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Processing Liaison-Initial Words in Native and Non-Native French: Evidence from Eye Movements

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Abstract

French listeners have no difficulty recognizing liaison-initial words. This is in part because acoustic/phonetic information distinguishes liaison consonants from (non-resyllabified) word onsets in the speech signal. Using eye tracking, this study investigates whether native speakers of English, a language that does not have a phonological resyllabification process like liaison, can develop target-like segmentation procedures for recognizing liaison-initial words in French, and if so, how such procedures develop with increasing proficiency.

Index Terms: speech segmentation, non-native, French liaison

1. Introduction and background

To segment speech into words, it is not sufficient to know the individual words present in the speech signal; one must also adjust for the phonological processes that contribute to making word boundaries fuzzy. This can be difficult for non-native listeners, particularly when the native and non-native languages differ substantially in their phonological systems [1, 2]. Yet, relatively little research has examined whether (and if so, how) non-native listeners become able to adjust for such processes in order to recognize words in a second/foreign language (L2) (examples include [3, 4]). The present study investigates this issue with the goal of determining how the development of non-native speech segmentation procedures unfolds. It does so by investigating the recognition of vowel-initial words preceded by a liaison consonant (henceforth, liaison-initial words) in native and non-native French.

Liaison is a phonological process by which a latent word-final consonant is resyllabified as the onset of the following vowel- (or glide-) initial word (e.g., *gros ours* [gʁo.z#uχs] 'big bear,' where the period (.) represents a syllable boundary and the pound sign (#) a word boundary; cf. *gros chat* [gʁo.#ʃa] 'big cat'). This resyllabification creates a misalignment of the syllable and word boundaries, with the liaison consonant being realized similarly but not identically to a (non-resyllabified) word onset (e.g., *gros zoo* [gʁo.#zo] 'big zoo'). The difference between the former and the latter is acoustic (and sometimes phonetic) rather than phonological. For example, of the most frequent liaison consonants /z, n, t, ʁ, p/ [5], the fricatives (e.g., *gros ours* [gʁo.z#uχs], *dernier ours* [dɛʁ.nje.ʁ#uχs] 'last bear') are shorter in liaison contexts than in word onset contexts [6]. These acoustic/phonetic differences are subtle (e.g., in [6], liaison consonants are on average 12 ms. shorter than word onsets), but they are reliable (cf. [7]).

Despite the role that syllable onsets play as segmentation points in French [8, 9], the misalignment of the syllable and word boundaries that liaison creates has not been found to incur a processing cost for native French listeners. In their cross-modal priming study, Gaskell et al. [10] show that visually presented vowel-initial targets (e.g., *Italien* 'Italian') are recognized more rapidly when heard in a liaison context (e.g., *généreux Italien* [ʒe.ne.ʀø.z#i.ta.ljɛ̃] 'generous Italian') than when heard in a context where they are not preceded by a resyllabified consonant (e.g., *chapeau italien* [ʃa.po.#i.ta.ljɛ̃] 'Italian hat'). This advantage persists in truncated auditory stimuli where lexical information is not available (e.g., *ita–* in *–reux ita–* vs. *–peau ita–*). On the basis of these findings, the authors conclude that acoustic/phonetic information plays a key role in the recognition of liaison-initial words. Also using cross-modal priming tasks, Spinelli et al. [6] report greater facilitation for the recognition of visually presented vowel- and consonant-initial targets (e.g., *ami* 'friend' and *tamis* 'sifter') in acoustically/phonetically matching auditory stimuli (e.g., respectively, *grand ami* [gʁɑ̃.t#a.mi] 'good friend' and *grand tamis* [gʁɑ̃.#ta.mi] 'large sifter') than in mismatching ones, thus providing further evidence for the role of acoustic/phonetic cues in the recognition of liaison-initial words.

Given that English does not have a phonological process by which word-final consonants are resyllabified as the onset of the following word, and since the syllable is not the most efficient segmentation unit in English [8, 9], English L2 learners of French should find it difficult to adjust for the misalignment of the syllable and word boundaries that liaison creates, and they may not be able to use acoustic/phonetic cues in the speech signal to recognize liaison-initial words rapidly and efficiently. Using a phoneme-monitoring task, Dejean de la Bâtie and Bradley [11] show that second-year English L2 learners of French make more errors than native French speakers when asked to detect [t]-initial words in potential liaison contexts (e.g., *grand éléphant* [gʁɑ̃.t#e.le.fɑ̃] 'large elephant' vs. *grand théâtre* [gʁɑ̃.#te.ɑ.tʁ] 'large theater'), but not in contexts where liaison is not possible (e.g., *vrai éléphant* [vʁɛ.#e.le.fɑ̃] 'real elephant' vs. *vrai théâtre* [vʁɛ.#te.ɑ.tʁ] 'real theater'). This confirms that liaison poses segmentation difficulties for English listeners.

Using eye tracking, this study attempts to specify the exact locus of these difficulties by examining the time course of word recognition for liaison-initial targets and their word onset counterparts. Moreover, it investigates the development of non-native speech segmentation procedures by testing English L2 learners of French at three different proficiency levels. Since it is (to my knowledge) the first liaison study that uses eye tracking, it can also contribute to the literature on native French listeners' processing of resyllabified words.

2. Method

2.1. Participants

Thirty-three adult native English speakers who have learned French as a second/foreign language (experimental group) and 10 adult native French speakers from France (control group) participated in this study. The native English and French speakers did not speak languages other than English and French (respectively) before puberty. They had normal or corrected-to-normal vision and did not have hearing problems.

The L2 learners' proficiency in French was identified with the help of a cloze (i.e., fill-in-the-blank) test, whose validity, reliability, and discriminability had been established independently of this study [12]. Such tests are commonly used as proficiency measures in L2 research, because they correlate highly with standardized proficiency tests [13]. The L2 learners were evenly divided into three proficiency groups (low, mid, high) on the basis of their cloze test scores. The "low," "mid," and "high" labels are intended to be arbitrary.

The participants completed a questionnaire in which they specified relevant biographical information. For the learners, this information included their age of first exposure to French (A-FE), their number of years of instruction in/on French (Y-Ins), the number of months they had spent immersed in a French-speaking environment (M-Imm), and their percent weekly use of French (%Use). The participants' biographical information (mean (standard deviation)) is shown in Table 1.

Table 1. *Biographical information.*

	Cloze/45	Age	A-FE	Y-Ins	M-Imm	%Use
Low L2 (n=11)	15(2)	20(1)	12(2)	7(1)	0.3(0.5)	5(7)
Mid L2 (n=11)	21(1)	22(3)	13(3)	6(2)	4(5)	8(9)
High L2 (n=11)	28(4)	22(3)	12(3)	9(4)	4(6)	16(16)
Natives (n=10)	n/a	26(6)	birth	n/a	n/a	n/a

2.2. Materials and procedures

The participants completed a cross-modal word-monitoring task with eye tracking using the visual world paradigm. In each trial, they heard an auditory stimulus and saw four orthographic words, one of which was heard in the stimulus. The experimental stimuli were neutral sentences containing a singular adjective and a (real/nonce) noun (the target) in direct object position. Two within-subject factors were manipulated: the onset of the target in the stimuli (liaison- (i.e., vowel-) initial, /z/-initial) and the presence of a lexical competitor in the display (yes, no). The resulting four conditions are summarized in Table 2 and illustrated with an example (*fameux* = 'infamous,' *élan* = 'swing,' *zélé* = 'zealous one').

Table 2. *Experimental Conditions.*

		Display	
		No competitor	Competitor
Stimuli	Liaison-initial	*...fameux élan...* [...fa.mø.z#e.l...] "élan" + 3 distracters	*...fameux élan...* [...fa.mø.z#e.l...] "élan," "zélé" + 2 distracters
	/z/-initial	*...fameux zélé...* [...fa.mø.#ze.l...] "zélé" + 3 distracters	*...fameux zélé...* [...fa.mø.#ze.l...] "zélé", "élan" + 2 distracters

The pivotal consonant /z/ was selected, because it is the most frequent liaison consonant [5] and the L2 learners should have been exposed to it. The liaison consonant was lexical (i.e., it belonged to the adjective) rather than morphological (e.g., plural /z/), because agreement morphology might pose difficulties for L2 learners. The stimuli were "ambiguous" between a liaison- and /z/-initial word until the onset of the vowel in the second syllable of the noun, thus allowing for a possible cohort effect in the conditions with a competitor.

The real nouns were controlled for lemma frequency across liaison- and /z/-initial conditions [14]. Given the difficulty in finding matching noun pairs, nonce nouns were used for half of the experimental items. They approximated the real nouns in the phonemic content of their first syllable and its following onset (e.g., *élin* for *élan*, *zéla* for *zélé*). As much as possible, the nouns were controlled for length within each display and across liaison- and /z/-initial conditions. Each condition included a total of 24 items (12 real nouns, 12 nonce nouns), interspersed with 144 fillers.

The duration of /z/ in the stimuli was measured in PRAAT [15]. The acoustic analyses (mean (standard deviation)) indicated that liaison /z/ was shorter than word onset /z/ (76(15) vs. 90(14) ms.). A two-tailed paired-samples t-test confirmed that this difference was reliable ($t[23] = 4.843$, $p<.001$).

The experiment was run with a desktop-mounted EyeLink 1000 eye tracker (SR Research). In each trial, the participants saw four orthographic words in a (non-displayed) 2×2 grid for 4,000 milliseconds. This long reading time ensured that the L2 learners would be able to read each word before the onset of the auditory stimulus. The words then disappeared and a fixation cross appeared in the middle of the screen for 500 milliseconds. As the fixation cross disappeared, the four words reappeared on the screen and the auditory stimulus was heard (synchronously). The participants were instructed to click on the target as soon as they heard it. The trial ended with the participants' response, with an inter-trial interval of 500 ms. The participants' accuracy rates, reaction times (RTs), and eye movements were recorded, with the latter two being measured from the onset of /z/ in the auditory stimuli.

2.3. Data analysis and predictions

For each condition, the results were averaged between the two experimental items that contained the corresponding real and nonce words (e.g., *élan* and *élin*). This was done to eliminate the variance that was not of interest to this study. Note, however, that the results patterned in a similar way on both real- and nonce-word items.

Statistical analyses were conducted on the subject (F_1) and item (F_2) means for the accuracy rates, RTs, and eye movements (201-400 ms., 401-700 ms., and 701-1,000 ms. time windows). Assuming a 200-millisecond delay for the eye to reflect processing, the first time window corresponds to the first syllable of the target noun in the auditory stimulus, which was "ambiguous" between a liaison- and /z/-initial word, and the second and third time windows represent processing after the disambiguation point. The within-subject variables were onset type (liaison-initial, /z/-initial) and competitor (yes, no). A first analysis was conducted on the participants' results with native language (L1) (English, French) as between-subject variable. A second analysis was conducted on the L2 learners' results with proficiency (low, mid, high) as between-subject variable. Only the significant effects ($\alpha = .05$) are reported.

Since English does not have a phonological process like liaison, the L2 learners should recognize liaison-initial words more slowly and less accurately than /z/-initial words and, in the presence of a lexical competitor, they should show evidence of mis-segmentation and reanalysis by fixating the /z/-initial competitor before the liaison-initial target. This asymmetry between liaison- and /z/-initial words was predicted to decrease with higher proficiency in French. By contrast, given the acoustic/phonetic information in the stimuli, native French speakers should recognize liaison-initial words as rapidly and accurately as /z/-initial words, whether or not a lexical competitor was present.

3. Results

Table 3 gives the participants' RTs (mean (standard deviations)) for each condition (N = no competitor; C = competitor).

Table 3. *Reaction times.*

	liaison-N	/z/-N	liaison-C	/z/-C
Low L2 (n=11)	2423(580)	2591(667)	2453(518)	2774(643)
Mid L2 (n=11)	2072(506)	2255(490)	2087(438)	2512(543)
High L2 (n=11)	1853(473)	1861(476)	1975(450)	2225(645)
Natives (n=10)	1475(226)	1463(298)	1746(315)	1565(203)

Repeated-measures ANOVAs on the participants' RTs revealed significant effects of competitor ($F_1[1,41]=29.2$, $p<.001$; $F_2[1,46]=36.8$, $p<.001$), L1 ($F_1[1,41]=15.2$, $p<.001$; $F_2[1,46]=58.7$, $p<.001$), onset × L1 interaction ($F_1[1,41]=11.7$, $p<.001$; $F_2[1,46]=11.1$, $p<.003$), and competitor × onset × L1 interaction ($F_1[1,41]=8.3$, $p<.006$; $F_2[1,46]=6.5$, $p<.014$). More restricted repeated-measures ANOVA on native speakers' RTs yielded significant effects of competitor ($F_1[1,9]=48.7$, $p<.001$; $F_2[1,11]=24$, $p<.001$), onset ($F_1[1,9]=8.7$, $p<.016$; $F_2[1,11]=5.3$, $p<.042$), and competitor × onset interaction in the subject analysis ($F_1[1,9]=6.2$, $p<.034$). Repeated-measures ANOVAs on L2 learners' RTs revealed effects of competitor ($F_1[1,30]=22.9$, $p<.001$; $F_2[1,33]=29.6$, $p<.001$), onset ($F_1[1,30]=20$, $p<.001$; $F_2[1,33]=17.8$, $p<.001$), competitor × onset interaction ($F_1[1,30]=8.8$, $p<.006$; $F_2[1,33]=6.5$, $p<.016$), and proficiency ($F_1[2,30]=3.7$, $p<.036$; $F_2[2,33]=28.1$, $p<.001$).

As shown by these results, contrary to expectations, the L2 learners recognized liaison-initial words more rapidly than /z/-initial words, especially in the presence of a lexical competitor, whereas the native speakers did just the opposite. Higher-level L2 learners responded more rapidly in all the conditions, but they did not show a different pattern of results.

Table 4 presents the participants' percent accuracy rates.

Table 4. *Percent accuracy rates.*

	liaison-N	/z/-N	liaison-C	/z/-C
Low L2 (n=11)	93(7)	90(10)	91(7)	88(8)
Mid L2 (n=11)	97(3)	96(7)	93(5)	89(9)
High L2 (n=11)	99(2)	97(3)	94(5)	95(5)
Natives (n=10)	99.6(0.1)	100(0)	98(0.4)	99 (0.3)

Repeated-measures ANOVAs on the participants' accuracy rates revealed effects of competitor ($F_1[1,41]=10.5$, $p<.002$; $F_2[1,46]=6.3$, $p<.016$) and L1 ($F_1[1,41]=11.6$, $p<.002$; $F_2[1,46]=21.1$, $p<.001$). Repeated-measures ANOVAs on L2 learners' accuracy rates yielded effects of competitor ($F_1[1,30]=22.5$, $p<.001$; $F_2[1,33]=29.6$, $p<.001$), onset in the item analysis ($F_2[1,33]=17.8$, $p<.001$), competitor × onset interaction in the item analysis ($F_2[1,33]=6.5$, $p<.016$) and proficiency ($F_1[2,30]=4.8$, $p<.015$; $F_2[2,33]=28.1$, $p<.001$).

As these analyses indicate, the L2 learners tended to recognize liaison-initial words more accurately than /z/-initial words, whereas the native speakers were at ceiling. Higher-level L2 learners were more accurate across all the conditions, but again, they did not show a different pattern of results.

Figure 1 shows the participants' percent target fixations in the two conditions without a lexical competitor. The *x*-axis represents time in milliseconds (from the onset of /z/), and the *y*-axis represents the percentage of fixations. Note that for each group, the liaison- and /z/-initial conditions (seen in different trials) are plotted in the same area for the sake of comparison.

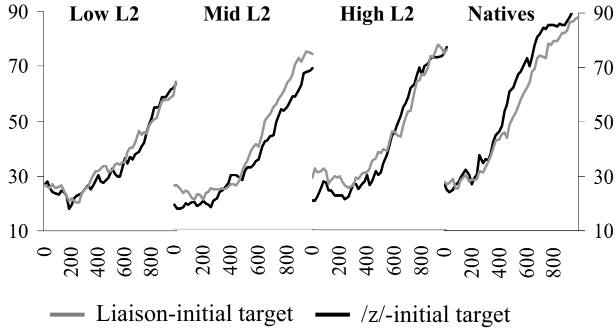

Figure 1. *Target fixations, no lexical competitor.*

Figure 2 presents the participants' percent target (full line) and competitor (patterned line) fixations in the two conditions with a lexical competitor. The lines seen within the same trial have the same color.

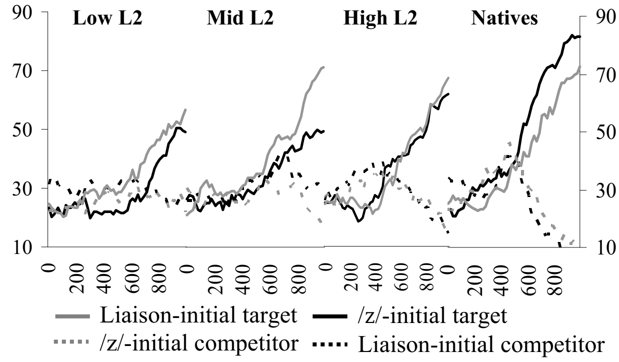

Figure 2. *Target and competitor fixations, lexical competitor.*

Repeated-measures ANOVAs on the participants' target fixations for the first time window (201-400 ms.) yielded an effect of L1 ($F_1[1,41]=11.2$, $p<.002$; $F_2[1,46]=14$, $p<.001$). Repeated-measures ANOVAs on L2 learners' competitor fixations (first time window) revealed an effect of proficiency in the subject analysis ($F_1[1,41]=7.4$, $p<.002$). No other effect reached significance for this time window.

These results indicate that L2 learners initially show fewer target fixations than native speakers and more competitor fixations as their proficiency increases. This suggests that they process the target words more rapidly with increasing proficiency but more slowly than native speakers.

Repeated-measures ANOVAs on the participants' target fixations for the second time window (401-700 ms.) revealed effects of competitor ($F_1[1,41]=46.5$, $p<.001$; $F_2[1,46]=25.8$, $p<.001$), L1 ($F_1[1,41]=29.7$, $p<.001$; $F_2[1,46]=92.1$, $p<.001$), competitor × L1 interaction ($F_1[1,41]=19.8$, $p<.001$; $F_2[1,46]=8.9$, $p<.005$), and onset × L1 interaction ($F_1[1,41]=11.4$, $p<.002$; $F_2[1,46]=11.9$, $p<.001$). Subsequent repeated-measures ANOVAs on native speakers' target fixations (second time window) yielded main effects of competitor ($F_1[1,9]=30.6$, $p<.001$; $F_2[1,11]=16.2$, $p<.002$) and onset ($F_1[1,9]=21.5$, $p<.001$; $F_2[1,11]=6.4$, $p<.028$). Repeated-measures ANOVA on L2 learners' target fixations (second time window) revealed main effects of competitor ($F_1[1,30]=6.9$, $p<.013$; $F_2[1,33]=4.9$, $p<.035$) and proficiency in the item analysis ($F_2[2,33]=5.5$, $p<.008$). Similar analyses on their competitor fixations (second time window) revealed an effect of proficiency in the item analysis ($F_2[2,33]=5.7$, $p<.008$).

As these analyses show, after the disambiguation point (i.e., roughly the onset of the second time window), the L2 learners did not show proportionally different fixations on liaison- versus /z/-initial targets. This contrasts with the native speakers, who fixated /z/-initial targets more than liaison-initial ones. Again, L2 learners showed earlier recognition of the targets and more fixations to the competitors as proficiency increased, but not a different pattern of results.

Repeated-measures ANOVAs on the participants' target fixations for the third time window (701-1000 ms.) revealed effects of competitor ($F_1[1,41]=39.7$, $p<.001$; $F_2[1,46]=60.8$, $p<.001$), L1 ($F_1[1,41]=31.2$, $p<.001$; $F_2[1,46]=105.8$, $p<.001$), competitor × L1 interaction in the item analysis ($F_2[1,46]=7.1$, $p<.011$), and onset × L1 interaction ($F_1[1,41]=12.9$, $p<.001$; $F_2[1,46]=9.5$, $p<.003$). Subsequent repeated-measures ANOVA on native speakers' target fixations (third time window) yielded effects of competitor ($F_1[1,9]=30.3$, $p<.001$; $F_2[1,11]=69.9$, $p<.001$) and onset ($F_1[1,9]=32$, $p<.001$; $F_2[1,11]=11.4$, $p<.006$). Repeated-measures ANOVA on L2 learners' target fixations (third time window) revealed effects of competitor ($F_1[1,30]=23.1$, $p<.001$; $F_2[1,33]=21.8$, $p<.001$), onset ($F_1[1,30]=4.5$, $p<.043$; $F_2[1,33]=4.2$, $p<.049$), and proficiency ($F_1[2,30]=5.1$, $p<.013$; $F_2[2,33]=35.6$, $p<.001$). Finally, similar analyses on the participants' competitor fixations (third time window) yielded effects of L1 ($F_1[1,41]=33.2$, $p<.001$; $F_2[1,46]=31.6$, $p<.001$) and proficiency for learners ($F_1[2,30]=3.4$, $p<.047$; $F_2[2,33]=17.5$, $p<.001$).

These results indicate that, in a later stage of word recognition, the L2 learners fixated liaison-initial targets more than /z/-initial ones, whereas native speakers did the opposite. The L2 learners' asymmetry was found only in the third time window, probably because they process the language more slowly than native speakers. Again, higher-level L2 learners recognized the targets more rapidly and showed more competitor fixations, but not a different pattern of results.

4. Discussion and conclusion

Contrary to predictions, the above results show that English L2 learners of French recognize liaison-initial words faster than /z/-initial words, whether or not a lexical competitor is present in the display. These findings suggest that a procedure for segmenting liaison-initial words does not develop gradually as proficiency increases, but rather abruptly, to the extent that L2 learners over apply it to contexts where the pivotal consonant is not resyllabified. To be able to complete the eye-tracking experiment used in this study, the L2 learners needed to have reached a proficiency level where they could recognize French words in continuous speech. Since English does not have a resyllabification process similar to liaison, it seems reasonable to conclude that, prior to this study, these L2 learners must have passed through a stage where they adjusted their procedure from segmenting French words at the onset of /z/ to segmenting French words at the offset of /z/. Such a stage would not be captured unless very low-level L2 learners were tested (with an easier task).

Although these findings were not expected, they make sense in light of the liaison consonant examined: /z/ is the most frequent liaison consonant [5], but also one of the least frequent word onsets in French [14]. Developing a parsing procedure that predictably segments French words at the offset of /z/ will result in much more efficient parsing, given the high frequency of vowel-initial words and the likelihood that they will be preceded by liaison /z/. This perhaps explains why the L2 learners did not use the acoustic/phonetic information in the stimuli for distinguishing liaison- from /z/-initial targets. Extending this research to other liaison consonants and to more advanced English L2 learners of French is necessary to investigate the role that acoustic/phonetic information plays in the segmentation of liaison-initial words by non-native listeners.

More puzzling are the native speakers' results. Contrary to expectations, the native speakers recognized liaison-initial targets more slowly than /z/-initial ones, whether or not a lexical competitor was present in the display. While this finding is in line with research on the role of syllable onsets as segmentation points [8, 9], it is inconsistent with previous studies on the processing of resyllabified words in French [6, 10], which show that the acoustic/phonetic cues in the speech signal facilitate French listeners' recognition of liaison-initial words. A few hypotheses might explain the present results: (1) orthography might have influenced the native listeners (although it is unclear why it did not also influence the L2 learners); (2) due to their low frequency in French, the /z/-initial words might have stood out for the native listeners; or (3) eye tracking might capture a processing cost for segmenting liaison-initial words that cross-modal priming does not capture. Extending this research to other liaison consonants, and using pictures rather than orthography, will specify which of these scenarios is correct.

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