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Abstract

Perception studies have shown priming effects of intonational boundaries in disambiguating sentences. Recently, we found evidence for boundary priming in the production of relative clause attachment constructions in English. This study investigates the generalizability of priming effects of boundary location in production in another language, French, characterized by a different way of organizing phrasing from English. We measured word-and-pause durations at critical locations in relative clause constructions, when participants repeated prime sentences and when they produced new ambiguous target sentences. Primes were manipulated to either include a boundary (half early, half late) or not. Our results showed that in French, as in English, boundary location in primes affected both the repetition of prime sentences and the production of new ambiguous targets. When repeating primes, participants produced the longest word-and-pause duration at the primed critical location. When producing targets, the default late boundary preference at the relative clause boundary was smoothed if the prime presented an early boundary. Our results replicate priming effects of boundary location in production previously observed in English. Taken together, these findings support the robustness of the claim that boundaries can be primed and affect sentence processing, suggesting a somewhat abstract representation of prosodic structure computed in early stages of production planning.

Index Terms: intonational phrase boundaries, prosodic representation, production, sentence processing, cross-linguistic variation

1. Introduction

If early models of prosodic structure postulated isomorphism to and dependency from syntactic structure [1, 2], recent models acknowledge significant differences and a complex relationship among the two. These models now argue for an independent - albeit to varying extents - representation of prosodic structure, computed in parallel with, or completely separately from, syntactic structure [3, 4, 5, for review]. A large body of research using various methods [6, 7, 8] has specifically explored this question and shown the role of intonational phrase boundaries (IPBs) as "informative" [9, 10] to signal and disambiguate syntactic structure in real-time. Recent empirical perception work seems to suggest that the prosodic information conveyed by IPBs is already computed at early stages of processing [11, 12, 13].

Priming studies have further sought to explore the extent to which this prosodic information is represented and planned in advance. Perception studies have revealed clear priming effects of boundary location in disambiguating sentences. In the classic [14], it was shown that boundary location in auditory primes affects the interpretation of new ambiguous sentences in silent reading. And this effect persists even with delexicalized primes [15]. In a series of production studies, researchers tested the generalizability to production of priming effects of boundary location, by means of a specific prosodic priming paradigm. Early experimental attempts [16, 17] did not observe the effect found in perception, suggesting that there was no empirical support for primed boundary affecting the production of new ambiguous sentences. However, we recently observed some limitations in this line of work challenging this claim (e.g., strong structural processing biases and too coarse-grained analyses) [18, 19]. Once these limitations were addressed, we found evidence for boundary priming in the production of ambiguous relative clause attachment constructions in British English [18, 19]. This evidence suggests that IPBs can be primed in perception but also in production, indicating that some overall prosodic phrasing information is computed in early stages of production planning and informs them, in line with Prosody First proposals [20, 21].

The goal of this study was to investigate the generalizability and validate the robustness of these priming effects of boundary location in production across languages. To address this question, we replicated the British English study with parallel materials in French. Mainstream varieties of English and French differ significantly in the way of organizing prosodic phrasing. In the AM framework, English is described as a head-prominence [22] intonation language [23], characterized by pitch-related events (notably, pitch accents) which contribute to a stress-timed rhythm. In contrast, French is described as an edge-marking language [23, 24]. It does not mark stress at the lexical level. However, it clearly marks events at the phrase-level, via phrase accents (notably, final accents) and durational cues at the boundaries [25, 26, 27]. This results in a highly regular prosodic structure contributing to a strong temporally-marked right-headed macro rhythm [22]. In turn, such an edge-marking structure should entail high sensitivity to boundaries. Hence, English and French use distinct, and differently-weighted, cues to mark IPBs.

Our hypothesis was that it would be possible to prime IPBs in production in French as in English, conscious that language-specific prosodic markings might affect the magnitude of the effect but not the robustness of the claim. Specifically, we predicted a boundary location effect, with speakers producing the longest duration at the primed boundary location, when repeating a heard sentence, but also when producing a novel ambiguous read sentence. If met, it would extend and validate the robustness of the claim on the primeability of IPBs in production, and indirectly on their representation and planning at early stages of production.

2. Methods

Experimental materials and scripts are available at https://osf.io/htxjr. This study was approved by the Ethics Committee of Université Paris Cité (n° IRB : 00012021-106).

2.1. Participants

Young adult French speakers grown up and living in the same region (Greater Parisian area) participated in the study. All data were collected in the lab. We report results from 23 participants (*M* age = 25.83 (18-35); 13 of them self-identified as female, 10 as male) included in the final sample out of the 33 participants tested. All participants identified French as their first language, and still had it as their strongest and dominant language. As normal for French young adults, most of them speak, have been exposed to or formally instructed in other languages. All participants self-reported normal or corrected-to-normal vision, no hearing impairments, and no known neurological, speech, or communication disorders at the time of testing.

2.2. Materials

The experimental stimuli consisted of 40 globally-ambiguous relative clause (RC) attachment constructions. The sentences were parallel translations of the stimuli originally tested in the English study [18, 19], to allow for between-studies comparisons and cross-linguistic investigation. A few modifications were necessary due to cultural adaptations or language-specific constraints relevant for the analysis (i.e., word-length, avoidance of vowel-initial words and liaison contexts).

Two examples of experimental items are given in (1-4). In RC-attachment sentences such as these, two plausible alternative interpretations are possible. The subject of the RC can be the first noun (henceforth N1), in which case the RC attaches high. Or the subject can be the second noun (henceforth N2), in which case the RC attaches low. The ambiguity can be solved in spoken communication, with the prosodic structure of the sentence driving listeners towards one interpretation [28]. Specifically, a boundary after N2 can boost a high N1-attachment interpretation (4); whereas a boundary after N1 can boost a low N2-attachment interpretation (3).

1. *Il vient avec le collègue du reporter qui écrit dans Le Monde.*
   'He comes with the colleague.SG of the reporter.SG who writes.SG for Le Monde'
   (NO (EARLY) BOUNDARY, AMBIGUOUS)
2. *Elle reste avec le patient du médecin qui attend les résultats.*
   'She stays with the patient.SG of the doctor.SG who waits.SG for the blood results'
   (NO (LATE) BOUNDARY, AMBIGUOUS)
3. *Il vient avec le collègue % du reporter qui écrit dans Le Monde.*
   (EARLY BOUNDARY, AMBIGUOUS)
4. *Elle reste avec le patient du médecin % qui attend les résultats.*
   (LATE BOUNDARY, AMBIGUOUS)

All experimental sentences were controlled for length, semantic plausibility, structure, and known factors triggering strong attachment preferences. Particularly, given the nature of French language, no perceptual verbs were used in the matrix and N1s were embedded in prepositional phrases, to avoid pseudo-relative availability promoting high attachment [29, 30]. All RC modifiers were controlled for length and information load, to avoid any strong preference for low or high attachment [31, 32]. All critical nouns where a boundary was primed or expected (N1 for sentences primed with an early boundary in the boundary condition; N2 for sentences primed with a late boundary in the boundary condition) were created to have the same length in terms of syllables (disyllabic nouns).

2.2.1. Design

Following the prosodic priming paradigm [17], each item was manipulated to either be ambiguous or not, and to either include a boundary or not (Figure 1). Half of the sentences with boundaries presented an early boundary (after N1); half of the sentences presented a late boundary (after N2).

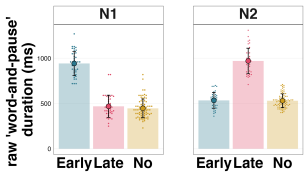


Figure 1: *Raw word-and-pause durations automatically extracted at different boundary conditions in the stimuli used as primes (N=160).*

Sentences were paired to form prime-target pairs. Sentences in the prime position were assigned one experimental condition. Sentences in the target position were always ambiguous and without a boundary, being visually presented. PRIME BOUNDARY (present, with half early and half late; or absent) and PRIME AMBIGUITY (present, or absent) were counterbalanced within items and within participants in four experimental lists. Additional four lists were created by swapping the SENTENCE POSITION (prime or target), and consequently adjusting the sentence manipulations within the pairs. Each participant was presented with all 40 sentences (5 sentences per prime-condition), with no more than two sentences in the same condition in a row.

2.2.2. Audio Stimuli

All prime sentences were recorded by a trained native speaker (female) of French in a sound-attenuated booth. To avoid reading prosody, the speaker was instructed to first read each sentence silently and then produce it. Her speaking rate remained as constant as possible throughout the recording session (*M* = 5.58 (4.88-6.11) syll/sec for the NO BOUNDARY condition; *M* = 4.86 (4.13-5.37) syll/sec for the BOUNDARY condition). Sentences were recorded in block by condition. The speaker was instructed to first produce all sentences naturally but without producing any strong prosodic markings (NO BOUNDARY condition). Then, she was asked to produce an explicit boundary in the location now signaled by a slash (EARLY/LATE BOUNDARY condition). The audio stimuli were not further acoustically manipulated. This allowed us to prevent any artificial disruptions in the acoustic contour, to avoid any neutralizations of other prosodic cues signaling an IPB, and to preserve the prosody of the entire sentence crucial for incremental processing and boundary strength perception.

2.3. Procedure

The experiment was conducted entirely in the lab. The task was created in PCIbex [33] and executed on the university-hosted

Ibex farm server. The experimental procedure was the same as in previous experiments using the prosodic priming paradigm in production [17]. Participants were instructed to repeat back out loud each sentence they heard or silently read, and to press the spacebar to advance. For each trial, participants listened to (and repeated) a prime sentence, and then silently read and produced a novel ambiguous target sentence. Filler sentences presenting various syntactic structures, ambiguous or not, and IPBs at various plausible locations were added as audio or visual stimuli between each prime-target pair.

The experimental session lasted on average less than 30 minutes, including setup, instructions, and practice trials. After completing the production task, participants were asked to complete a self-reported musical training questionnaire and the Empathy Quotient questionnaire [34].

2.4. Data Processing and Analyses

Participant productions were transcribed and analyzed offline on Praat [35] by a native French speaker blinded to conditions, and double checked by a second coder. Two simultaneous bilingual participants were entirely excluded from analysis. Sentences with only minor word changes were included in the final sample, following the same procedure adopted for English (detailed exclusion criteria available on OSF). This process led to the exclusion of 8 participants providing unusable recordings for more than 10 out of the 40 experimental sentences, and of 14% of the 920 remaining productions. The data were then force-aligned with the Montreal Forced Aligner [36].

Following previous studies, for each produced sentence included in the final sample, we assessed boundary production at both critical locations (after N1, and after N2) by measuring the 'word-and-pause' duration, from the onset of the pre-boundary word through the onset of the first post-boundary word. As in the English study [18, 19], raw durations were normalized as a function of the produced noun length and the total duration of the produced sentence. The relative size (as percentage) of the normalized duration at the critical locations was our final measure of interest.

3. Results

Data processing resulted in a sample of 791 recordings across 23 participants. The distributions of the normalized duration of the nouns at critical locations for each condition are displayed in Figure 2.

We adopted a Bayesian approach to test our prediction of prosodic priming effects depending on the boundary location. All models were constructed and performed using the brms package [37] in R [38], and so-called weakly informative priors. We entered the normalized duration of the 'word-and-pause' at the critical location as DV, and included main effects of PRIME AMBIGUITY, PRIME BOUNDARY LOCATION, SENTENCE POSITION, NOUN, and all their interactions, as well as by-ITEM and by-SUBJECT random effects.

The effect of PRIME BOUNDARY LOCATION on the duration of the critical location is plotted in Figure 3a. The model revealed an interaction effect of PRIME BOUNDARY LOCATION and NOUN of β=-5.50, SE=0.87, with a 95% CrI of [-7.19, -3.71] and a probability of 1 of the estimate being smaller than 0 for the EARLY BOUNDARY×NOUN 2 interaction, and of β=4.78, SE=0.70, CrI [3.40, 6.18], P(β>0)=1 for the LATE BOUNDARY×NOUN 2 interaction, suggesting a rather clear effect of boundary location on critical location durations.

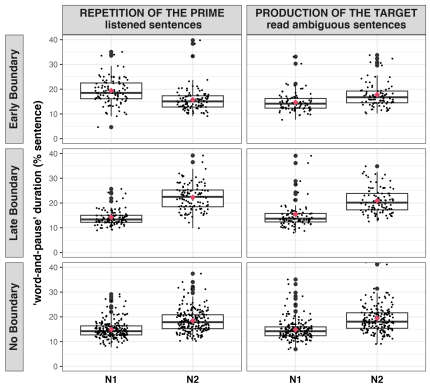
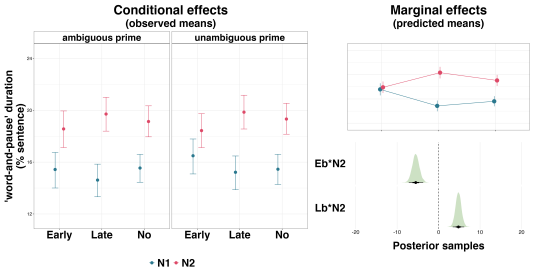
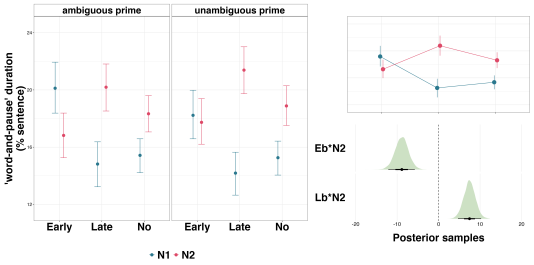


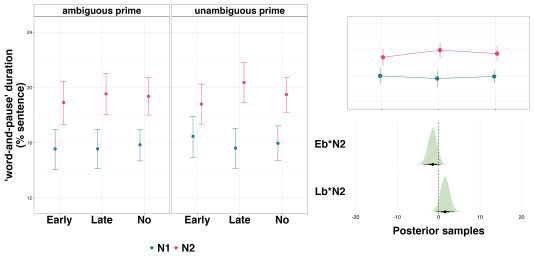
Figure 2: *Normalized duration at critical locations after hearing prime-sentences in different boundary conditions (red dots represent the mean).*



(a) *Across prime/target conditions*



(b) *Repetition of the prime (listened sentences)*



(c) *Production of the target (novel read ambiguous sentences)*

Figure 3: *Conditional effect of prime boundary location by ambiguity on normalized durations (on the left), and predicted means and probabilities of Noun 2 durations by prime boundary location (on the right). Main categorical predictors sum-coded; intercept reflecting the weighted grand mean across conditions. Error bars indicate 95% credible intervals.*

To explore whether the effect was driven only by the repetitions of the listened sentences or it was indeed carried over to the production of novel ambiguous sentences, we fitted separate models for each of the two modality conditions (prime/target SENTENCE POSITION). Post-hoc models showed that the priming effect pattern is clearly present in the repetition of the prime sentences (β=-8.89, SE=1.61, CrI [-12.13, -5.73], P(β<0)=1, for the EARLY BOUNDARY×NOUN 2 interaction; β=7.46, SE=1.40, CrI [4.67, 10.25], P(β>0)=1, for the LATE BOUNDARY×NOUN 2 interaction), as displayed in Figure 3b. To a lower extent, PRIME BOUNDARY LOCATION modulates critical region durations in the production of target sentences (Figure 3c; β=-1.46, SE=1.07, CrI [-3.64, 0.57], P(β<0)=0.92, for the EARLY BOUNDARY×NOUN 2 interaction; β=1.57, SE=1.74, CrI [-0.63, 3.79], P(β>0)=0.93, for the LATE BOUNDARY×NOUN 2 interaction).

As for PRIME AMBIGUITY, the main model did not return compelling evidence for an effect of ambiguity on the critical location duration (β=-0.53 and a credible interval of [-1.51, 0.47] substantially overlapping with the 0). The output of the separate model for the repetition of the prime sentences did indeed show evidence for an effect of ambiguity, with ambiguous primes overall decreasing the duration of N2 (β=-1.78, SE=0.75, CrI [-3.24, -0.29], P(β<0)=0.99), and some weak evidence for an interaction effect of AMBIGUITY and EARLY BOUNDARY on N2 duration (β=-2.05, SE=1.87, CrI [-5.73, 1.57], P(β<0)=0.87). However, the effect seems to disappear in the production of the target sentences (β=0.07, SE=0.74, CrI [-1.38, 1.53], P(β>0)=0.54 for the AMBIGUITY×NOUN interaction; and only weak evidence for an interaction effect ofAMBIGUITY and EARLY BOUNDARY on N2 duration, β=1.88, SE=1.71, CrI [-1.44, 5.28], P(β>0)=0.86).

4. Discussion

We replicated previous research on IPBs priming in English with parallel materials in French to investigate the generalizability of priming effects of boundary location in production across languages. Our results show that boundary location in primes affects both the repetition of prime sentences and the production of novel ambiguous target sentences. When repeating heard prime sentences, participants produced the longest word-and-pause duration at the primed critical location. When producing novel target sentences, critical region durations (namely, the relative clause boundary at N2) seem to be modulated by boundary location in the prime. Specifically, results revealed interaction effects of early or late boundary prime on the N2 durations.

In prime repetitions, the early boundary effect on N2 duration is particularly strong in ambiguous sentences, where participants seem to closely repeat the heard early boundary as a means of marking disambiguation. Vice versa, when repeating unambiguous sentences, participants do not seem to blindly reproduce an early boundary, although they do still drastically reduce N2 durations. These results are consistent with previous experimental literature reporting asymmetric effects of boundary location in ambiguity resolution, with early boundary triggering particularly strong effects [39].

When it comes to target productions, our results reveal quite robust evidence for a modulation effect of prime boundaries on N2 durations. Although sentences primed with an early boundary do not show longer durations for N1 than N2, the interaction effect can be safely interpreted as enough evidence for IPBs priming. The pattern of speakers' productions in the other prime conditions offers a first insight in this direction. Notably, sentences primed in the No Boundary condition indicate a general preference for a late boundary - already in the repetition of the primes, and regardless of any potential structural priming effect. This natural preference is consistent with the Implicit Prosody Hypothesis' [31] prediction of a large prosodic RC boundary for high attachment preference languages such as French. A late boundary in the prime lengthened the N2 word-and-pause duration, as expected, and it strengthened this seemingly default prosody. In contrast, an early boundary in the prime attenuated N2 durations, without overwriting the projection of the default late boundary preference in speakers' productions. Moreover, we cannot forget that prosodic information is not limited to the boundary, and that boundary information is not limited to the presence of a pause. Listeners rely on multiple cues when perceiving a boundary in sentence processing. It may be the case that speakers, especially speakers of an edge-marking language like French expected to show great sensitivity to boundaries, make use of a full prosodic representation of IPBs in sentence processing as well as in sentence production. In other words, it is possible that other cues contributed more than the pause to boundary perception, and/or that speakers relied more on other cues than the mere pause when producing primed boundaries. Alternatively, it is also possible that the predominantly phrase-level and phrase-final marking of prosodic structure in French poses more constraints and less flexibility in IPBs use, so that French speakers are less primeable for IPBs than speakers of head-prominence languages. In light of these observations, we think that, even in absence of longer durations at N2 than N1 in the early boundary condition, the interaction effect can safely be interpreted as an effect of IPBs priming.

These findings in French mirror priming effects of boundary location in production previously observed in English [18, 19]. First, this points to the robustness of the effect across languages. This cross-linguistic validation gains even further relevance when considering how French and English distinctly organize phrasing, and use different and differently-weighted cues to mark IPBs. Second, this points to the robustness of the effect across modalities. By replicating English findings, the current study provides further evidence on the primeability of IPBs in production, in line with the clear evidence from perception studies [14, 15].

Taken together, the English and French findings on boundary priming effects in production provide novel experimental contribution to previous work on the role of IPBs. Prosodic information conveyed by IPBs is not only confirmed to be informative in real-time. But, in line with recent work [12, 13], our findings suggest that the production system does not simply formulate prosodic boundaries as a response to cues from syntactic and semantic stages; rather that overall prosodic phrasing information is abstractly represented to some extent, and already computed in early stages of production planning.

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