Experiment 2, Prosodic Word condition, mean 5.5, st. error 0.26; Phonological phrase boundary condition, mean 5.8, st. error 0.18). There were 15 pairs of sentences in the Prosodic Word condition, and nine in the Phonological Phrase condition (see Appendix A.4). Nouns preceding the target phoneme were all monosyllabic, and they were matched in overall frequency (Prosodic Word Boundary: mean frequency for ambiguous vs non-ambiguous sentences, 47.6 vs 28.0, $t(29) < 1$; Phonological phrase boundary: mean frequency for ambiguous vs non-ambiguous sentences, 200.2 vs 81.4, $t(17) < 1$). As in Experiments 1 and 2, we computed diphone statistics. Diphones spanning the word boundary were more likely to occur within words than across a word boundary in ambiguous sentences, while the reverse was true for non-ambiguous sentences (difference in diphone probabilities, ambiguous, −0.10%, non-ambiguous, 0.03%, $t(23) = 3.1$, $p < .01$). This was true for both prosodic conditions and there was no interaction with Prosodic Boundary ($F(1,22) < 1$). Thus, phonotactic probabilities may contribute to an overall ambiguity effect, but cannot modulate the size of the effect in each Prosodic condition. Sentences from a pair were identical until the crucial noun phrase, and their syntactic and prosodic structures were matched immediately after it (see example above).

In addition, 24 sentences contained the target at the beginning of a syllable but in the middle of a noun, adjective or verb (e.g., target /ch/, "un éCHafaudage"; "a scaffolding"). Participants had to respond to these targets in the generalized version of the task but not in the word-initial one. Finally, 24 sentences did not contain the target at all. The carrier word could appear anywhere in the sentences (beginning, middle, or end). The target phonemes used in the experiment were p, t, k, b, d, g, f, s, v, j, m, l, and they were all present in all conditions.

The non-ambiguous sentences were read by the same speaker and at the same time as the other sentences used in Experiment 2. Two blocks of sentences were constructed so that each member of a given pair appeared in a different block. Half the participants had Block A first and then Block B, and the reverse was true for the other half of the participants. Within each block of the experiment, the order of presentation of trials was semi-random and different for each participant, with the constraints that no target could be repeated over two successive trials, and that there were never more than five sentences in a row that contained the target.

A prosodic analysis of the experimental sentences from Experiment 4 revealed the same effects that were observed for the sentences of Experiment 2 (see Table 1), which is not surprising given that the same speaker pronounced all stimuli (and that the ambiguous sentences were physically identical).

Procedure

Each participant was tested individually in a quiet room. A trial began with the visual presentation of the target phoneme for 1 s. The screen was left blank for another second, then one sentence was played. The trial ended 2.5 s after the participant's response or the end of the auditory presentation (whichever came first) and a new trial began immediately. Response times were measured from the onset of target phonemes. Speed and accuracy were emphasized. The auditory stimuli were stored at a sampling rate of 16 kHz and were presented directly through a ProAudioSpectrum Pro 16-bit soundboard. Before the experiment began, participants received 14 practice trials. The whole experimental procedure was controlled by the Expe program (Pallier et al., 1997).

Results

One item generated many misses and was excluded from further analysis (item 9 from the Prosodic word condition; analyses conducted without excluding this item yielded the same results). Reaction times below or above 2 standard deviations of the mean by participant and by condition (task by ambiguity by boundary, i.e., 8 conditions) were replaced by the cutoff (means and standard deviations were thus computed on either 14 or 9 values each). The distractor sentences that did not contain the target phoneme generated 9.3% false alarms in the generalized task, and 3.9% false alarms in the word-initial task. Sentences that contained the phoneme in a non-initial position generated 8.3% false alarms in the word-initial task (participants in the generalized task had to respond to these sentences). Mean reaction times and error rates per condition are displayed in Fig. 4.

Two ANOVAs were conducted on both the reaction time and error data, one with participants as the random factor, and one with items as the random factor. The by-subjects ANOVA had two between-subjects factors, Experimental Task (word-initial vs generalized), and Order (counterbalancing factor, starting with Block A vs starting with Block B) and two within-subject factors, Ambiguity (non-ambiguous vs ambiguous), and Boundary Type (prosodic word vs phonological phrase). The by-items ANOVA had one between-item factor, Boundary Type, and two within-item factors, Experimental Task and Ambiguity.

In the reaction time data, there was a significant main effect of Experimental Task, word-initial responses being slower than generalized responses (effect size 85 ms, $F_1(1,44) = 9.3$, $p < .01$, $F_2(1,21) = 26.8$, $p < .001$; min-$F'(1,64) = 6.9$, $p < .02$), a main effect of Boundary Type significant by subjects only, with prosodic word boundaries generating longer reaction times than phonological phrase boundaries (effect size 45 ms, $F_1(1,44) = 26.7$, $p < .001$, $F_2(1,19) = 1.5$, $p > .1$), and no main effect of Ambiguity (effect size 1.6 ms, $F_1(1,44) < 1$, $F_2(1,21) < 1$). The interaction between Task and Boundary Type was significant (effect size 72 ms, $F_1(1,44) = 17$, $p < .001$, $F_2(1,21) = 3.8$, $p < .06$; min $F'(1,31) = 3.1$, $p < .09$), reflecting the fact that there was a significant Task effect in the Prosodic Word condition (120 ms, $F_1(1,44) = 21.0$, $p < .001$, $F_2(1,13) = 24.8$, $p < .001$; min $F'(1,44) = 11.4$, $p < .01$) but not in the Phonological Phrase con-

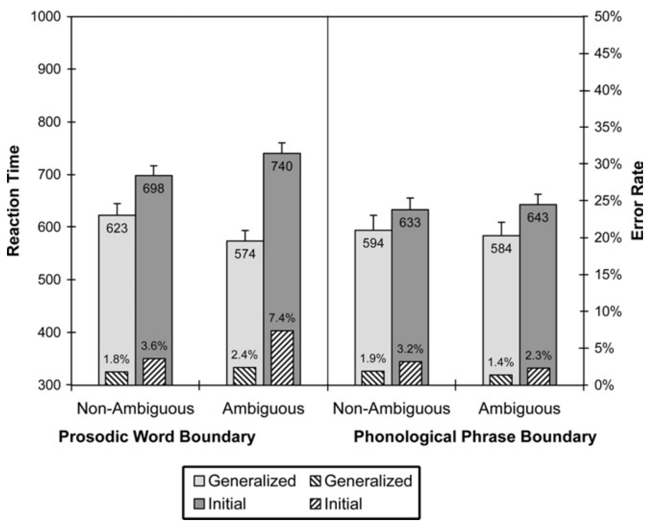

Fig. 4. Mean reaction times and error rates (misses) for the generalized and the word-initial phoneme detection tasks in Experiment 4. Sentences featured a local lexical ambiguity or were completely unambiguous, and the local ambiguity either spanned a prosodic word boundary or a phonological phrase boundary. The results for the prosodic word boundary replicate Experiment 3 (interaction between ambiguity and task, left-hand half of the graph). In contrast, there is no such interaction when a phonological phrase boundary intervenes at the point of local ambiguity. Error bars represent one standard error of the mean.

dition (49 ms, $F_1(1,44) = 2.4$, $p > .1$, $F_2(1,8) = 3.6$, $p = .09$). In other words, participants were more slowed down in the word-initial phoneme detection task when the target phoneme occurred at a prosodic word boundary within a phonological phrase, than when it occurred at a phonological phrase boundary (suggesting that phonological phrase boundaries are more readily available). The interaction between Task and Ambiguity was also significant (55 ms, $F_1(1,44) = 9.4$, $p < .01$, $F_2(1,21) = 6.0$, $p < .05$; $\min F'(1,47) = 3.7$, $p = .06$), reflecting the fact that the Task effect was much greater for ambiguous sentences (113 ms) than for non-ambiguous sentences (55 ms). There was no interaction between Boundary Type and Ambiguity.

Finally, the triple interaction between Task, Ambiguity, and Boundary Type was marginally significant (effect size 71 ms, $F_1(1,44) = 3.9$, $p = .055$, $F_2(1,21) = 1.8$, $p > .1$), reflecting the fact that there was a significant interaction between Task and Ambiguity in the Prosodic Word condition (effect size 91 ms, $F_1(1,44) = 12.9$, $p < .001$, $F_2(1,13) = 6.0$, $p < .05$; $\min F'(1,26) = 4.1$, $p = .05$), while this interaction was not significant in the Phonological Phrase boundary condition (effect size 20 ms, $F_1(1,44) < 1$, $F_2(1,8) < 1$). In other words, the Prosodic Word condition replicated Experiment 3, showing the expected interaction between Task and Ambiguity (see left-hand side of Fig. 4); in contrast, the Phonological Phrase condition showed no interaction between Task and Ambiguity, suggesting that a local ambiguity did not influence participants' behavior when it spanned a phonological phrase boundary (thus replicating Experiment 2). The counterbalancing Order factor showed no main effect and did not interact with any of the other factors. The same analyses on the error data (misses) revealed the same pattern of results (with some effects not reaching significance); the tendencies went in the same direction as the reaction time data, indicating that the reaction time data were not due to a speed–accuracy trade-off (see Fig. 4).[6]

Discussion

This experiment replicated the main result of Experiment 2 with a different experimental technique: Namely, it confirmed the result that phonological phrase boundaries are available early in processing and constrain lexical activation. First, we observed that the effect of Experimental Task was much greater in the Word Boundary condition than in the Phonological Phrase boundary condition; in other words, participants found it rather easy to respond specifically to word-initial phonemes when these phonemes were also phonological-phrase-initial. Second, the Prosodic Word Boundary condition replicated Experiment 3, with a significant interaction between Task and Ambiguity (showing that the embedded competitor word was sufficiently activated in ambiguous sentences to slow down the identification of the words with which it competed). In contrast, no such interaction was observed in the Phonological Phrase boundary condition, suggesting that the presence of the embedded competitor word did not influence lexical access.[7] As we mentioned in the discussion of Experiment 2, this may be due to two separate mechanisms, possibly operating simultaneously: the presence of the phonological phrase boundary makes 'chat#grin' a poor match for the competitor word 'chagrin' (so that this competitor word gets only weakly activated, or not at all); and, the prosodic boundary is interpreted as a word boundary, boosting the activation of words ending or beginning at that boundary, and allowing fast identification of the following phoneme as a word-initial phoneme.

Experiments 3 and 4 thus fully replicate Experiments 1 and 2 with a different experimental technique, confirming with phoneme-monitoring the results observed with word-monitoring. Both experimental tasks revealed

[6] In Experiment 1, we noted that the ambiguity effect could have been due, at least in part, to the fact that diphones crossing the boundary were more likely to occur at word boundaries in the non-ambiguous than in the ambiguous condition. The same was true for the experimental sentences of Experiment 4, in both prosodic conditions. Participants may thus have found it easier to decide that the target phoneme was word-initial in non-ambiguous sentences; however, this should happen in both prosodic conditions. We checked the correlation between the size of the diphone probability difference and the size of the ambiguity effect in the word-initial phoneme detection task; there was a non-significant positive correlation overall, $r^2 = .002$, $t(21) < 1$, and a non-significant negative correlation in the word boundary condition, $r^2 = .01$, $t(12) < 1$. Differences in phonotactic probabilities thus cannot explain the difference between prosodic boundary conditions in the present experiment.

[7] Note that reaction times in the phoneme-monitoring task are rather long compared with word-monitoring reaction times (range 570–740 ms in phoneme-monitoring, relative to 420–600 ms for word-monitoring). As a result, one may fear that at least part of the observed effects could be due to some task-specific strategies rather than to lexical access itself. To check this point, we conducted a post hoc analysis, splitting participants into fast and slow (we thank James McQueen for this suggestion). We observed the same effects in both sub-groups of participants as in the overall population, and the Slow/Fast factor did not interact with any of the experimental factors or significant interactions (all $F_1(1,44) < 1$). Fast participants had a mean reaction time of 565 ms, and slow participants of 707 ms. There was a significant Task by Ambiguity interaction, fast participants, $F_1(1,22) = 5.1$, $p < .05$, slow participants, $F_1(1,22) = 4.6$, $p < .05$; this interaction was significant in the Word Boundary condition, fast participants, $F_1(1,22) = 5.9$, $p < .05$, slow participants, $F_1(1,22) = 6.9$, $p < .05$, but not in the Phonological Phrase Boundary condition, fast participants, $F_1(1,22) < 1$, slow participants, $F_1(1,22) < 1$.

themselves suited to the study of lexical access in fluent sentences. They both have advantages and disadvantages. Thus, word-monitoring provides results with fewer participants (twice as many participants are needed in phoneme-monitoring because there are two versions of the task). Word-monitoring also yields very fast mean reaction times, which leaves little space for post hoc response strategies. On the other hand, phoneme-monitoring relies on the comparison between two groups of subjects on the very same sentences; as a result, there is no way that an artifact in the experimental material could bias the observed results. For instance, if targets in the non-ambiguous condition were longer or more clearly pronounced than targets in the ambiguous condition, this could yield a spurious main effect of ambiguity; however, such an artifact could not create a spurious interaction between ambiguity and experimental task (if targets were easier to detect because of some acoustic factor, they should be easier to detect in all versions of the task). All in all, we think that the results using these two experimental techniques reinforce each other.

General discussion

In this series of four experiments, we observed two main results. First, we found evidence for multiple activation of overlapping lexical candidates, at least within phonological phrases, thus extending previous results with two new experimental paradigms and the French language. Second, we showed that lexical competitors that straddle a phonological phrase boundary do not influence lexical access. This may obtain because they are only weakly activated (i.e., 'chat#grin' is not a good match for 'chagrin'), and/or because the phonological phrase boundary boosts the activation of words ending or starting at that boundary, making the identification of words that immediately precede a phonological phrase boundary fast and efficient, regardless of the words that follow.

Let us spell out in more detail the implications of this result for lexical access models. Several studies had shown that participants can exploit prosodic boundary cues to segment speech into words (see, e.g., Cutler & Butterfield, 1990; Nakatani & Schaffer, 1978; Rietveld, 1980). What remained unclear, however, was when in the lexical access process this prosodic information intervened. There are two main logical possibilities: First, it could be that lexical segmentation is performed mainly on the basis of lexical recognition, and that, whenever an ambiguity arises, prosodic boundary cues are called upon to help resolve the ambiguity (together with other potentially disambiguating cues, e.g., semantic context or syntactic well-formedness). In that case, prosodic boundaries would be used as a last-resort strategy when lexical recognition failed. Second, the prosodic analysis of sentences might be computed in parallel with lexical activation and recognition. In that case, prosodic boundaries would be one of the cues that contribute to the activation of lexical candidates. The relative influence of prosodic and lexical factors would depend on the reliability with which they signal word boundaries at each point in a sentence.

Can our results distinguish between these two hypotheses? The first hypothesis predicts no influence of prosodic boundaries in any type of on-line task: they would be exploited only after lexical recognition fails. Since the ambiguity was only local in our experiments, and the next syllable always permitted unambiguous lexical access, lexical recognition never failed (in fact, neither the speakers nor the participants became aware of the local ambiguities). In Experiments 2 and 4, we did observe an effect of prosodic structure (two distinct patterns of results depending on the size of the prosodic boundary, prosodic word vs phonological phrase). Thus, the first hypothesis is clearly ruled out by our results. The second hypothesis predicts a potential on-line influence of prosodic boundaries, depending on the relative strength of prosodic versus lexical factors. More precisely, prosodic boundary cues are supposed to be taken into account at the same time that lexical activation takes place, and can either speed up or slow down the recognition of lexical candidates. This hypothesis is consistent with our results, since we observed that the influence of a competitor word depended on whether it spanned a phonological phrase boundary or a prosodic word boundary only. This suggests that prosodic boundary information is computed at the same time as lexical activation and recognition, and can influence it.

How can one model this interaction between two different types of information? Two possibilities exist: it may be implemented either in the activation procedure or in the representation of lexical items themselves. In the first option, adults would compute a prosodic analysis of incoming speech simultaneously with a segmental analysis, and lexical activation would be based on all the information available at any moment in time. Whenever evidence for a prosodic boundary would be encountered (e.g., rime or onset lengthening, decreased coarticulation, and pitch discontinuity), some extra activation would be awarded to lexical candidates that begin or end at that boundary, the amount of extra activation depending on the reliability with which this boundary was signaled in the acoustic input; possibly, lexical candidates spanning this boundary would also get deactivated. In the second option, lexical representations would encode the prosodic modifications typical of boundaries, such as final lengthening or reduced coarticulation, so that a portion of acoustic signal exhibiting these cues would be a better match for a lexical item in which this portion is word-final, and a bad match for a lexical candidate in which this portion is word-medial. This option is endorsed by Davis et al. (2002) to account for their results that 'cap' from 'cap tucked' is a better match for the word 'cap' than 'cap' from 'captain.' They write: "Results suggest that acoustic differences in embedded syllables assist the perceptual system in discriminating short words from the start of longer words. The ambiguity created by embedded words is therefore not as severe as predicted by models based on phonemic representations" (p. 218).

Is there a way to distinguish between these two alternative interpretations? Probably not on the basis of the present set of results. Thus, in Experiments 2 and 4, we observed that well-marked prosodic boundaries could modulate lexical activation to the point that no influence of lexical candidates spanning the boundary could be observed: this is easily accounted for within the first interpretation, by postulating that some prosodic boundaries, even though they are not marked by a pause, receive a 100% confidence rating (in other words, they are very efficient in triggering the end of current lexical searches). Whether a radical increase or decrease of activation of lexical candidates can be due to prosodic cues alone in the second interpretation, probably depends on the parameters of the implementation. At any rate, the present results suggest that prosodic boundaries have a strong influence on lexical processing, strong enough to dramatically enhance or reduce the activation elicited by segmental information. Salverda et al. (2003) also argue in favor of the first interpretation (independent prosodic analysis) on the basis of several experiments relying on on-line measurements of eye movements. They observed that a monosyllabic competitor word (e.g., 'ham') embedded in a longer target word (e.g., 'hamster') received more activation when it was longer in duration (thus bearing prosodic cues typical of a monosyllabic word). Even though these results demonstrate once more the influence of prosodic factors (such as duration) on lexical activation, they still do not entirely rule out the alternative interpretation (that these prosodic factors are directly encoded into lexical representations).

What type of experimental evidence would allow us to effectively distinguish between these two interpretations? One potential line of research would consist in manipulating the prosodic context *preceding* the crucial word(s) (so that the crucial syllables would be physically identical but preceded by different prosodic contexts, and would therefore receive different prosodic interpretations). A prosodic analysis of sentences has to exploit information over stretches of speech; for instance, in order to analyze a pitch contour, it does not suffice to look at the pitch of one or two vowels. In contrast, if prosodic information is encoded in the lexical representations themselves, then it can be exploited only locally. Even if one assumes that some kind of normalization applies before lexical matches are computed (at least, rate normalization, since lengthening cannot be evaluated independently of speech rate), there is no way normalization could play the role of computing pitch contours. Therefore, if one found effects of the preceding prosodic context on the lexical activation of competitors straddling potential boundaries, this could be interpreted as evidence in favor of the independent computation of prosodic structure.

Even though the present experimental results cannot distinguish between these two interpretations (independent prosodic analysis vs prosodically rich lexical representations), there are two reasons why we favor an independent prosodic analysis. The first one relates to syntactic analysis, and the second one to acquisition. As we mentioned in the introduction, phonological phrase boundaries depend heavily on the syntactic structure of sentences. Thus, phonological phrase boundaries always coincide with syntactic phrase boundaries, even though the reverse is not true (e.g., in the sentence [he kicked]$_{PP}$ [the ball]$_{PP}$, where brackets mark phonological phrases, the main syntactic boundary between the subject 'he' and the verb phrase 'kicked the ball' is not marked prosodically). As a result, if adults indeed compute a prosodic analysis of sentences (independently of lexical access) they could exploit phonological phrase boundaries to constrain their on-line syntactic analysis of sentences. In other words, the input to the syntactic analyzer would come from two sources: the lexicon that provides words, and the prosodic analyzer that provides prosodic boundaries. In contrast, if the only way in which prosodic boundaries influence lexical access is through the lexical representations themselves, then prosodic boundary information would not be available for syntactic processing. Recent results suggest that adults are able to exploit phonological phrase boundaries to constrain their on-line syntactic analysis of sentences (in French, Millotte & Christophe, 2003).

The second reason why we favor an independent prosodic analysis comes from considering the acquisition problem: Infants have to acquire a lexicon, and to this end, they have to be able to segment incoming speech into word-like units. Following the first interpretation, as soon as infants have learnt how to perform a prosodic analysis of sentences, they can use prosodic boundaries in order to learn new words. In contrast, if the second interpretation is correct, then prosody can help only for those words that are already represented in the lexicon: prosodic boundaries would not help infants to learn new words. Experimental evidence suggests that infants perceive phonological phrase boundaries at around 9 months of age (Gerken, Jusczyk, & Mandel, 1994). Thus, the independent prosodic analyzer hypothesis suggests that from 9 months of age, infants can actively rely on prosodic boundaries in order to segment sentences and learn new words. Even though not all word boundaries are marked by prosodic boundaries (a phonological phrase typically contains 2–3 lexical items), having access to prosodic boundaries would considerably reduce the number of possible parses. Recent experimental results suggest that infants, like adults, exploit phonological phrase boundaries in the course of lexical access. Using a design parallel to the present one, Gout, Christophe, and Morgan (in press) showed that 10- and 13-month-old English-speaking infants who were trained to turn their head in response to the word 'paper' responded significantly more often to sentences that contained 'paper' than to sentences that contained both its syllables separated by a phonological phrase boundary (as in: "[the man] [with the least *pay*] [*per*spires constantly]"). It thus seems that infants are able to exploit phonological phrase boundaries to constrain lexical access, early enough to significantly help their learning of new lexical items.

To conclude, current phonological theories suggest that the construct of phonological phrase is useful in the description of all languages (Nespor & Vogel, 1986; Selkirk, 1984). The present study showed that at least in French, phonological phrases influence lexical access on-line. Thus, phonological phrases could potentially be exploited universally for lexical access and syntactic analysis. As a matter of fact, prosodic cues to phonological phrases have been measured in several unrelated languages (e.g., Barbosa, 2002, for Brazilian Portuguese; de Pijper & Sanderman, 1994, for Dutch; Fisher & Tokura, 1996, for Japanese; Rietveld, 1980, for French; and Wightman et al., 1992, for English). Future work should allow us to specify better how the prosodic structure of utterances is exploited by listeners, and how universal these processes are.

Appendix A. Experimental materials for Experiments 1–4

A.1. Materials for Experiment 1

The target noun is indicated in capitals. Thirty-six pairs of sentences.

Item	Sentence (Competitor Word)
1	Il attira son attention vers un BANC différent qui semblait être un petit peu plus à l'ombre. (bandit)
1	Il attira son attention vers un BANC majestueux qui était entouré d'une foule admiratrice. (*banm)
2	Dans le salon il y a un joli BANC doré qui date du règne de Louis XIV. (bandeau)
2	Dans le salon il y a un joli BANC massif sur lequel les enfants aiment jouer. (*banm)
3	Le livre racontait l'histoire d'un grand CHAT grincheux qui avait mordu un facteur. (chagrin)
3	Le livre racontait l'histoire d'un grand CHAT drogué qui dormait tout le temps. (*chad)
4	Son oncle voulait des renseignements sur son CHAT légendaire qui avait sauvé quelqu'un d'un incendie. (chalet)
4	Son oncle voulait des renseignements sur son CHAT déficient qui ne retombait jamais sur ses pattes. (*chad..)
5	Elle regrettait amèrement le jour où elle avait acheté son CHAT possessif qui était agressif avec tous ses amis. (chapeau)
5	Elle regrettait amèrement le jour où elle avait acheté son CHAT déloyal qui a laissé entrer un cambrioleur. (*chad...)
6	La jeune fille perd beaucoup trop de temps à réfléchir à son COU singulier qui l'empêche de porter des pulls à col roulé. (coussin)
6	La jeune fille perd beaucoup trop de temps à réfléchir à son COU basané qu'elle veut faire admirer à tout le monde. (*coub...)
7	Le COU renflé de l'enfant a déconcerté tous les médecins qui ont essayé de le guérir. (courant)
7	Le COU musclé du taureau faisait l'admiration de tous les gens qui étaient venus pour la corrida. (*coum...)
8	Le médecin m'a parlé des DENTS géniales qu'il pourrait me poser pour quatorze mille francs. (danger)
8	Le médecin m'a parlé des DENTS gâtées que j'aurais sûrement si je mangeais du sucre. (*dang...)
9	Les DENTS difformes de ma soeur la forcent à porter un appareil orthodontique. (dandy)
9	Les DENTS pointues de Bernard le font passer pour un vampire. (*damp...)
10	Un FOU larmoyant suivait le psychiatre dans le couloir. (foulard)
10	Un FOU murmurant a essayé de m'enlever mon chapeau. (*foum...)
11	Un voisin m'a raconté l'histoire du grand FOU robuste qui avait mis tous ses meubles dans la salle de bains. (fourreau)
11	Un voisin m'a raconté l'histoire du grand FOU fâché qui martelait sans cesse les murs de l'hôpital. (*fouf...)
12	Les gens du village étaient très fiers des beaux PINS somptueux du grand bosquet. (pinson)
12	Les gens du village étaient très fiers des beaux PINS luxuriants au bord de la rivière. (*pinl...)
13	Le vieux matelot se souvenait avec plaisir des PINS séduisants de la forêt californienne. (pincée)
13	Le vieux matelot se souvenait avec plaisir des PINS canadiens des rives de St. Laurent. (*pink...)
14	Au bout du chemin il y a un RANG parfumé de roses trémières. (rempart)
14	Au bout du chemin il y a un RANG larmoyant d'enfants perdus. (*ranl...)
15	Son mari détestait les TOUX pénibles qui l'empêchaient de dormir. (toupet)
15	Son mari détestait les TOUX lassantes qui avaient tendance à le miner. (*toul...)
16	L'enfant avait une petite TOUX pitoyable qui trahissait sa maladie. (toupie)
16	L'enfant avait une petite TOUX menaçante qui inquiétait les médecins. (*toum...)

17 Il a expliqué à sa petite sœur que la VIE personnelle de leur frère était un véritable désastre. (vipère)
17 Il a expliqué à sa petite sœur que la VIE malfaisante de Hitler avait été beaucoup étudiée. (*vim…)
18 Il pensait que la VIE réglée des moines franciscains devait être d'une tristesse sans nom. (virée)
18 Il pensait que la VIE modeste de l'Abbé Pierre était plus louable que la sienne. (*vim…)
19 Il haïssait les BALS congestionnés de l'ambassade. (balcon)
19 Il haïssait les BALS majestueux du palais. (*balm…)
20 C'était impressionnant de voir à quel point les jeunes CERFS voraces du château pouvaient manger vite. (cer-veau)
20 C'était impressionnant de voir à quel point les jeunes CERFS dansants du jardin étaient gracieux. (*cerd…)
21 Dans le calme du bois, le CERF pensif contemplait la mare. (serpent)
21 Dans le calme du bois, le CERF docile suivait la petite fille. (*cerd…)
22 Il a eu le souffle coupé en voyant le CORPS bosselé du vieil homme rachitique. (corbeau)
22 Il a eu le souffle coupé en voyant le CORPS chancelant en haut de l'échafaudage. (*corch…)
23 Les CORPS veinés de ces vieilles dames m'ont rappelé combien la vie est fragile. (corvée)
23 Les CORPS replets de mes deux frères en ont fait des objets de risée quand ils étaient petits. (*corre…)
24 Tout le monde disait que le vieux FORT bancal allait s'écrouler. (forban)
24 Tout le monde disait que le vieux FORT désert était hanté. (*ford…)
25 Le FORT magnifique du duc de Bretagne attire aujourd'hui beaucoup de touristes. (format)
25 Le FORT colossal du duc de Bretagne repoussait facilement les envahisseurs. (*fork…)
26 J'ai été impressionné par le grand FOUR byzantin qui a été construit par l'empereur Constantin. (fourbi)
26 J'ai été impressionné par le grand FOUR futuriste qui a été découvert dans une pyramide égyptienne. (*fourf…)
27 Les FOURS microscopiques sont de plus en plus utilisés dans l'industrie électronique de pointe. (fourmi)
27 Les FOURS conventionnels sont de moins en moins répandus depuis l'invention récente des micro-ondes. (*fourk…)
28 Mon frère a été écoeuré quand je lui ai parlé du LARD synthétique que j'avais acheté. (larcin)
28 Mon frère a été écoeuré quand je lui ai parlé du LARD pourrissant au fond du frigo. (*larp…)
29 J'ai expliqué au policier que j'avais un PERE mirifique qui n'aurait jamais pu commettre un crime pareil. (permis)
29 J'ai expliqué au policier que j'avais un PERE richissime qui serait reconnaissant s'il ne m'arrêtait pas. (*perri…)
30 Elle détestait le PERE silencieux de son mari, qui refusait même de la saluer. (persil)
30 Elle détestait le PERE répugnant de sa fille, qui était parti avec tout leur argent. (*perré…)
31 Dans le parc les gens du village voient souvent le PERE vertueux de l'église locale, qui vient faire des sermons aux passants. (pervers)
31 Dans le parc les gens du village voient souvent le PERE rondelet de la famille Thibaut, qui fait des pique-niques sur l'herbe. (*perr..)
32 Les PORTS ténébreux du XVIII^{e} siècle grouillaient affreusement de rats et de cafards. (portée)
32 Les PORTS commerciaux des années trente servaient de promenades pour les riches et les élégants. (*pork…)
33 Il se souvenait du beau PORT trépidant d'Amsterdam où il avait passé douze années de son enfance. (portrait)
33 Il se souvenait du beau PORT primitif de Stockholm qu'il préférait à celui qu'on venait de construire. (*porp…)
34 Le guide touristique du château affirmait à son public que les SOLS dallés étaient très faciles d'entretien. (soldat)
34 Le guide touristique du château affirmait à son public que les SOLS chauffés rendaient les pièces très confortables en l'hiver. (*solch…)
35 Elle a un VER gélatineux qu'elle sort de temps en temps pour faire peur à sa mère. (verger)
35 Elle a un VER parasitique que les médecins veulent guérir le plus vite possible. (*verp…)
36 Les petits VERS séchés qu'il utilisait comme appâts étaient très efficaces. (verset)
36 Les petits VERS chétifs qu'il élevait dans un bocal faisaient vraiment pitié. (*verch…)

A.2. Materials for Experiment 2

The target word is indicated in capitals.

Sixteen pairs of sentences with a prosodic word boundary at the point of local ambiguity:

Item Sentence (Competitor Word)
1 Il attira son attention vers un BANC différent qui semblait être un petit peu plus à l'ombre. (bandit)
1 Il attira son attention vers un BANC majestueux qui était entouré d'une foule admirative. (*banm..)
2 Dans le salon il y a un BANC doré qui date du règne de Louis XIV. (bandeau)
2 Dans le salon il y a un BANC massif sur lequel les enfants aiment jouer. (*banm…)
3 Le livre racontait l'histoire d'un CHAT grincheux qui avait mordu un facteur. (chagrin)
3 Le livre racontait l'histoire d'un CHAT drogué qui dormait tout le temps. (*chad…)
4 Son CHAT possessif était agressif avec tous ses amis. (chapeau)
4 Son CHAT déloyal avait laissé entrer un cambrioleur. (*chad…)
5 Des FOUS larmoyants suivaient le psychiatre dans le couloir. (foulards)

5 Des FOUS murmurants ont essayé de m'enlever mon chapeau. (*foum...)
6 Les gens du village étaient très fiers des PINS somptueux du grand bosquet. (pinsons)
6 Les gens du village étaient très fiers des PINS luxuriants du bord de la rivière. (*pinl...)
7 Il haïssait les BALS congestionnés de l'ambassade. (balcons)
7 Il haïssait les BALS majestueux du palais. (*balm...)
8 Les CERFS voraces du château mangeaient très vite. (cerveaux)
8 Les CERFS dansants du jardin étaient gracieux. (*cerd...)
9 Dans le calme du bois le CERF pensif contemplait la mare. (serpent)
9 Dans le calme du bois le CERF docile suivait la petite fille. (*cerd...)
10 Tout le monde disait que le FORT bancal allait s'écrouler. (forban)
10 Tout le monde disait que le FORT désert était hanté. (*ford...)
11 Le FORT magnifique attire aujourd'hui beaucoup de touristes. (format)
11 Le FORT colossal repoussait facilement les envahisseurs. (*fork...)
12 Ce FOUR byzantin a été construit par l'empereur Constantin. (fourbi)
12 Ce FOUR futuriste a été découvert dans une pyramide égyptienne. (*fourf...)
13 Les FOURS microscopiques sont utilisés dans l'industrie électronique de pointe. (*fourmis)
13 Les FOURS conventionnels sont moins répandus depuis l'invention récente des micro-ondes. (*fourk...)
14 Les PORTS ténébreux du XVIII^{e} siècle grouillaient affreusement de rats et de cafards. (portée)
14 Les PORTS commerciaux des années 30 servaient de promenades pour les riches et les élégantes. (*porko...)
15 Il se souvenait du PORT trépidant d'Amsterdam où il avait passé douze années de son enfance. (portrait)
15 Il se souvenait du PORT primitif de Stockholm qu'il préférait à celui qu'on venait de construire. (*porp...)
16 Les SOLS dallés sont très faciles d'entretien. (soldats)
16 Les SOLS chauffés rendent les pièces confortables en hiver. (*solch...)

Sixteen pairs of sentences with a phonological phrase boundary at the point of local ambiguity:

Item Sentence (Competitor Word)
17 Même le grand BANC bougeait sous l'effet du séisme. (bambou)
17 Même le grand BANC cédait sous le poids du Sumo. (*bans...)
18 Elle affirmait que le drôle de BANC donnait à la pièce un caractère particulier. (bandeau)
18 Elle affirmait que le drôle de BANC penchait dangereusement sur la gauche. (*bamp...)
19 D'après ma sœur, le gros CHAT grimpait aux arbres. (chagrin)
19 D'après ma sœur, le gros CHAT dressait l'oreille. (*chad...)
20 Le vieux FOU larmoyait au milieu de la place du village. (foulard)
20 Le vieux FOU parcourait les rues à la recherche de son éléphant rose. (*foup...)
21 Le très vieux PIN sombrait dans la solitude la plus totale. (pinson)
21 Le très vieux PIN régnait sur toute la forêt. (*pinr...)
22 D'après le livre, le très grand FORT magnifiait le génie architectural de l'époque. (format)
22 D'après le livre, le très grand FORT paraissait véritablement imprenable. (*forp...)
23 De manière surprenante, presque tous les JEUX dissipaient les élèves. (jeudis)
23 De manière surprenante, presque tous les JEUX passionnaient les élèves. (*jeup...)
24 Elle nous racontait que le mauvais TEMPS bourdonnait à ses oreilles. (tambour)
24 Elle nous racontait que le mauvais TEMPS malmenait son parapluie. (*temm..)
25 Une grande quantité de BOUE giclait au passage de la diligence. (bougie)
25 Une grande quantité de BOUE nivelait le relief du paysage. (*boun...)
26 Devant la grille, le superbe PAON flemmardait au soleil. (pamphlet)
26 Devant la grille, le superbe PAON grelottait sous les arbres. (*pang...)
27 Le terrible VENT tardait à se lever. (vantard)
27 Le terrible VENT corsait plus encore la course. (*venk...)
28 Après l'accident, le vieux MAT touchait définitivement le fond. (matou)
28 Après l'accident, le vieux MAT vibrait à chaque secousse. (*mav...)
29 Sa mystérieuse MORT surprenait tous les médecins de l'hôpital. (morsure)
29 Sa mystérieuse MORT constituait un événement politique majeur. (*mork...)
30 Le gigantesque PHARE dominait toute la côte. (fardeau)
30 Le gigantesque PHARE vacillait sur ses bases. (*farv...)
31 Il est heureux que son PERE milite pour les droits de l'homme. (permis)
31 Il est heureux que son PERE bataille dur pour gagner son procès. (*perb...)
32 Le nouveau CHAR bombardait les positions ennemies. (charbon)
32 Le nouveau CHAR fascinait les soldats par sa puissance de feu. (*charf...)

A.3. Materials for Experiment 3

Twenty-two pairs of experimental items.

Item	Target	Sentence (Competitor Word)
1	f	Il avait un dé faussé qui lui permettait de jouer des tours à ses amis. (défaut)
1	f	Il avait un nez faussé qui lui donnait l'air ridicule. (*néfo)
2	g	C'était son chat grincheux qui le rendait nerveux. (chagrin)
2	g	C'était son pas gracieux qui trahissait sa profession de danseur. (*pagr..)
3	r	Le chef cuisinait des mets roumains pour ses amis. (mérous)
3	r	Le chef cuisinait des geais rôtis avec une sauce au poivre. (*gèro..)
4	p	L'enfant avait une toux pitoyable, qui trahissait sa maladie. (toupie)
4	p	L'enfant avait une moue pitoyable, qui montrait qu'il était prêt à pleurer. (*moup..)
5	s	Les pins somptueux de la forêt californienne sont célèbres. (pinson)
5	s	Les vins somptueux de l'abbaye de Beaune sont réputés à juste titre. (*vins..)
6	d	Il attira son attention vers un banc différent, qui datait d'une autre époque. (bandit)
6	d	Il attira son attention vers un paon dynamique, qui arpentait tout le jardin en faisant la roue. (*pandi..)
7	p	La vie personnelle de mon frère est un véritable désastre. (vipère)
7	p	La fille persifleuse du patron va lui faire perdre sa clientèle. (*fip..)
8	p	Au bout du chemin, il y a un rang parfumé de roses trémières. (rempart)
8	p	Au bout du chemin, il y a un banc parsemé de feuilles mortes. (*bamp..)
9	v	Mon grand-père a un pas vigoureux et alerte. (pavillon)
9	v	Mon grand-père a un chat vénérable et ancien. (*chavé…)
10	m	Il se passionnait pour les cas médicaux, que son frère médecin lui racontait. (caméra)
10	m	Il se passionnait pour les chats métissés, qu'il élevait lui-même dans sa maison. (*chamé..)
11	p	Jean avait découvert un sou pittoresque chez l'antiquaire. (soupirail)
11	p	Jean avait découvert un fou pyromane dans la grange, qui s'apprêtait à mettre le feu. (*foup..)
12	p	Le touriste était amateur de chants pittoresques, et n'hésitait pas à faire un détour pour en écouter. (champignons)
12	p	Le touriste était amateur de gens pittoresques, et il en remplissait des pellicules entières. (*genp..)
13	m	En venant ici, j'ai vu un rat moribond couché dans le caniveau. (ramoneur)
13	m	En venant ici, j'ai vu un gars mollasson se dirigeant par ici. (*gamo..)
14	k	Il adorait les mots cabalistiques, et ne se lassait pas de les introduire dans sa conversation. (mocassins)
14	k	Il adorait les pots catalytiques, et invitait tous ses amis à changer de voiture. (*pok..)
15	d	Les sols dallés sont faciles d'entretien. (soldats)
15	d	Les colles danoises sont réputées pour leur efficacité. (*cold..)
16	k	Il haïssait les bals compassés de l'ambassade. (balcons)
16	k	Il haïssait les salles confinées du château. (*salk..)
17	b	De la fenêtre de l'hôtel, on voyait les tours byzantines du grand palais. (tourbillon)
17	b	De la fenêtre de l'hôtel, on voyait les cours byzantines de la mosquée. (*courbi..)
18	b	Il y avait un char bohémien sur le chemin. (charbonnier)
18	b	Il y avait un jars boudiné sur la route. (*jarb..)
19	t	La mule timorée refusait de monter dans la carriole. (multitude)
19	t	La bulle titanesque émerveillait le gamin qui jouait avec l'eau savonneuse. (*bulti..)
20	m	Le vieillard avait l'habitude de visiter le phare majestueux qui domine la crique. (pharmacie)
20	m	Le vieillard avait l'habitude de visiter le char majestueux qui servait pour les processions religieuses. (*charmaj..)
21	m	Il évoquait souvent la terre miraculeuse qui était censée guérir le cancer. (termitière)
21	m	Il évoquait souvent la guerre mythologique qui avait opposé les Horaces aux Curiaces. (*guerm..)
22	m	Les fours microscopiques sont de plus en plus utilisés dans l'industrie électronique de pointe. (foumi)
22	m	Les jours miraculeux de la Libération resteront longtemps dans les mémoires. (*jourm..)

A.4. Materials for Experiment 4

Fifteen pairs of sentences with a prosodic word boundary at the point of local ambiguity:

Item	target	Sentence (Competitor Word)
1	d	Il attira son attention vers un banc différent qui semblait être un petit peu plus à l'ombre. (bandit)
1	d	Il attira son attention vers un quai différent qui servait à décharger les fruits et légumes. (*kèd…)

3	g	Le livre racontait l'histoire d'un chat grincheux qui avait mordu un facteur. (chagrin)
3	g	Le livre racontait l'histoire d'un pou grincheux qui détestait le shampooing. (*poug..)
4	p	Son chat possessif était agressif avec tous ses amis. (chapeau)
4	p	Son geai possessif était toujours jaloux. (*jèp..)
5	l	Des fous larmoyants suivaient le psychiatre dans le couloir. (foulards)
5	l	Des boeufs larmoyants ruminaient dans le champ. (*beul..)
6	s	Les gens du village étaient très fiers des pins somptueux du grand bosquet. (pinsons)
6	s	Les gens du village étaient très fiers des bains somptueux construits par les romains. (*bins..)
7	k	Il haïssait les bals congestionnés de l'ambassade. (balcons)
7	k	Il haïssait les bourgs congestionnés des environs. (*bourk..)
8	v	Les cerfs voraces du château mangeaient très vite. (cerveaux)
8	v	Les porcs voraces de la ferme mangeaient beaucoup. (*porv..)
9	p	Dans le calme du bois le cerf pensif contemplait la mare. (serpent)
9	p	Dans le calme du bois le sire pensif regardait son château au loin. (*sirp..)
10	b	Tout le monde disait que le fort bancal allait s'écrouler. (forban)
10	b	Tout le monde disait que le phare bancal était dangereux. (*farb..)
11	m	Le fort magnifique attire aujourd'hui beaucoup de touristes. (format)
11	m	Le saule magnifique ombrageait tout le jardin. (*solm..)
12	b	Ce four byzantin a été construit par l'empereur Constantin. (fourbi)
12	b	Ce phare byzantin s'élevait non loin de Constantinople. (*farb..)
13	m	Les fours microscopiques sont utilisés dans l'industrie électronique de pointe. (*fourmis)
13	m	Les piles microscopiques sont très difficiles à remplacer. (*pilm..)
14	t	Les ports ténébreux du XVIIIe siècle grouillaient affreusement de rats et de cafards. (portée)
14	t	Les bourgs ténébreux du moyen-âge regorgeaient de voleurs et de mendiants. (*bourt…)
15	t	Il se souvenait du PORT trépidant d'Amsterdam où il avait passé douze années de son enfance. (portrait)
15	t	Il se souvenait du bar trépidant de Bruxelles où il avait rencontré Jacques Brel. (*bart..)
16	d	Les sols dallés sont très faciles d'entretien. (soldats)
16	d	Les cours dallées résonnent des cris des enfants. (*kourd..)

Nine pairs of sentences with a phonological phrase boundary at the point of local ambiguity:

Item	target	Sentence (Competitor Word)
21	s	Le très vieux pin sombrait dans la solitude la plus totale. (pinson)
21	s	Le très vieux loup sombrait dans la mélancolie. (*lous..)
22	m	D'après le livre, le très grand fort magnifiait le génie architectural de l'époque. (format)
22	m	D'après le livre, le très grand port magnifiait l'ingéniosité des anciens grecs. (*porm..)
24	b	Elle nous racontait que le mauvais temps bourdonnait à ses oreilles. (tambour)
24	b	Elle nous racontait que le mauvais coup bourdonnait dans sa tête. (*koub..)
25	j	Une grande quantité de boue giclait au passage de la diligence. (bougie)
25	j	Une grande quantité de lait giclait de la bouche du bébé. (*lèj..)
26	f	Devant la grille, le superbe paon flemmardait au soleil. (pamphlet)
26	f	Devant la grille, le superbe geai flemmardait sur une branche. (*jèf..)
28	t	Après l'accident, le vieux mât touchait définitivement le fond. (matou)
28	t	Après l'accident, le vieux nain touchait doucement sa jambe blessée. (*nint..)
30	d	Le gigantesque phare dominait toute la côte. (fardeau)
30	d	Le gigantesque four dominait toute la cuisine. (*fourd..)
31	m	Il est heureux que son père milite pour les droits de l'homme. (permis)
31	m	Il est heureux que son rôle milite en faveur des réfugiés. (*rolm..)
32	b	Le nouveau char bombardait les positions ennemies. (charbon)
32	b	Le nouveau maire bombardait ses subalternes de circulaires. (*mèrb..)

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