# Gradient behavior without gradient underlying representations: the case of French liaison

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## 1 Introduction

In French, some words ending in a vowel have a consonant-final variant that only occurs before vowel-initial words. For instance, the adjective *grand* 'tall-MASC' is generally realized as [gʁɑ̃] with a final vowel but may be realized as [gʁɑ̃t] with a final [t] before vowel-initial words. Similarly, the indefinite determiner *un* 'a' is generally realized as [ɛ̃] with a final vowel but is realized as [ɛ̃n] with a final [n] before vowel-initial words. The consonants occurring at the end of consonant-final variants (e.g. [t] in *grand* and [n] in *un*) are called *liaison consonants*.

Liaison consonants are challenging for phonological theory because they pattern ambiguously between stable word-final consonants and word-initial consonants. Stable word-final consonants are consonants that are always realized regardless of the following context, as in *trente* [tʁɑ̃t] 'thirty', where final [t] remains present across contexts. The intermerdiary status of French liaison can be clearly illustrated with Quebec French (Côté, 2014). Quebec French has a process of affrication that turns /t d/ into [$t^s$ $d^z$] before /i y j ɥ/. But this process affects differently liaison consonants, stable word-final consonants, and word-initial consonants. More specifically, the liaison consonant /t/ has a rate of affrication that is intermediary between stable word-final /t/ and word-initial /t/: liaison /t/ (e.g. (1a)) is more prone to affrication than stable word-final /t/ (e.g. (1b)) but less so than word-initial /t/ (e.g. (1c)).

(1) Affrication in Quebec French (Côté, 2014; based on data collected in the *Phonologie du Français Contemporain* (PFC) project)

| | | Example | Rate of affrication |
|---|---|---|---|
| (a) | Liaison consonant | *gran*/t/ *innocent*<br>'tall-MASC innocent-MASC' | 66.0% |
| (b) | Stable word-final consonant | *tren*/t/ *innocents*<br>'thirty innocent-MASC.PLUR' | 36.5% |
| (c) | Word-initial consonant | /t/*imide*<br>'shy' | 99.2% |

In recent works, the gradient behavior of liaison consonants has been used to motivate different *underlying* representations for liaison consonants and non-liaison consonants, in frameworks using lexical constructions (Côté, 2014:41-42) or gradient underlying representations (Smolensky & Goldrick, 2016). In these analyses, the liaison consonant is underlyingly specified as a blend between a stable word-final consonant and a word-initial consonant, explaining for instance the intermediary rate of affrication of the liaison consonant in (1).

This paper argues that this move is not necessary. The gradient behavior of liaison consonants can indeed be derived through constraint interaction while maintaining that liaison consonants and non-liaison consonants have the *same* underlying representation. The difference between liaison and non-liaison consonants will ultimately stem from underlying differences in the *words* that contain them: liaison words come with two lexically listed variants (e.g. *grand* [gʁɑ̃] ∼ [gʁɑ̃t] 'tall.MASC') whereas non-liaison words come with a single variant (e.g. *trente* [tʁɑ̃t] 'thirty'). Once this basic lexical difference is recognized, the

* I would like to thank Marie-Hélène Côté for introducing me to this puzzle and drawing my attention to the Quebec French data. I also thank the participants in AMP for giving me feedback on the project, and Shigeto Kawahara for very useful comments on the paper. All errors are my own.


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gradient behavior of liaison consonants essentially comes for free under the two following, independently motivated hypotheses: output-variant correspondence (H1) and bidirectionality of coarticulation in CV (H2). Output-variant (OV) correspondence establishes a relation between independently occurring surface forms (namely variants of a word) and is therefore a subtype of output-output correspondence (Benua, 1997).

(H1) Output-variant (OV) correspondence (e.g. Kawahara, 2002; Steriade, 1997)
Variants of a word stand in correspondence with the base form of this word, namely the citation form. OV-faithfulness constraints militate for the identity between these variants and the base form.
(H2) Bidirectionality of coarticulation in CV (e.g. Lindblom, 1963)
A change affecting C in CV also affects V via coarticulation.

In a nutshell, hypotheses (H1) and (H2) predict that, everything else being equal,[1] liaison consonants will be less protected against changes than stable word-final consonants (Prediction 1) but more protected than word-initial consonants (Prediction 2), explaining for instance the intermediary rate of affrication of liaison consonants in (1). Two facts will play a key role in deriving this result: (i) liaison consonants are absent from the citation forms of liaison words whereas stable final consonants are present in citation forms and (ii) concatenating two words (word 1 and word 2) has phonetic/phonological consequences on word 1's final segment and on word 2's initial segment. Section 2 presents the analysis, with subsection 2.1 focusing on Prediction 1 and subsection 2.2 on Prediction 2. Section 3 shows how the analysis can be implemented in a probabilistic grammatical framework to derive the specific rates of affrication in (1). Section 4 concludes with a discussion of the lexical affiliation of liaison consonants.

## 2 Analysis

**2.1** *Liaison consonants vs. stable word-final consonants* Output-variant (OV) correspondence (=H1) provides a way to distinguish liaison consonants from stable word-final consonants. The first two paragraphs of this section provide some background on OV correspondence. OV correspondence has been proposed by Kawahara (2002) to account for cases where a phonological process underapplies or overapplies to increase similarity among variants of a word.[2] An example of underapplication is provided by Japanese postnasal voicing (Kawahara, 2002:18-22). Japanese has a general process of postnasal voicing. For instance, /sin-ta/ 'die-PAST' is realized as [sinda] with voicing of the postnasal coronal stop. However, this process is blocked in variant formation. For instance, the word [anata] 'you' has a variant where the penultimate [a] is syncopated but postnasal voicing fails to apply: the variant is realized as [anta] and not as the expected *[anda]. Kawahara accounts for these facts by positing an OV-faithfulness constraint $\text{Ident}_{\text{OV}}$(voice) requiring that variants of a word have the same voice specification for consonants as in the base form. The base form corresponds to the careful-speech variant according to Kawahara, i.e. the variant without any syncope. $\text{Ident}_{\text{OV}}$(voice) outranks *NT, the constraint responsible for postnasal voicing. In turn, *NT outranks $\text{Ident}_{\text{IO}}$(voice), the input-output faithfulness constraint protecting underlying voicing contrasts. These two ranking conditions ensure that postnasal voicing applies in input-output mappings but is blocked in variant formation.

An example of overapplication is provided by patterns of word-final devoicing (Steriade, 1997:55-58, Myers & Padgett, 2014). This example is particularly interesting here because it provides evidence for the citation form as being the base form in OV correspondence. The citation form corresponds to the word uttered in isolation, with the word's beginning and end matching the utterance's beginning and end. The citation form will play a key role in the analysis of French liaison. Word-final devoicing is motivated phonetically utterance-finally, but not utterance-medially. Yet languages overapply word-final devoicing utterance-medially. For instance, in Lithuanian, underlying /daug/ is realized as [dauk] with devoicing before a vowel-initial word, despite the fact that the following vowel would have permitted to provide sufficient cues to the voicing contrast. Steriade (1997) proposes that devoicing overapplies in this case to increase similarity with the citation form. In the citation form, word-final devoicing is motivated phonetically by the absence of robust

[1] Other factors arguably play a role in determining the realization of liaison and non-liaison consonants but are left aside here. For instance, it has been shown that lexical frequency matters in determining whether a liaison consonant will surface between word 1 and word 2: the likelihood of realizing the liaison consonant increases as the frequency of word 1 increases and as the frequency of the collocation of word 1 and word 2 increases (Kilbourn-Ceron, 2017).
[2] Similar ideas have been proposed earlier by other authors as well (see Myers & Padgett, 2014 for an overview).

cues to the voicing contrast utterance-finally. Through OV correspondence, devoicing is extended from the citation form to utterance-medial occurrences of the word.

Now let us turn to the case of liaison consonants. Assume that there is an OV-faithfulness constraint requiring consonants in variants of a word to be featurally identical to the corresponding consonants in the base form of this word (=$\text{Ident}_{\text{OV}}$(C)). Following Steriade (1997), assume further that the base form relevant for OV correspondence is the citation form. For words with stable final consonants, the base form contains a word-final consonant (e.g. *trente* [tʁã**t**] 'thirty', as shown in (2a)). However, for words with liaison consonants, the base form lacks a word-final consonant. For instance, *grand* is realized as [ɡʁã] prepausally, as shown in (2b), but never as [ɡʁãt]. Now suppose that a phonological process affects final consonants in the language. For instance, affrication turns final /t/ to [$t^s$] in (2a) and (2b). $\text{Ident}_{\text{OV}}$(C) will be violated in words with stable final consonants (e.g. (2a)) but not in word variants with liaison consonants (e.g. (2b)), due to their base form lacking a final consonant. In general, stable final consonants will therefore be more protected against changes than liaison consonants, explaining why the rate of affrication is greater in (2b) than in (2a) in Québec French.

(2) Liaison consonants vs. stable word-final consonants

| | | | Base form | Affricated variant | $\text{Ident}_{\text{OV}}$(C) | Rate of affrication |
|---|---|---|---|---|---|---|
| (a) | Stable word-final C | *trente* | [tʁã**t**] | [tʁã**t$^s$**] | $*_{(t\rightarrow t^s)}$ | 36.5% |
| (b) | Liaison C | *grand* | [ɡʁã] | [ɡʁã**t$^s$**] | ✓$_{(\emptyset\rightarrow t^s)}$ | 66.0% |

**2.2** *Liaison consonants vs. word-initial consonants* Together with OV correspondence, the bidirectional nature of coarticulation (=H2) provides a way to distinguish word-final consonants (whether they are liaison consonants or stable consonants) from word-initial consonants. Before showing this, I briefly provide some background on coarticulation in CV sequences, focusing on the well studied pattern of assimilation in second formant (F2) frequency between consonants and vowels (see Flemming, 2001:16-23). A large number of studies have shown that C assimilates to V in CV, in particular F2 at consonant release can be described as an increasing linear function of F2 in the middle of the vowel: as the F2 in the middle of the vowel increases, the F2 at consonant release also increases (Lindblom, 1963; Sussman et al., 1991). In turn, V has also been found to assimilate to C in CV, with F2 in the middle in the vowel being higher when F2 at consonant release is higher (Lindblom, 1963; Broad & Clermont, 1987). These results suggest that coarticulation is bidirectional in CV sequences: both C and V are affected when the two sounds are combined in a CV sequence, and any change affecting one of the two sounds should also affect the other one.

Now let us turn to the case of liaison consonants. Suppose that a phonological process affects prevocalic consonants, whether within a word or across words. For instance, affrication turns /t/ to [$t^s$] before /i/. Due to the bidirectional nature of coarticulation, this process will also affect the vowel immediately following the consonant that has undergone the change. This vowel is the initial vowel of W2 in the case of final consonants (e.g. word-initial /i/ in *gran*[$t^s$] *innocent* 'great.MASC innocent' and *tren*[$t^s$] *innocents* 'thirty innocent.MASC.PLUR') and the vowel following the relevant consonant within the same word in the case of initial consonants (e.g. the /i/ following word-initial [$t^s$] in [$t^s$]*imide* 'shy').

How could affrication affect an underlying following /i/? There is evidence from Japanese that high vowels are more reduced spectrally after voiceless fricatives than after other consonants (Beckman & Shoji, 1984). A similar spectral reduction seems to happen after affricate [$t^s$] in Quebec French, as shown in Figures 1 and 2. These figures show the realizations of *grand innocent* by two speakers in Trois-Rivières (Quebec), TR_jb and TR_ad, respectively. The data come from the PFC Trois-Rivières survey (see Côté, 2016 for a general presentation of this survey).[3] According to Marie-Hlne Ct (personal communication), speaker TR_jb does not affricate liaison /t/ whereas Speaker TR_ad does. This difference correlates with a difference in the realization of the following underlying /i/ by the two speakers. /i/ is realized as a full vowel with clear spectral structure by the speaker who does not affricate /t/ (i.e. Speaker TR_jb in Figure 1). However, /i/ is completely reduced by the speaker who affricates /t/ (i.e. Speaker TR_ad in Figure 2): the frication noise is immediately followed by the nasal murmur, without any intervening phonetic vowel. These data suggest that affrication actually involves the following mapping: /ti/ → [$t^s$i̥], where [i̥] is the spectrally reduced allophone of /i/.[4]

[3] I am grateful to Marie-Hélène Côté for making these data available to me.

[4] Alternatively, affrication could be considered as a fusion of the two phonemes /t/ and /i/ into a single affricated segment

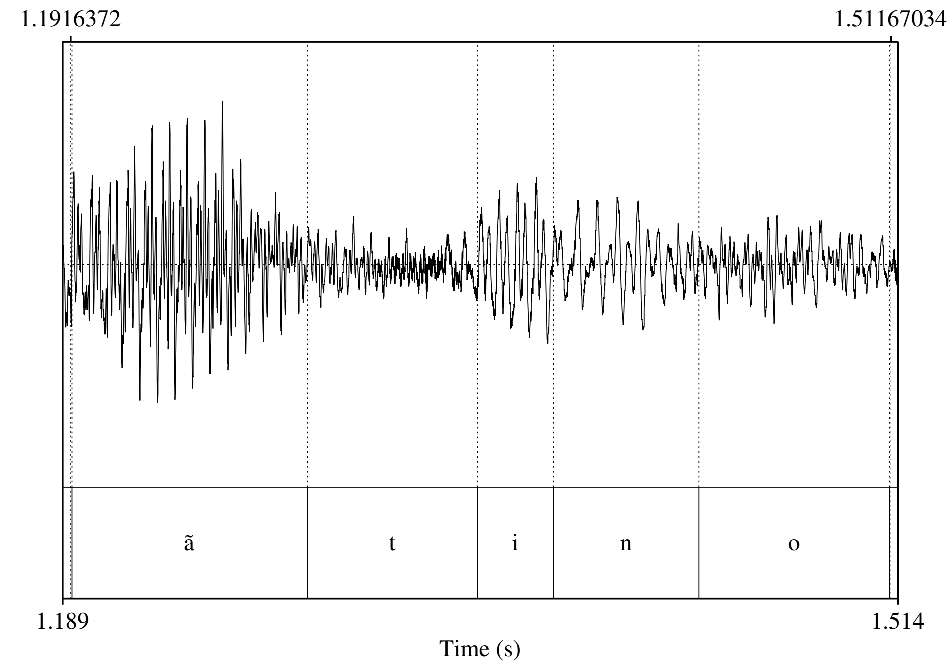


**Figure 1:** Non-affricated liaison /t/ in *grand innocent* (Speaker TR_jb)

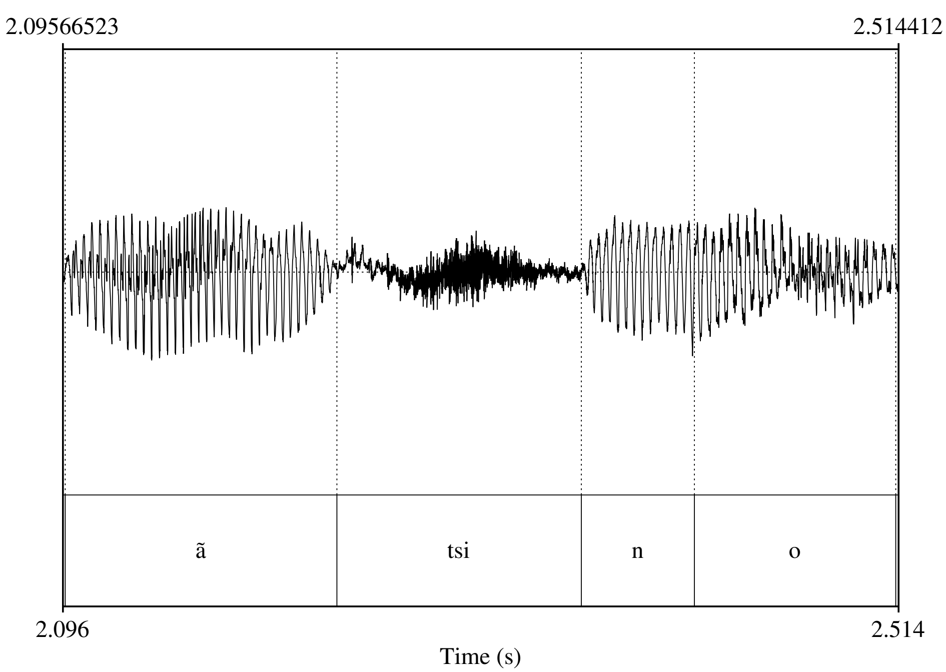


**Figure 2:** Affricated liaison /t/ in *grand innocent* (Speaker TR_ad)

Now suppose that there is an OV-faithfulness constraint requiring vowels in variants of a word to be featurally identical to the corresponding vowels in the base form of this word (=Ident$_{OV}$(V)). In case of a change affecting final consonants, this constraint is violated by the initial vowel of word 2 (W2) because, due to the bidirectional nature of coarticulation, changing the final consonant of word 1 (W1) entails changing also the initial vowel of W2. For instance, *innocent* is realized as [i̥]*nnocent* after [t$^s$], in violation of OV faithfulness, as shown in (3a). Indeed, OV faithfulness requires [i]*nnocent* without spectral reduction. However, in case of a change affecting word-initial consonants, Ident$_{OV}$(V) is not violated, as shown in (3b): if a process like affrication has already happened in the base form, there is no way for OV faithfulness to block it. For instance, *timide* is already realized as [t$^s$i̥]*mide* in the base form and therefore any variant of this word featuring affrication and spectral reduction of /i/ will not violate OV faithfulness. In general, final consonants will therefore be more protected against changes than initial consonants, explaining why the rate of affrication is smaller in (3a) than in (3b).

(3) Liaison consonants vs. word-initial consonants

| | | | Base form | Variant with /i/-reduction | Ident$_{OV}$(V) | Rate of affrication |
|---|---|---|---|---|---|---|
| (a) | Liaison C | *innocent* | [**i**nosã] | [t$^s$#**i̥**nosã] | *$_{(\text{i}\rightarrow\text{i̥})}$ | 66.0% |
| (b) | Word-initial C | *timide* | [t$^s$**i̥**mid] | [t$^s$**i̥**mid] | ✓$_{(\text{i̥}\rightarrow\text{i̥})}$ | 99.2% |

## 3 Application

The analysis captures the gradient behavior of liaison consonants at a conceptual level but can it also match the specific rates of affrication attested in Quebec French? To test this hypothesis, the grammatical model described in section 2 was fit to Côté's count data shown in Table 1, using Maxent (Hayes & Wilson, 2008) as framework for probabilistic grammars.

| *Consonant* | *Affricated* | *Not affricated* |
|---|---|---|
| Liaison consonant | 68 (66.0%) | 35 (34.0%) |
| Stable word-final consonant | 31 (36.5%) | 54 (63.5%) |
| Word-initial consonant | 715 (99.2%) | 6 (0.8%) |

**Table 1:** Affrication before /i y j ɥ/ in the PFC Trois-Rivières survey: count and frequency data (Côté, 2014:38)

In addition to the two OV-faithfulness constraints introduced in section 2 (=Ident$_{OV}$(C) and Ident$_{OV}$(V)), a markedness constraint is needed to trigger affrication. This constraint is called *ti. The analysis presented in this section will only include these three constraints: Ident$_{OV}$(C), Ident$_{OV}$(V), and *ti. The remainder of this paragraph motivates the exclusion of other potentially relevant constraints. The constraint that motivates the insertion of liaison consonants (arguably the anti-hiatus constraint *VV) is left aside because no information is provided about the frequency of realization vs. non-realization of liaison consonants in the data in Côté (2014). The candidate with affrication is also assumed to always feature a change in vowel quality, i.e. the candidate with affrication only, [t$^s$i], is not included in the candidate set. In a more complete analysis, this candidate would be penalized by the constraint that motivates bidirectional coarticulation. This constraint is left aside here because no information is provided about the frequency of [i] vs. [i̥] allophones in the data. Finally, the analysis presented in this section only includes OV-faithfulness constraints, leaving aside input-output (IO) faithfulness. The reason for leaving IO faithfulness aside is that it does not permit to distinguish the three relevant types of consonants: the mapping /ti/ → [t$^s$i̥] violates input-output faithfulness constraints Ident$_{IO}$(C) and Ident$_{IO}$(V) regardless of whether /t/ is a liaison consonant, a stable word-final consonant, or a word-initial consonant. The full model of correspondence relations among phonological forms (inputs and outputs) is shown in Figure 3. The model assumes base priority (Benua, 1997:240), i.e. the phonology of the base form is computed first and then the resulting output form is used in the evaluation of variants. The analysis in this section focuses on OV correspondence alone.

[t$^s$]. The two options are compatible with the current proposal.

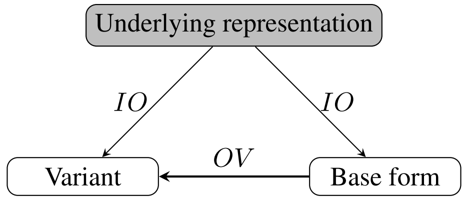


**Figure 3:** Correspondence relations among phonological forms (inputs are in the grey box and outputs in the white boxes). Only input-output (IO) correspondence plays a role in determining the shape of the base form, according to base priority. Both IO correspondence and output-variant (OV) correspondence play a role in variant formation. The analysis in this section focuses on OV correspondence.

Constraint violations of candidates [ti] and [$\text{t}^{\text{s}}$i̥] are shown in Tableaux (4a-c) in the three following conditions: liaison consonant, stable word-final consonant, and word-initial consonant. The liaison consonant is represented underlyingly as /(t)/ in Tableau (4a): this is a shortcut for two listed allomorphs (with and without word-final /t/). In Tableaux (4a-b), Base$_{\text{W1}}$ and Base$_{\text{W2}}$ stand for word 1's and word 2's base forms, respectively. Base forms are words' citation forms. For words with liaison /t/, the base form ends with a vowel and hence is schematized as [...V#] in Tableau (4a). For words with stable word-final /t/, the base form ends with [t] and hence is schematized as [...t#] in Tableau (4b). For words with initial /ti/, the base form already features affrication and spectral reduction[5] and hence is schematized as [$\text{t}^{\text{s}}$i̥...] in Tableau (4c).

(4) (a) Liaison consonant (Base$_{\text{W1}}$=[...V#], Base$_{\text{W2}}$=[#i...])

| /(t)#i/ | *ti $w = 2.15$ | Ident$_{\text{OV}}$(C) $w = 1.23$ | Ident$_{\text{OV}}$(V) $w = 1.48$ | Harmony | Predicted frequency | Attested frequency |
|---|---|---|---|---|---|---|
| [ti] | 1 | | | 2.15 | 34.0% | 34.0% |
| [$\text{t}^{\text{s}}$i̥] | | | 1 | 1.48 | 66.0% | 66.0% |

(b) Stable word-final consonant (Base$_{\text{W1}}$=[...t#], Base$_{\text{W2}}$=[#i...])

| /t#i/ | *ti $w = 2.15$ | Ident$_{\text{OV}}$(C) $w = 1.23$ | Ident$_{\text{OV}}$(V) $w = 1.48$ | Harmony | Predicted frequency | Attested frequency |
|---|---|---|---|---|---|---|
| [ti] | 1 | | | 2.15 | 63.5% | 63.5% |
| [$\text{t}^{\text{s}}$i̥] | | 1 | 1 | 2.71 | 36.5% | 36.5% |

(c) Word-initial consonant (Base=[$\text{t}^{\text{s}}$i̥...])

| /ti/ | *ti $w = 2.15$ | Ident$_{\text{OV}}$(C) $w = 1.23$ | Ident$_{\text{OV}}$(V) $w = 1.48$ | Harmony | Predicted frequency | Attested frequency |
|---|---|---|---|---|---|---|
| [ti] | 1 | 1 | 1 | 4.87 | 0.8% | 0.8% |
| [$\text{t}^{\text{s}}$i̥] | | | | 0 | 99.2% | 99.2% |

The intermediary status of liaison consonants appears clearly in the patterns of faithfulness violations by the two candidates. In the case of stable word-final consonants illustrated in Tableau (4b), OV-faithfulness strongly favors [ti], the candidate without affrication. Indeed, this candidate does not violate any OV-faithfulness constraint while candidate [$\text{t}^{\text{s}}$i̥] violates both OV-faithfulness constraints, namely the faithfulness constraint protecting the final /t/ in W1 and the faithfulness constraint protecting the initial /i/ in W2. In the case of word-initial consonants illustrated in Tableau (4c), OV-faithfulness strongly favors [$\text{t}^{\text{s}}$i̥], the candidate with affrication. Indeed, this candidate does not violate any OV-faithfulness constraint, as the changes have already happened in the base, while candidate [ti] violates both OV-faithfulness constraints. Liaison consonants stand in the middle: in Tableau (4a), OV-faithfulness favors [ti], but not as strongly as in the case

[5] Here I assume that variants have a single base form. The base form is derived in a grammar where only IO faithfulness is active, as schematized in Figure 3. In this grammar, the weight of *ti needs to be sufficiently large compared to the weights of Ident$_{\text{IO}}$(C) and Ident$_{\text{IO}}$(V) to trigger affrication.

of stable word-final consonants in Tableau (4b). Indeed, in the case of liaison consonants, candidate [t$^{s}$i̥] only violates the faithfulness constraint protecting the initial /i/ of W2. The faithfulness constraint protecting consonants in W1 is not violated by this candidate because /t/ is not present in W1's base form.

For each of the three constraint weights, Tableaux (4a-c) show the mean of their posterior distribution as estimated by a Bayesian binomial regression implemented in Rjags (Plummer, 2016). Following Goldwater & Johnson (2003), a Gaussian prior with mean equal to zero was chosen for each constraint weight. Informally, this prior specifies that zero is the default weight of any constraint (which means that the constraint has no effect on the output). The variance of the Gaussian prior was set to 1,000. Three MCMC chains were used with 100,000 samples and a thinning interval of 10 (which means that every 10th value in the chain was kept in the final MCMC sample while all other values were discarded). The first 5,000 samples of each chain were used for burn-in (which means they were also discarded). Convergence of the chains on the posterior distribution was assessed using the Gelman-Rubin statistic: it was equal to 1, indicating that the samples were representative of the posterior distribution (Kruschke, 2015:181). The effective sample size for each constraint weight was superior to 10,000, indicating that the MCMC samples were large enough for stable and accurate numerical estimates of the posterior distributions (Kruschke, 2015:184).

The three rightmost columns in Tableaux (4a-c) show the candidates' harmony scores along with their attested and predicted frequencies. All harmony scores and predicted frequencies were calculated using the three weights inferred by the Bayesian binomial regression.[6] For each candidate, the harmony score corresponds to the weighted sum of its constraint violations, as is usual in Harmonic Grammar (Smolensky & Legendre, 2006). Following Hayes & Wilson (2008), the predicted frequency of a candidate was calculated by dividing the maxent value of this candidate by the sum of the maxent values of all candidates. The maxent value of a candidate is obtained by taking the opposite of its harmony score and exponentiating the result.

Tableaux (4a-c) show that the candidates' predicted frequencies perfectly match the attested frequencies in the three conditions. Hence, the analysis not only captures the gradient behavior of liaison consonants at a conceptual level but can also derive the specific rates of affrication of liaison and non-liaison consonants in Quebec French. It is therefore possible to maintain that liaison consonants have the same underlying representation as non-liaison consonants while still accounting for their gradient behavior.

## 4 Conclusion

This section concludes the paper with a discussion of liaison consonants' lexical affiliation. In the current work, liaison consonants are assumed to belong to word 1 underlyingly, as in most traditional analyses (see Côté, 2014 for an overview). This analysis presents a very basic advantage over alternatives as it straightforwardly accounts for the fact that word 1 (and not word 2) determines whether a liaison consonant and which specific liaison consonant (e.g. [t z n ʁ]) will appear between word 1 and word 2. However, in approaches using lexical constructions or gradient underlying representations, this assumption was abandoned and liaison consonants were instead assumed to belong to a construction involving both word 1 or word 2 (Côté, 2014) or to both word 1 and word 2 (Smolensky & Goldrick, 2016). Besides the gradient behavior of liaison consonants discussed in this paper, one of the main arguments for this alternative analysis is the fact that children sometimes produce word 2 with a liaison consonant outside of liaison contexts, e.g. they may say *le navion* 'the plane' instead of expected *l'avion* ([n] is extended from the liaison context *un avion* to other contexts). However this fact can be interpreted differently in the present account. French-speaking children could start with a lexicon where liaison consonants are interpreted as word-initial segments. This would explain why they may use forms like *navion* instead of *avion* outside of liaison contexts. As they grow, they would then evolve toward a more adult-like lexicon where liaison consonants are reanalyzed as optional word-final segments that only occur before vowel-initial words. The current account predicts that this reanalysis should correlate with a change in the realization of the liaison consonant, e.g. liaison /t/ should become less likely to affricate as it gets reanalyzed as an optional word-final segment. This prediction should be tested in future work.

[6] The constraint weights in Tableaux (4) were rounded. Therefore calculations based on these rounded weights will not give the exact same numbers as the ones reported in Tableaux (4) for harmony scores and predicted frequencies.

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