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Glottal stop insertion and production planning domains in French

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Abstract: The article introduces an experimental study of glottal stops that are generated by h aspiré (H) in French (*il [ʔ] hoche la tête*). To date the phenomenon is merely mentioned in passing, and evidence only comes from native speaker intuitions and cursory personal observation. Participants pronounced verbs that either did (*hocher*) or did not (*aimer*) begin with an H, whereby the left context was controlled for: the preceding word could end in a vowel (*tu hoches*/*aimes*), in a consonant (*il hoche*/*aime*) or in a liaison consonant (LC *nous hochons*/*aimons*). Results confirm the observation made in the literature regarding the high variability of H: lexical (elision is much more frequent in *j'harcèle* than in *j'hais*), inter-speaker (some participants chose unelided *je* for 10 out of 12 H verbs, while others only for 4 H verbs) and intra-speaker (participants pronounced *vous [z] hissez* with liaison, while they chose *je hisse* in a multiple choice-based pretest). Results also confirmed that H is indeed a glottal stop creator: glottal stops occur much more often before H-initial than before V-initial words. The glottal stop rate also depended on the left context: while LC + H (*nous hochons*) and C + H (*il hoche*) are statistically indistinguishable, both are significantly distinct from V + H (*tu hoches*). This suggests that glottal stop insertion is sensitive to all types of preceding consonants, whether they are pronounced (C + H) or not (LC + H). This result is relevant in the debate on French liaison where it was claimed that (some) LCs are epenthetic, that is absent from phonological computation when unpronounced: this view is challenged by the experimental evidence. On the analytic side, the article argues that all glottal stops that occur stand in Strong Position, i.e. word-initially or after a consonant {#,C}__ (Ségéral, Philippe & Tobias Scheer. 2001. La Coda-Miroir. *Bulletin de la Société de Linguistique de Paris* 96. 107–152). The word-initial position is in fact domain-initial, and it is a long standing observation in the literature that H sets off its word into a separate domain. Thus even glottal stops in V + H (*tu hoches*) that appear to occur in intervocalic position may in fact be domain-initial V + [H]. The question then is what kind of domain could be responsible for the (rare) presence of glottal stops in V + V (*tu aimes*): such a domain V + [V] cannot stem from H, nor can it be of morpho-

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syntactic origin. It is argued that these domains are production planning domains in the sense of Wagner (2012. Locality in phonology and production planning. *McGill Working Papers in Linguistics* 22. 1–18 and following).

Keywords: French liaison; glottal stop insertion; h aspiré; production planning domains; Strong Position; experimental evidence

1 Introduction

French h aspiré (henceforth: H) plays an important role in liaison (as well as in elision) and is therefore typically studied in this context: there is a massive body of literature, both descriptive and analytical, concerned with liaison/elision and, as an aside, with H (Côté 2011; Tranel 1995b offer a competent overview). An aside of the aside is the observation that a glottal stop often occurs to the left of H (Dell 1973: 186, 262 note 85). On the pages below, this H-generated glottal stop is studied in greater detail.

In the sparse literature on H-generated glottal stop, typically the phenomenon is merely mentioned in passing, and evidence to date only comes from native speaker intuitions and cursory personal observation. The empirical heart of the article is a production experiment where speakers pronouncing written stimuli were recorded. The production was then coded by a phonetically trained linguist for the presence or absence of glottal stops (based on auditory evaluation, wave form and spectrogram inspection, on which more in Section 3.1).

Questions that the experimental data speak to include the following:

(1) questions regarding H-generated glottal stop
   a. is H really a glottal stop generator? That is, do more glottal stops appear before H-initial than before V-initial words (all things being equal regarding the left context)?
   b. what, if any, is the influence of the left context, i.e. of a preceding C-final (C+H *il hache*) vs. V-final word (V+H *tu haches*)?
   c. how does glottal stop insertion behave when preceded by a liaison consonant (LC), which before H remains unpronounced but according to the classical analysis is present (LC+H *nous [...u ʔa...] hachons*)? Will LCs side with preceding vowels (V+H *tu haches*), or rather with preceding pronounced consonants (C+H *il hache*)?

Data on H-generated glottal stop are always gradient since they are subject to two loci of variation: i) the presence of H itself shows lexical, inter- and intra-speaker variation (Section 2.1); ii) the insertion of a glottal stop is optional (Section 2.2).

It is argued that the intricate puzzle of glottal stop insertion, despite its ramifying sub-patterns and multiple loci of variation, may be reduced to a single context: all instances of glottal stop insertion occur in the Strong Position {#,C}__, i.e. domain-initially or after codas. No glottal stops are inserted anywhere else. This supports the idea that glottal stop insertion is a form of strengthening (Pagliano 2003: 664f; Ségéral and Scheer 2001: 117 note 18).

The Strong Position generalization is based on the insight that H has the virtue to set its word off in a separate domain, an analysis found in the classical literature since the 70s (*syllable islands*, e.g. Tranel 1995b). That is, C + HV (*il hache*) is in fact C + [V] where the initial vowel of the H word sits in an extra domain (indicated by square brackets), in contrast to C + V (*il arrive*) where no extra domain is created in absence of H.

The H-created domains at hand do not appear to stem from morpho-syntactic divisions: within the stable frame Pronoun + Verb that is used in the experiment, no morpho-syntactic property plays any role. Also consider that H and thus H-created domains are a lexical property of words. Rather than reflecting morpho-syntactic structure, it is argued that the domains to which glottal stop insertion is sensitive identify as production planning domains in the sense of Wagner (2012 and following): production planning domains are created post-phonologically when speakers decide which items are grouped into chunks whose production is planned in one go. They are inherently variable and decided "on the fly" in production upon every speech act. This appears to be a good characterization of the kind of variation observed in H-generated glottal stop insertion.

As a by-product, it is shown that glottal stop insertion takes into account preceding consonants, whether they are pronounced (C + H *il [...l ʔa...] hache* 'he hacks') or not (case of liaison consonants LC + H *nous [...u ʔa...] hachons* 'we hack'): the glottal stop rate of both contexts is statistically indistinguishable, but both groups show a significantly higher glottal stop rate than V + H (*tu [...y ʔa...] haches* 'you (sg) hack'). This suggests that the liaison consonant is present in the string submitted to phonological computation even when it remains unpronounced, thus challenging analyses where it is epenthetic and occurs only in order to break up hiatus.

Section 2 introduces properties of H and H-generated glottal stop, as well as relevant literature. The design of the experiment is described in Section 3 and results are reported in Section 4, regarding the variation that H is subject to (Section 4.1) and the factors bearing on glottal stop insertion (Sections 4.2–4.4). They are discussed in Section 5. Section 6 introduces production planning domains and applies them to glottal stop insertion. Section 7 concludes.

2 H and glottal stop

2.1 H

H is a lexical, i.e. unpredictable property of vowel-initial words that has no phonetic realization itself but (among other effects) blocks liaison and elision. This is shown under (2), using the homophones *hêtre* [ɛtχə] 'beech' and *être* [ɛtχə] 'living being', the former bearing an H, the latter lacking it (regular V-initial word). EV is shorthand for elidable vowel.

(2) H in French liaison and elision

	before C	before H	before V
a. LC (liaison)	les *[z] cafés	les *[z] hêtres [le ɛtχə]	les [z] êtres [le z ɛtχə]
b. EV (elision)	le [ə] café	le [ə] hêtre [lə ɛtχə]	l'être [l ɛtχə]

Regarding liaison and elision, H words thus behave as if they were C-initial, although they are phonetically V-initial.

H is subject to variation of various kinds: i) diachronic (*haricot* 'bean' used to be an H word, but today with many speakers is not), ii) usage-based (high word frequency favours H effects, see Section 4.1.1), iii) inter-individual (a given word may have an H for some speakers, but not for others), and iv) intra-individual (a given speaker may use the same word with and without H).

This variation is described in detail by, among others, Cornulier (1981), Morin (1987: 831f) and Tranel (1995b: 812f). Cornulier (1981: 203) says regarding intra-individual variation that for some words "many people who are supposed to know and obey the norm seem to toss a coin every time, but, when interviewed, have sharp and definitive judgements following what the grammarians say" (my translation). As will be seen below, this is confirmed by experimental data (Section 4.1.3): the behaviour of speakers may or may not correspond to their elicited explicit judgements regarding the presence or absence of an H in a given word.

Finally, it is noteworthy that H is not just a relic from the history of the language that is slowly dying out. It was introduced by Franconian vocabulary that made it into French in the wake of the Germanic invasions of Gaul (4th–5th century AD) and was pronounced as [h] until the 13th century. When it stopped being pronounced, its phonological status changed from a phoneme to what is called h aspiré today and represented as H in this article. Note that today H also occurs in words that have no Germanic origin (*hennir* < OF *henir* < lat. hinnī̱re, *hurler* < OF *uller* < lat. ūl(u)lā̱re). It often occurs in loans (*hamburger*, *harem*, *humus*, *hyène*, *husky*) and proper names (*les troupes de Hitler* 'Hitler's troops', but *l'hitlérisme* 'hitlersim') and is not always graphically marked by h- (*le onzième* 'the elevenths'), *la une* 'the headline (media)'). New H words are productively created namely by acronyms: *le RER* [lə ɛʁəɛʁ] 'the suburb train', *le HLM* [lə aʃɛlɛm] 'the social housing block'.[1]

2.2 H-generated glottal stop

The literature reports that H may generate an optional glottal stop to its left: Dell (1973: 186, 262 note 85), Tranel (1981: 311), Pagliano (2003: 635), Côté (2008: 66), Gabriel and Meisenburg (2009).

Some authors mention this in passing based on personal observation without further discussion or empirical inquiry (Dell 1973: 186, 262 note 85, Encrevé 1988: 198ff). When more attention is devoted to the phenomenon, only the context after consonants C + H is considered: *mille […l ʔi…] hiboux* 'thousand owls' in Côté (2008: 66), *grosse […s ʔu…] housse* 'big seat cover' in Pagliano (2003: 635–637), *sept […t ʔɔ̃…] Hongrois* 'seven Hungarians' and *une […n ʔo…] hausse* 'an increase' in Gabriel and Meisenburg (2009: 166–168). Encrevé (1988: 198) mentions the occurrence of the glottal stop in V + H (*le […ə ʔi…] hibou* 'the owl', *le […əʔ ɛ…] hêtre* 'the beech'), but leaves it at that.

A few authors contrast C + H and V + H regarding the occurrence of the glottal stop. Tranel (1981: 310) timidly figures that the former context may be more conductive for glottal stop generation than the latter: "[a] glottal stop may occur before an h-aspiré word, in particular when it is preceded by a consonant-final word."

Encrevé and Scheer (2005) are less cautious: they asterisk the glottal stop in V + H (*joli *[ʔ] hêtre* 'pretty beech') but acknowledge it in C + H (*quel [ʔ] hêtre* 'which beech'). They are followed by Côté (2008: 91), who asterisks V + H *joli *[ʔ] hibou* 'pretty owl' (as opposed to C + H *mille [ʔ] hiboux* 'thousand owls'). Along the same lines, Ségéral and Scheer (2001: 117 note 18) say that "ʔ only appears in post-consonantal position (strong) and is lenited (>zero) intervocalically" (my translation).

The literature quoted should be near-exhaustive regarding H-generated glottal stop. There does not appear to be any experimental study on the subject, except for Gabriel and Meisenburg (2009). These authors enquire on the inter-speaker variation

1 Abouda et al. (2020) argue that certain lexical or graphically defined words are especially conductive for developing an H: letters of the alphabet (*le L* [lə ɛl]), colours (*le orange* 'the orange') numbers (*le onzième* 'the elevenths'), proper names (see above: *les troupes de Hitler*), acronyms (see above: *le HLM*). This is hard to assess since for each category there are also cases without H (or, for numbers, there is only one single V-initial number in the language): *l'Aubry* (politician), *le voyage d'Hidalgo en Polynésie* (politician) for names, *l'azur* or *l'émeraude* for colours, *l'ONU*, *l'OLP* etc. for acronyms.

observed for H in C + H (some speakers realize LCs before H in *tout [t] Hongrois* ‘every Hungarian’) and regarding glottal stop insertion (some speakers insert a glottal stop in *sept […tʔ ɔ̃…] Hongrois* ‘seven Hungarians’ and *une […n ʔo…] hausse* ‘an increase’, others do not). In a production experiment where 12 participants read aloud items that appeared on a screen, Gabriel and Meisenburg have tested 16 different H words in three contexts: after C-final words (*sept Hongrois* ‘seven Hungarians’), after LC-final words (*tout Hongrois* ‘every Hungarian’) and after Cə-final words (*une hausse* ‘an increase’). But the authors do not report overall statistics, limiting their discussion to just two H words, *Hongrois* and *hausse*. Also, the contexts tested do not include V + H.

In sum, given the evidence available, it is unclear which items to the left of H, if any, are favouring or disfavouring the appearance of a glottal stop (C + H, CL + H, V + H). We cannot even assert beyond gut feeling that H indeed triggers glottal stop insertion to its left: glottal stops are documented in C + H, but we ignore the behaviour of C + V (I could find one single mention of a glottal stop in this environment, by Encrevé 1988: 196 for *quel [ʔ] arbre* ‘which tree’).

Finally, we may take stock of the fact that H-generated glottal stop cumulates two loci of variation: H may be present or absent (Section 2.1) and in the latter case of course will not generate any glottal stop. In case H is present, the insertion of the glottal stop itself is always optional.

2.3 Emphasis and the glottal stop

In pre-vocalic position, the glottal stop is also an exponent of emphasis or focus in French. In these contexts, it may occur in any environment, including in absence of H (Grammont 1914: 144; Malécot 1975; Tranel 1981: 310f; Pagliano 2003: 628ff).

Thus emphasis on *impossible* in *c’est impossible* ‘this is impossible’ may result in the presence of a glottal stop when optional liaison is realized (C + V: *c’est […ɛt ʔ…] impossible*), as well as in case it is not (V + V: *c’est […ɛ ʔ…] impossible*). Malécot (1975: 53–55) provides numerous instances of emphatic glottal stops from a corpus of spoken Parisian French.

Emphatic glottal stops are a morpheme in the sense that they have a meaning, unlike H-generated glottal stops. They are therefore easy to identify. The present article is not concerned with emphatic glottal stops: all contexts studied are non-emphatic.

3 Experiment design

3.1 Data acquisition and interpretation

French natives were asked to pronounce overtly a written stimulus that appeared on a screen, and their production was recorded. They were instructed to pronounce as naturally, fluently and spontaneously as they could. There was a training session where participants experienced the experimental conditions and were coached by the instructor aiming at a natural, fluent and spontaneous pronunciation.

Stimuli were full sentences (the complete list is available in the Appendix), and the order of appearance was randomized. In the main experiment, participants pronounced a total of 72 stimuli, which were split into two runs of 36 stimuli each, separated by a break (pilot study: 20 stimuli without break). After the initial training phase and the break, participants started each run by pressing a button, and were then presented with a continuous flow of stimuli, which were separated by a fixation cross on the screen. Stimuli were visible for 5 s, and the fixation cross lasted 4 s. Participants were instructed to first read the stimulus silently, then to pronounce it aloud (initial silent reading helps avoiding influent pronunciation due to the reading task, as well as various blunders such as leaving out a word or substituting another word).

Every stimulus was recorded in a separate sound file and a phonetically trained linguist coded them for the presence or absence of a glottal stop in the relevant position (as well as for liaison, possible schwas etc.) based on auditory evaluation, wave form and spectrogram inspection. The latter were generated by Praat (Boersma 2001).

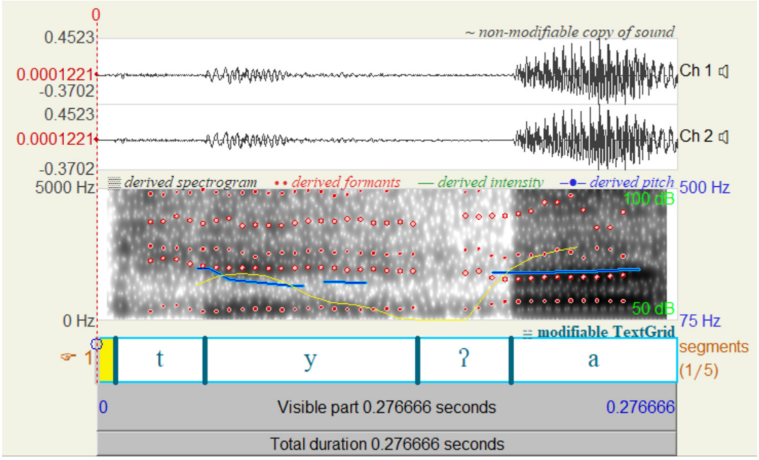
Glottal stops are often realized without full closure (Ladefoged and Maddieson 1996: 74ff). Cues that are reported to identify glottal stops in absence of a full closure are drops in intensity or pitch, as well as creak or other irregularities in the periodicity of the vowel wave (Hillenbrand and Houde 1996; Priestly 1976; Schwartz 2013).

In the data examined, items counted as glottal stops most often did not produce a full closure, but were rather identified by a discontinuation or dip of the pitch contour (in blue in the spectrograms below) and/or a dip in the intensity contour (in yellow in the spectrograms below).

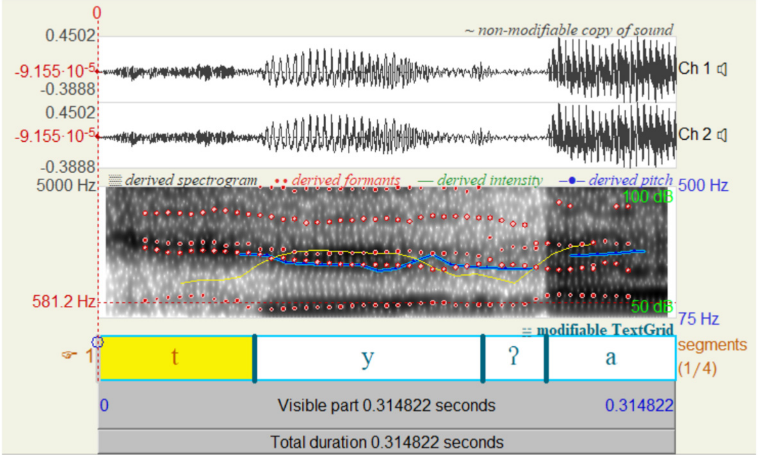
The three illustrations (3)–(5) show the same stimulus, V + H *tu haches le persil*, pronounced by three different participants. Under (3), a glottal stop produced with a closure (or what comes close to that) is shown (formants are disrupted).

The glottal stop under (4) comes without a closure (formants are continuous), but is identified by a dip in both intensity and pitch. Finally under (5) where no glottal stop is inserted, the transition between the two vowels [y] and [a] shows no dip in intensity or pitch, and no discontinuity in either is observed (the same goes for formants).

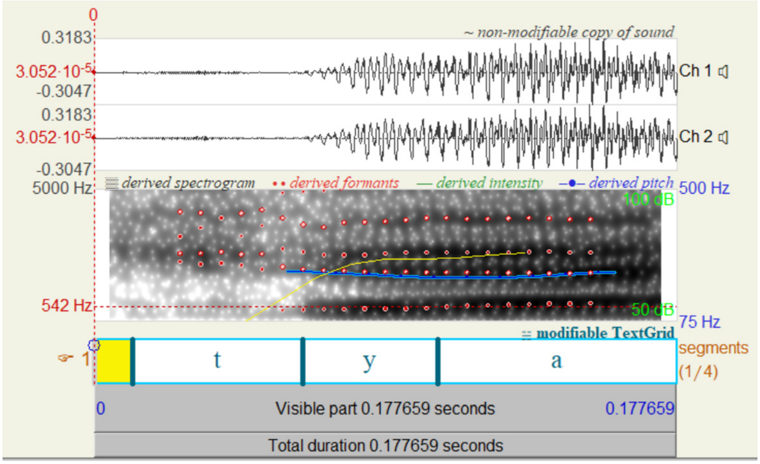
(3) Glottal stop with closure and dip in intensity: wave form and spectrogram. Stimulus pronounced: *tu haches le persil*. Visible: *tu ha…* (participant 7)



(4) Glottal stop without closure, identified by dips in both pitch and intensity: wave form and spectrogram.
Stimulus pronounced: *tu haches le persil*. Visible: *tu ha…* (participant 16)



(5) Absence of glottal stop: wave form and spectrogram.
Stimulus pronounced: *tu haches le persil*. Visible: *tu ha…* (participant 1)



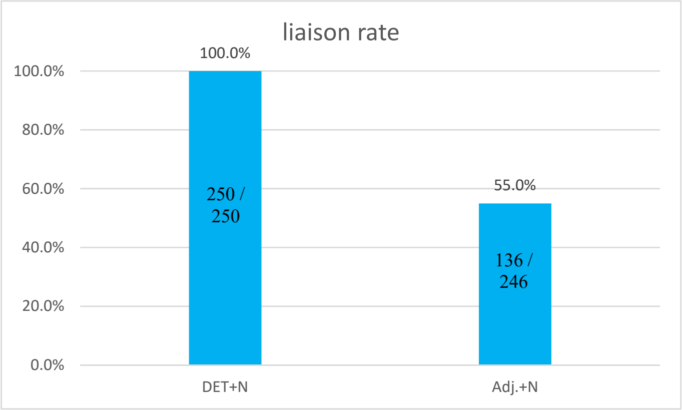
This setup was used for both the pilot study (Section 3.2) and the main experiment (Section 3.4).

3.2 Pilot study: H nouns

In a pilot study with 25 participants (university students in their early twenties or older in some cases, all native speakers of French), among other patterns tested, LC + V was probed in the configuration Adj + N (*un grand évier* 'a big sink') and DET + N (*des éviers* 'sinks'). Participants pronounced 10 instances varying word 1 and word 2 for each stimulus group (the stimuli list appears in an Appendix to this article). There were thus 250 trials each for Adj + N and DET + N (25 participants times 10 stimuli). Results are shown under (6).[2]

2 When the number of trials reported is below the number of trials submitted to participants (here 246 reported out of 250 for Adj + N), the delta was unusable because the participant pronounced something different from the stimulus, did not know the word or blundered while pronouncing (getting stuck, etc.). The same goes for other cases of this kind in the data presented below.

(6) LC+V: liaison in DET+N vs. Adj+N



For Adj + N, pronunciations without liaison such as *un grand [...ã e...] évier* or *un gros [...o ã...] enjeu* 'an important stake' thus occurred in 45 % of trials. This result corroborates, but is even more severe than the (conversational) data from the PFC corpus (*Phonologie du Français Contemporain*, Durand et al. 2014) reported by Durand (2014: 258) where LC + V in Adj + N scored a liaison rate of 88 %. Durand is surprised by this discrepancy with received wisdom: liaison is supposed to be obligatory in Adj + N (Delattre 1966: 43; Encrevé 1988: 46ff; Tranel 1987: 185ff). In fact it is held to be obligatory within the Determiner Phrase between prenominal items and nouns, thus also including DET + N. But Tranel (1987: 186) already notes in 1987 that "[t]he syntactic solidarity within an 'adjective + noun' sequence usually guarantees an obligatory liaison, but in spontaneous speech, exceptions to this general principle may be found".

The results under (6) thus support the idea that liaison is obligatory in DET + N, but indicate that this is not the case (anymore) for Adj + N. Given that there is no reason to assume that previous observers who have said liaison is obligatory in this context were mistaken any more than they were for DET + N, an ongoing diachronic evolution may be at play (older recordings would need to be explored to see).

3.3 Verbs, rather than nouns

The goal of the experiment is to study glottal stop insertion to the left of H. Factors to be controlled for are the left (word 1 ending in C, V or LC) and the right (word 2 beginning with H or V) context. Recall from Section 2.2 that glottal stop insertion is subject to two types of variation, concerning H (present/absent) and the inherent optionality of the glottal stop.

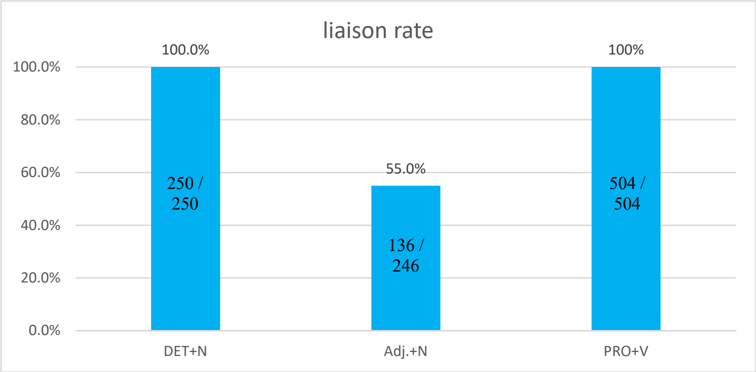
The pilot study showed that liaison is not obligatory in Adj + N, a property that makes this configuration unsuited for the glottal stop experiment. It may indicate that the syntactic relationship between Adj + N and DET + N is not the same, the former being somehow more distant. That is, Adj + N instantiate one ([Adj + N]) or two ([Adj + [N]]) computational domains (cycles, phases, constituents of the Prosodic Hierarchy), liaison being possible only in the former case. The domain structure of Adj + N being thus variable in unpredictable ways and maybe in free variation (55 % against 45 %), using this configuration in the glottal stop experiment would add a third locus of variation to the two loci already identified. Note that glottal stop insertion is not expected to occur when liaison does not go into effect: it is known to be sensitive to domain structure (see Section 5.4.3 below on syllable islands).

The question, then, is whether this additional locus of variation can be avoided within the configuration X + N. The answer is no, since the alternative DET + N, which appears to guarantee 100 % liaison, does not offer the possibility to vary the end of word 1 (-C, -V, -LC): LC-final DETs are *un* (masc. sg. indef. art.), *les* (pl. def. art.), *des* (pl. indef. art.), V-final items include *la* (fem. sg. def. art.) and *le* (masc. sg. def. art.), while a C-final DET is *quel* (interrogative masc.). The sg. articles *la*/*le* cannot be used before a V-initial word 2, though, because their vowel is subject to elision (/la île/ appears as *l'île* 'the island', /lə enfant/ as *l'enfant* 'the child'). Also, it is unclear whether the syntactic relationship between *quel* and a following noun is the same as between Art + N.

Using DET + N for the intended experiment is thus not workable. Fortunately, an alternative candidate configuration is offered by verbs, though: the other classically endorsed context where liaison is obligatory is PRO + V, i.e. between a personal pronoun and a following verb. Personal pronouns offer the three configurations required: they may be C-final (3sg *il*, *elle*), V-final (2sg *tu*) or LC-final (1pl *nous*, 2pl *vous*). In addition, 1sg *je* allows us to test whether the following word is H-initial: *je* elides before V-initial words (/je arrive/ → *j'arrive* 'I arrive'), but remains stable before H (/je hache/ → *je hache* 'I hack'). Thus *je* was used as an H-detector in the pretest run in the main experiment (see Section 3.5).

PRO + V thus qualifies regarding the lexical requirements – but is liaison in this configuration really obligatory, as suggested by the classical literature? Experimental results show that the answer is yes: it produces 100 % of liaison, just as DET + N does. This is shown under (7) where (6) is repeated to contrast with PRO + V instantiated by CL + V (*nous arrivons* 'we arrive') (see Section 3.4 for the experimental setup).

(7) LC+V: liaison in DET+N, Adj+N and PRO+V



All conditions are thus met for using PRO + V in order to probe H-generated glottal stop while avoiding extra variation created by the syntactic relationship between word 1 and word 2.

3.4 Main experiment

Like the pilot study, the main experiment based on H verbs was designed according to the description in Section 3.1.

As was mentioned, the factors to be probed concern the initial item of word 2 (H-initial vs. V-initial) and the last item of word 1 (V-final, C-final, LC-final). This unfolds into six stimulus groups, as shown under (8).

(8) six stimulus groups

	X+H	example		X+V	example
a.	CL+H	nous hochons la tête	d.	CL+V	nous aimons le foot
b.	C+H	il hoche les épaules	e.	C+V	il aime les fraises
c.	V+H	tu hoches la tête	f.	V+V	tu aimes le cinéma

Twelve H-initial and twelve V-initial verbs were chosen and distributed over the stimuli groups shown: a group contained either the former (X + H) or the latter (X + V), for a total of 6 × 12 = 72 trials per participant.

The 24 verbs were chosen among the most frequent ones in order to avoid that participants would not know the word (which for H-initial items nonetheless turned out to be sometimes the case, see below). The 24 verbs appear under (9), where the lexical frequency is indicated by occurrences per million in the Lexique corpus of spoken French based on film subtitles (New et al. 2004).

Note that the only goal of the frequency control was to avoid that participants would not know a word: there was no intention to create comparable frequency classes for H-initial and V-initial words. Also note that H-initial verbs are fairly infrequent: the ones under (9a) are the most common items in the spoken corpus mentioned, others such as *happer* 'to snap up', *haleter* 'to pant', *humer* 'to smell', *hérisser* 'to bristle', *houspiller* 'to tell off', *héler* 'to hail', *honnir* 'to put shame on somebody', *haranguer* 'to address solemnly', *hennir* 'to whinny', *hoqueter* 'to have the hiccups' coming in below, and still another group being absent from the corpus altogether (*hachurer* 'to put hatching in', *hâler* 'to get suntanned', *houer* 'to hoe', *hucher* 'to call out loud', *hancher* 'to take a position showing the hip', *housser* 'to put a cover on something').

(9) 12 H-initial and 12 V-initial verbs chosen for the main experiment

a. H-initial verbs

verb	gloss	frq.	verb	gloss	frq.
haïr	'hate'	55.4	hâter	'hasten'	5.6
hurler	'howl'	33.2	hacher	'hack'	2.2
hanter	'haunt'	11.4	hocher	'nod'	1.8
harceler	'harass'	11.1	hausser	'raise'	1.8
heurter	'bump'	9.8	huer	'boo'	1.2
hisser	'hoist'	8.1	harponner	'harpoon'	0.3

b. V-initial verbs

verb	gloss	frq.	verb	gloss	frq.
aimer	'love'	1,655	essayer	'try'	670
attendre	'wait'	1,352	oublier	'forget'	487
appeler	'call'	1,166	ouvrir	'open'	413
arrêter	'stop'	994	occuper	'occupy'	375
entendre	'hear'	729	envoyer	'send'	360
aider	'help'	689	apprendre	'learn'	349

The experiment featured 42 participants (university students in their early twenties, all native speakers of French), who thus pronounced 12 stimuli in each of the six stimulus groups, for a total of 12 × 6 × 42 = 3,024 trials. The list of stimuli (12 verbs times 6 stimulus groups = 72) appears in an Appendix to this article.

Finally, note that the experimental settings based on written stimuli and an 'exam' situation induced a bias favouring high register or normative production. As was mentioned, an attempt to counteract this was made by explicitly instructing and training participants to produce a natural, fluent and spontaneous pronunciation. They were also told that this is not an exam, and that there is no right or wrong pronunciation. But quite predictably, a number of participants ignored these instructions, showing an over-normative pronunciation and hacking sentences into isolated words. Other indicators of normative pronunciation included instances of (optional) liaison that only occur in very high register (e.g. *tu hurles [z] à l'injustice* 'you complain about injustice').

Normative pronunciation that insulates words from their context artificially creates glottal stops independent of context (see Section 5.4.3 below on syllable islands), which makes data noisy. Two participants fell into this category and were discarded from analysis. One performed (in each case, out of 12 possible trials) 8 glottal stops in CL + H (66.7 %), 9 in C + H (75 %) and 10 in V + H (83.3 %). Given the average glottal stop rate of 42.2 % in CL + H, 48.1 % in C + H and 33.8 in V + H, the inclusion of this participant would have weighed a good deal against the general trend, in all three conditions. The same goes for the other participant discarded, who scored 9 glottal stops in CL + H (75 %), 11 in C + H (91.7 %) and 11 in V + H (91.7 %). Note that among all participants, these two also had the highest scores of cumulated glottal stop production across the three conditions: 27 for the former, 31 for the latter participant. Finally, note that the results reported below (namely in Section 4.4) would not change, had the two participants been included.

3.5 Pretest

Recall from Section 2.1 that H shows inter-speaker variation: H words may or may not have an actual H in the lexicon of individual speakers. In order to probe the presence or absence of H in the 12 H verbs under (9a) in the individual lexicon of participants, a pretest was conducted.

For each of the 12 H verbs, participants were asked whether they are preceded by the full or elided 1sg pronoun *je*: for *hacher* 'to hack' for example, non-elision in the response *je hache* 'I hack' indicates the presence of H, while elision in the answer *j'hache* shows that it is absent.

The H verb appeared on a screen (for example *hacher*) and participants were given three choices: i) j' + H verb (*j'hache*), ii) je + H verb (*je hache*), iii) I don't know this word. They could also choose both i) and ii) if they judged both options well-formed.

The goal of the pretest was to be able to remove trials from analysis when the verbs actually had no H in the personal lexicon of the participant. The experiment probes glottal stop insertion before H: thus items counted as H words when they are not would corrupt the data.

In case a participant did not know an H word, all trials where they pronounced this word were removed from analysis: obviously they had no idea whether the word had an H or not.

The pretest evidence from (non-)elision of *je* turned out to be deceptive, though, since in the main experiment, participants would regularly do the reverse of what they said in the pretest (see Section 4.1.3).

4 Results

4.1 H is variable: confirmation

Results of the pretest confirm the high lexical, inter- and intra-speaker variability of H that was discussed in Section 2.1.

4.1.1 Lexical variation

Regarding lexical variation, table (10) shows the number of participants who said that a given H verb is preceded by non-elided *je*, elided *je*, or that both are acceptable. The number of responses always equals the number of participants, that is 42, except for *huer* (39) and *hâter* (39). Three participants said they do not know these verbs (in one case the same participant said that for both verbs, in other cases the two unknown verbs are distributed over distinct participants).

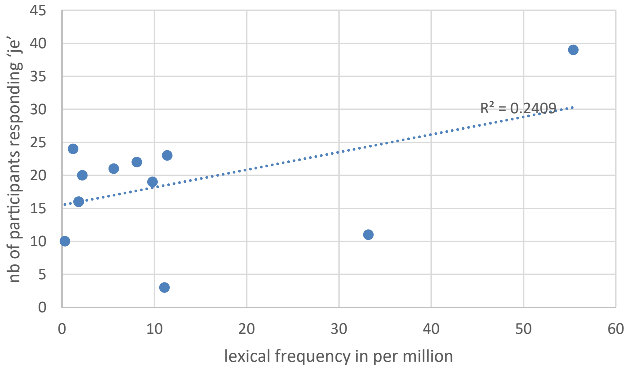
(10) lexical variation of H

nb of participants responded				nb of participants responded			
verb	je	j'	both ok	verb	je	j'	both ok
haïr	39	0	3	heurter	19	5	18
huer	24	8	7	hausser	16	11	15
hanter	23	4	15	hocher	16	13	13
hisser	22	4	16	hurler	11	9	22
hâter	21	12	6	harponner	10	19	13
hacher	20	9	13	harceler	3	29	10

There is thus an important variation between *haïr* for which 39 participants chose unelided *je*, and *harceler* that only 3 participants had preceded by unelided *je*, the other verbs coming in anywhere between these extremes.

In order to see whether there is a correlation between lexical frequency and unelided *je*, a Pearson correlation coefficient was calculated. It reveals a positive correlation of the two variables, $r(10) = 0.49$, $p = 0.105$. That is, the higher the frequency, the more unelided *je* responses are produced, but this correlation is not statistically significant ($p > 0.05$). The distribution of the two variables is shown under (11) below, where the dotted line indicates the linear trend estimation.

(11) correlation of lexical frequency and responses 'je'



A repeated measures ANOVA was performed to compare the effect of lexical frequency on the number of responses *je*. In line with the correlation, it revealed that the difference is statistically non-significant ($F(1,11) = 2.75$; $p = 0.13$; $\eta^2 = 0.068$).

4.1.2 Inter-speaker variation

Inter-speaker variation is documented by the fact that a given participant chooses a response, e.g. unelided *je*, for, say, 10 out of 12 H verbs, while another participant selects the same response for only 4 H verbs. The distribution of participants and their responses is shown under (12) below.

(12) H: inter-speaker variation

number of participants	je	j'	both ok	number of participants	je	j'	both ok
1	12	0	0	3	6	1 to 5	1 to 5
1	11	0	1	4	5	0 to 5	2 to 7
2	10	1	1	8	4	0 to 4	4 to 8
6	9	1 to 3	0 to 2	5	3	1 to 9	0 to 8
2	8	3 to 4	0 to 1	4	2	1 to 7	3 to 9
2	7	1	4	4	1	1 to 10	1 to 10

The table shows the number of participants (column 1) who have chosen unelided *je* for the number of H verbs (out of 12) indicated in the *je* column. Thus there was only one participant out of 42 who chose unelided *je* for all 12 H verbs (which is the pattern expected when all verbs in question are really H-initial). There were two participants who said that 10 H verbs are preceded by unelided *je*, and for the two remaining verbs thought one was preceded by elided *j'*, and both options (elided *j'* as well as unelided *je*) were suitable for the other. On the other end of the scale, four participants had an unelided *je* for only one H verb. These participants distributed the remaining 11 H verbs over elided *j'* and "both ok" in various ways: one said one verb was preceded by elided *j'* and admitted both options for the 10 others, while another participant entered the opposite pattern (10 H verbs take elided *j'*, one is good with both *je* and *j'*). The two other participants scoring only one H verb with unelided *je* came in with 8 *j'*/1 "both ok" (two H verbs were unknown to this participant) and 3 *j'*/8 "both ok", respectively.

The variation regarding the choices *j'* and "both ok" that participants produced who had the same number of unelided *je* responses is not shown in detail under (12) for the sake of exposition: only the lowest and the highest score is provided for the two rightmost columns.

It may thus be seen that among the 42 participants and according to their own judgement, for some H is present in all 12 H verbs, for others only in one, and there are participants having H for any number of H verbs in between these extremes. Optionality is also fully variable, as was mentioned regarding the two participants who had only one H verb with *je*: one said that 10 of the 11 other H verbs take only *j'* and the remaining H verb admits both options, while the other entered the reverse distribution.

4.1.3 Intra-speaker variation

The explicit judgement made by speakers in the forced choice setting of the pretest regarding the presence or absence of H turned out to be consistently unreliable. Thus on a great many occasions, participants said one thing in the pretest, but in actual pronunciation during the main experiment did the reverse.

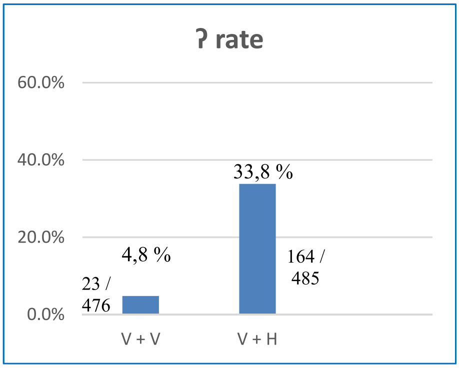
For example, a participant pronounced *vous [z] hissez la voile* with liaison (H absent), while they chose *je hisse* (H present) in the pretest. The reverse is just as frequently observed: a participant for example pronounced *nous […u y…] huons l'attaquant* without liaison (H present), but chose *j'hue* (H absent) in the pretest.

4.2 Glottal stop after V and in absence of H

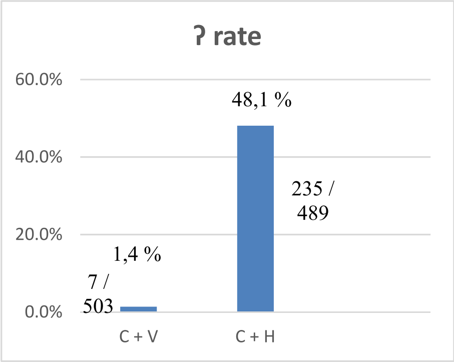
Recall from Section 2.2 that the literature offers only isolated reports of a glottal stop occurring after vowels and followed by H, and that some authors asterisk glottal stops in this context V + H (*tu hoches*), saying that they can only occur in C + H (*il hoche*).

Results of the experiment show that glottal stops not only occur in V + H (*tu hoches*), but also when no H is involved, i.e. in C + V (*il aime*) and V + V (*tu aimes*). The occurrence of the glottal stop after V (V + H, V + V) is shown under (13), after C (C + H, C + V) under (14).[3]

(13) occurrence of ʔ after V
V+V tu aimes le cinéma
V+H tu haches le persil



(14) occurrence of ʔ after C
C+V il aime les fraises
C+H il hait les examens



Results thus document the existence of glottal stops i) after V and ii) in absence of H. The glottal stop rate is very low in absence of H, i.e. 4.8 % in V + V and 1.4 % in C + V, but the existence of the glottal stop in these environments cannot be discussed away.

3 The total number of trials recorded is 12 stimuli times 42 participants, that is 504. Recall that results reported may be based on a lower number, since trials were removed form analysis where participants pronounced something different from the stimulus, did not know the word or blundered while pronouncing (getting stuck, etc.).

The multiple factors driving variation somehow concur to establish a low, but not zero probability for the glottal stop to occur in these contexts. An analysis of the gradient occurrence of the glottal stop must thus be able to account for its existence in V + V and C + V.

This is even more so in presence of H: while the literature is rife with examples after consonants (C + H), only isolated cases after vowels (V + H) are mentioned, and some authors asterisk glottal stops in V + H (see Section 2.2). As may be seen under (13), glottal stops do exist in V + H, and their occurrence is anything but marginal: 33.8 % (against 48.1 % in C + H).

The results under (13) also show that the glottal stop rate is much higher when V is followed by H (V + H) than when it is followed by V (V + V). The difference is of course highly significant: a repeated measures ANOVA was performed to compare the effect of V + H and V + V on the glottal stop rate. It revealed that the difference is statistically significant ($F(1,41) = 101$; $p < 0.001$; $\eta^2 = 0.44$). The same goes for the contrast of C + V and C + H under (14): $F(1,41) = 103$; $p = 0.001$; $\eta^2 = 0.055$.

4.3 Glottal stop insertion is favoured in Strong Position {#,C.}__

It is a well-established empirical fact cross-linguistically that the Strong Position plays a role in syllabic conditioning of phonological processes (lenition and fortition), including in Romance and French. While intervocalic V__V and coda V__{#,.C} positions are weak, i.e. conductive for lenition or loss of their hosts, the initial and the post-consonantal (in fact post-coda) positions {#,C.}__ are strong (Ségéral and Scheer 2001, 2008a).

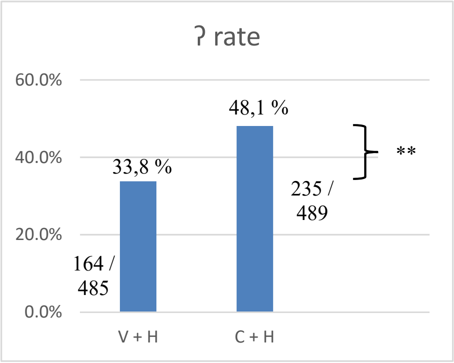
Results show that both contexts of the Strong Position disjunction, i.e. the post-consonantal C.__ (Section 4.3.1) and the word-initial #__ position (Section 4.3.2), are especially conductive for glottal stop insertion.

4.3.1 H-generated glottal stop occurs more often after C than after V

The contrast of V + H and C + H instantiates the difference between a weak and a Strong Position: the locus of the glottal stop, in case it appears, is after a vowel in V + H, but after a (heterosyllabic) consonant in C + H. Repeated from (13) and (14), the relevant figures are contrasted under (15).

(15) occurrence of ʔ in

V+H	tu haches le persil
C+H	il hait les examens



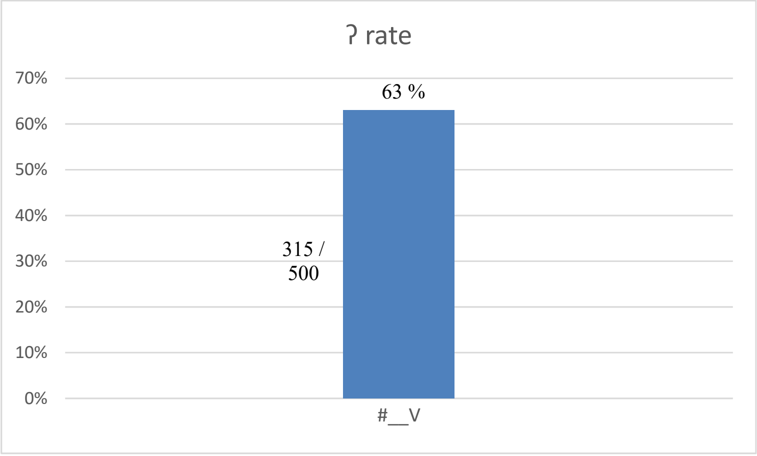
A repeated measures ANOVA was performed to compare the effect of C + H and V + H on the glottal stop rate. It revealed that the difference is statistically significant ($F(1,41) = 12.4$; $p < 0.01$; $\eta^2 = 0.068$).

4.3.2 Glottal stop in word-initial position

Although its observation was initially unintended and not explicitly included in the experiment design, the occurrence of the glottal stop in (pre-vocalic) utterance-initial position #__V could be measured in the stimulus set C + H, where stimuli always started with (C-final) *il* or *elle* (*il hait les examens*, *elle hache l'oignon*), which are also V-initial.

The result for pre-vocalic utterance-initial glottal stop insertion appears under (16) below.

(16) occurrence of ʔ in pre-vocalic utterance-initial position #__V
C+H il hait les examens



Note that glottal stop insertion in this context occurs in absence of H and any preceding segment (C or V): the only factor that the quite high insertion rate 63 % may be attributed to is the utterance-initial position. Recall from Section 4.2 that utterance-internally, the glottal stop rate before V is much lower: 1.4 % for C + V, 4.8 % for V + V.

Something is thus to be said regarding this strong discrepancy in the context before V, i.e. the strong conductivity of the utterance-initial position for glottal stop insertion.

4.4 Behaviour of LCs

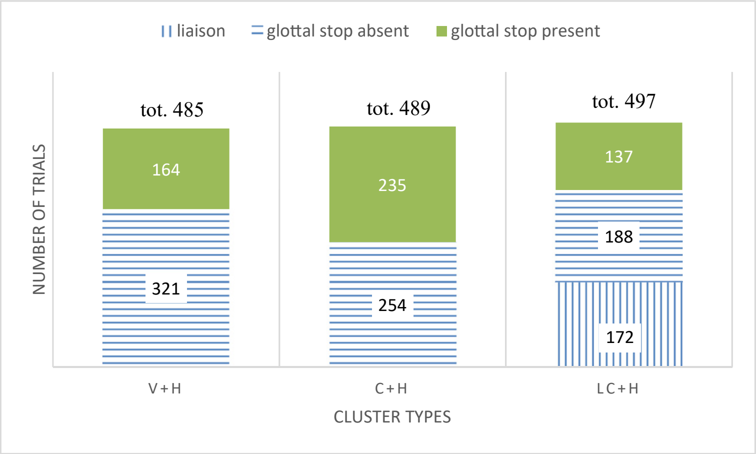
The question raised by LCs is whether the behaviour of LC + H (*nous hochons*) will follow its surface phonetic properties where H is preceded by a vowel (*nous [...u ʔo...] hochons*), or rather (on traditional assumptions) its lexical structure where H is preceded by an (unpronounced) LC (*nous / ... uz ʔo ... / hochons*). Thus, will LC + H side with V + H (*tu haches*), or rather with C + H (*il hache*)?

Table (17) shows the number of trials where glottal stops were present and absent, as well as the number of trials with liaison in the case of LC + H. Recall that the total number of trials recorded in all cases is 504 (42 participants × 12 stimuli), but that trials where participants did not know the word, pronounced something different from the stimulus, or blundered while pronouncing (getting stuck, etc.) were counted out. This "natural loss" produces 485, 489 and 497 trials counted for V + H, C + H and LC + H, respectively.

Unlike in V + H and C + H where no LC occurs, in LC + H participants also produced liaison, as in *nous* [...uz a...] *hachons* (H absent), instead of the expected *nous* [...u a...] *hachons* (H present). All cases of liaison were with enchaînement, which means that no glottal stop could (or did) occur in these trials (glottal stops may occur in liaison without enchaînement, see Encrevé 1988). The trials with liaison could thus not be used to enquire on the presence/absence of the glottal stop: they were discarded, leaving 137 (trials with glottal stop) + 188 (trials without glottal stop) = 325 trials for analysis.

(17) number of trials with and without glottal stop, and with liaison

V+H	tu haches le persil
C+H	il hait les examens
CL+H	nous hochons la tête



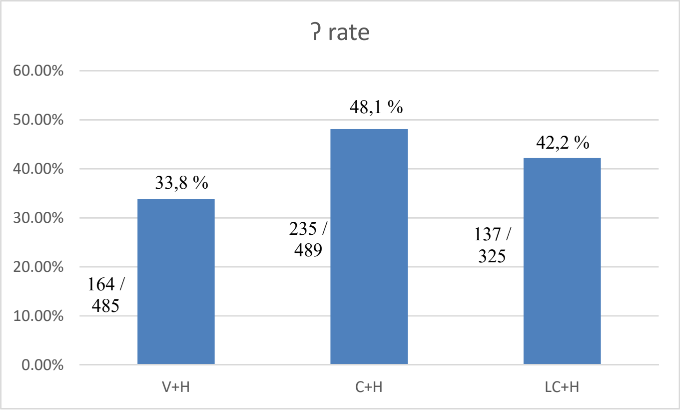
This explains the much lower number of trials analysed for LC + H (325) when compared to V + H (485) and C + H (489). Given this reference set, the glottal stop rate of the three cluster types V + H, C + H and LC + H is shown under (18).

(18) occurrence of ʔ in

V+H tu haches le persil

C+H il hait les examens

CL+H nous hochons la tête



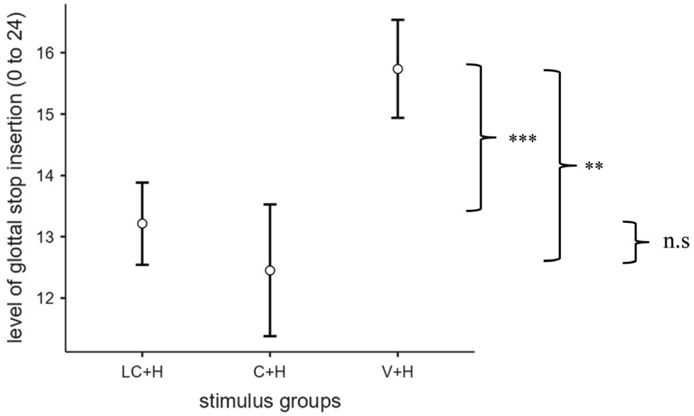
In order to see whether the difference in the glottal stop rate of LC + H and the two other groups V + H and C + H is statistically significant, a repeated measures ANOVA was conducted. Absolute numbers of trials with a glottal stop could not be used as an input to the ANOVA because, as was mentioned, the total number of usable trials strongly varies across the three groups CL + H, C + H and V + H.

Therefore the comparison of the three groups was based on the proportion of trials with and without glottal stop, rather than just on the number of trials with a glottal stop. The proportion of the presence/absence of glottal stops for each participant was calculated by subtracting the number of trials with a glottal stop from the number of trials without a glottal stop. That is, a participant having produced e.g. C + H 10 times without and 2 times with a glottal stop (out of the 12 H verbs) will have a score of 10 – 2 = 8, while a participant having done the reverse will score 2 – 10 = –8. For each participant, scores thus range over a theoretical scale going from –12 to +12, and this scale is identical for all three stimuli groups. Since negative values cannot be computed by an ANOVA, the integer 12 was added to each score, so that the lowest possible score –12 was turned into 0, and the highest possible score 12, into 24. The scale for glottal stop insertion for each participant and in each group thus ranged from 0 to 24: this is the dependent variable shown under (19).

The repeated measure ANOVA thus probed the effect of the three stimulus groups LC + H, C + H and V + H on the number of glottal stops inserted. It revealed that there was a statistically significant difference in glottal stop insertion between at least two groups: $F(2,41) = 8.21$; $p < 0.001$; $\eta^2 = 0.06$. Tukey's HSD Test for multiple comparisons found that the mean value of glottal stop insertion was significantly different between LC + H and V + H ($p < 0.001$), as well as between C + H and V + H ($p = 0.003$). But there was no statistically significant difference in glottal stop insertion between LC + H and C + H ($p = 0.7$). The variation in the estimates of LC + H, C + H and V + H was respectively: $M = 13.2$, 95 % C.I. [11.9, 14.6]; $M = 12.5$, 95 % C.I. [10.3, 14.6]; $M = 15.7$, 95 % C.I. [14.1, 17.4].

These results are shown under (19) with estimated marginal means and error bars indicating the SE.

(19) pairwise comparison of stimulus groups (estimated marginal means and SE)
LC+H vs. V+H: difference highly significant
C+H vs. V+H: difference highly significant
LC+H vs. C+H: difference non-significant



The statistical analysis thus reveals that LC + H sides with C + H: the two groups are statistically indistinguishable, while both are significantly distinct from V + H.

This suggests that glottal stop insertion is sensitive to all types of preceding consonants, whether they are pronounced (C + H) or not (LC + H).

5 Discussion

5.1 H

Results show that it is indeed correct to talk about H-generated glottal stop. Recall that this is taken for granted in the literature, without having been documented (Section 2.2). In the experimental data reported in Section 4.2, significantly more glottal stops occur when V is followed by H (V + H) than when it is followed by V (V + V). In the same way, more glottal stops are found in C + H compared to C + V. H thus produces significantly more glottal stops than V: it is indeed a glottal stop generator.

Results also document and confirm several types of variation known from reports in the literature that are based on intuition or cursory observation. Section 4.1 shows that H is subject to lexical variation (a given word is or is not H-initial with different participants), which grossly follows lexical frequency (the higher the frequency, the more often words are H-initial), the correlation being however non-significant.

Results also confirm inter-speaker (given a set of H words, different participants have H in different subsets) and intra-speaker variation (the same speaker uses a given word with or without H in different speech acts). The latter (Section 4.1.3) confirms Cornulier's (1981) observation mentioned in Section 2.1: speakers may use a given word with or without H. They toss a coin upon every speech act, and their explicit judgement is unreliable.

Recall from Section 3.5 that the pretest was supposed to determine whether a given H word really has an H in the personal lexicon of a given participant. The confrontation of the pretest results with production data show that there is no stable use of H in a given word by a given speaker, though (Section 4.1.3). Thus what speakers appear to have lexicalized is a difference between words that possess H and words that do not: the latter never produce H effects, while it is decided upon every speech act whether or not the H of the former is put to use.[4]

4 Recall from Section 3.5 that it was originally planned to remove trials with words that according to the pretest judgement of a given participant lack H. Given the situation described, though, this was of course abandoned: all trials were fed into the analysis, regardless of pretest results.

The main interest of this aspect of the study is the experimental documentation of the three types of variation discussed in the literature, which to date was lacking.

5.2 Syntactic domains: function versus content words

For the main experiment, H verbs were privileged over H nouns because experimental results showed that liaison goes into effect in 100 % of cases in the configurations DET + N and PRO + V, whereas it only occurs in 55 % of trials with Adj + N, corroborating Durand's (2014: 258) conversational data from the PFC where Adj + N scored 88 % of liaison (Section 3.3). As was mentioned, this is noteworthy in itself since for a century or so the literature has characterized all three configurations as contexts where liaison is obligatory.

The generalization thus appears to be that there is a distinction between function words (DET, PRO) and content words (Adj): when the former occur as word 1, liaison is truly obligatory, while it remains more or less often unrealized when the latter stands in this position.

This appears to be a new observation in the liaison literature. The distinction between function and content words is a cross-linguistically pervasive factor bearing on phonological phenomena (Selkirk 1996; Tyler 2019). It is syntactic in kind and documents the more or less close syntactic proximity of the sequence [word 1 – word 2]: in our case, function words are closer to word 2 than content words. While function words do not show any variation, content words do: they sometimes behave as function words (liaison goes into effect), but at other times block liaison.

Syntactic closeness bearing on phonological phenomena is a matter of domains: phonological computation goes into effect within a domain, but may be blocked by a domain boundary. According to theoretical inclination, phonologically relevant domains have been identified as computational (cycles or phases, Chomsky 2001; Kiparsky 1982) or representational (items of the Prosodic Hierarchy, Selkirk 1981 and following) in kind. This is orthogonal to the present purpose, where the only thing that matters is the existence of syntactically defined phonological domain structure.

The locus of variation regarding liaison in the pattern described may thus be domain structure, as shown under (20) below.

(20) domain structure depending on the syntactic closeness of word 1 and word 2

word 1	[word 1 + word 2]	[word 1] + word 2
function words (DET, PRO)	[DET + N]	–
	[PRO + V]	
content words (Adj)	[Adj + N]	[Adj] + N

While function words always make a single domain with word 2, content words may either instantiate this structure, or constitute a domain by themselves. Liaison then occurs only domain-internally.

5.3 Glottal stop insertion reacts on preceding Cs, whether pronounced or not

The results regarding the behaviour of LCs speak to an issue that is central in the debate on liaison: whether LCs are recorded in the lexicon or epenthetic.

The present article is about glottal stop insertion, not about liaison. Properly introducing the debate on liaison and the origin of LCs would go beyond its scope. The experimental results in this context are discussed elsewhere (Scheer and Encrevé forth). But since they are part of the experiment that is reported in detail above, a sketch of the issue is provided here.

The classical analysis of liaison since the 19th century (descriptive, structuralist and generative) holds that LCs belong to word 1, i.e. are lexically recorded in the locus where they come from diachronically, and where they are spelt.

Regarding LCs as epenthetic is an alternative introduced by Klausenburger (1974: 167), Tranel (1981: 237f) and Côté (2005, 2008: 82).[5] On this analysis, words are lexically marked i) for the fact that epenthesis will occur to their right and ii) for the particular consonant that is inserted (the specific LC that appears is a lexical, thus unpredictable property of word 1, e.g. *-t*, *-d*, *-z*). Epenthesis is then triggered by a hiatus at the boundary between word 1 and word 2. Thus in *petit [t] animal* 'little animal', the lexical recording of *petit* is /peti/ plus a diacritic saying that in case of hiatus, a *-t* will be inserted (while in *gros [z] animal* 'big animal', the diacritic specifies that *-z* will be inserted after /gro/). The hiatus in /peti animal/ and /gro animal/ then triggers epenthesis. By contrast in *joli animal* 'pretty animal', no epenthesis occurs because *joli* is lacking the diacritic marking for epenthesis.

In the classical autosegmental analysis, LCs are floating pieces of melody that occur in the lexical recording of word 1 (among others, Bermúdez-Otero 2018; Clements and Keyser 1983: 102f; Encrevé 1988; Paradis and El Fenne 1992; Tranel 1995a, 1995b, 2000; Wetzels 2002). They are thus present in the string [word 1 + word 2] that is submitted to phonological computation, which associates them to the initial

5 Côté (2005, 2008: 82) differentiates three types of liaison according to the origin of the LC: i) the LC is epenthetic in the default case like Adj + N; ii) in a small set of words, *y*, *en*, *on*, *il*, *elle*, that may be used as enclitics in imperatives or subject-verb inversion, the LC is lexically recorded at the beginning of word 2 ([z] in *vas-[z]-y* 'go!', [t] in *va-[t]-il* 'is he going to…?', etc.; iii) in a handful of adjectives that end in a nasal vowel like *bon*, *vilain*, *ancien* or *vain*, the LC is lexically recorded at the end of word 1.

empty onset of word 2 in case there is one, i.e. when word 2 is V-initial. Otherwise, the LC is present in the string computed, but remains afloat and thus unpronounced since it has nowhere to go.

On the epenthetic analysis, though, there is no such thing as unpronounced LCs, i.e. consonants that are present upon the phonological computation of word 1 + word 2, but remain silent. Thus in LC + H *nous hachons*, there is no /z/ anywhere: neither in the lexical recording of word 1 or word 2 nor as a result of epenthesis since only pronounced LCs are inserted (in order to avoid hiatus). Côté (2008: 93f) is explicit on the absence of any LC in the string that is submitted to phonological computation in LC + H: on her analysis, *petit hibou* 'little owl' is /peti $\text{ibu}_{\text{h-aspiré}}$/ where the lexical diacritic "h-aspiré" causes the sequence to be evaluated by an H-specific set of constraints that prohibit the epenthesis of an LC. Thus when *nous hachons* is submitted to phonological computation, there is no *z* anywhere.

The experimental evidence discussed suggests that the *z* is present but unpronounced in *nous hachons*, though: glottal stop insertion is sensitive to it (CL + H) in the same way as it is sensitive to fixed consonants (C + H), while both CL + H and C + H show a significantly higher glottal stop rate than V + H (Section 4.4). Thus when phonological computation evaluates the conditions for glottal stop insertion, it takes all preceding consonants into account, whether pronounced (C + H) or unpronounced (CL + H). Therefore unpronounced CLs exist in the string [word 1 + word 2] that is submitted to phonological computation: they must be present in the lexical recording of word 1.

5.4 Factors bearing on glottal stop insertion

5.4.1 Right and left context

The experimental results have identified two factors that bear on glottal stop insertion, shown under (21) below.

(21) factors bearing on glottal stop insertion

a. right context: presence/absence of H
the presence of H following the insertion site favours glottal stop insertion (Section 4.2)

b. left context: C vs. V
the presence of a C preceding the insertion site favours glottal stop insertion: its occurrence in C+H is significantly higher than in V+H (Section 4.3.1)

It was already mentioned that (21a) is an experimental confirmation of what is reported in the literature based on intuition and cursory observation: it is correct to talk about H-generated glottal stops.

By contrast, the influence of the left context under (21b) is more or less left unstudied in the literature (Section 2.2): the rare instances where the issue is addressed are only concerned with the context after C, and some authors make strong claims regarding the agrammaticality of V + ʔH, which in light of the experimental data turn out to be wrong. Only Tranel (1981: 310) was on the right track when suggesting that a preceding C is more conductive for glottal stop insertion than a preceding V: "[a] glottal stop may occur before an h-aspiré word, in particular when it is preceded by a consonant-final word."

5.4.2 What about glottal stops in other contexts?

Given this situation, the question is what the origin of the glottal stop is when it occurs in absence of these factors, i.e. in the contexts shown under (22) below.

(22) glottal stop in absence of H and a preceding V/C
- a. absence of H to the right (Section 4.2)
  1. C+V: glottal stop rate 1,4 %
  2. V+V: glottal stop rate 4,8 %
- b. absence of both H to the right and C/V to the left
  in utterance-initial position #__V, the glottal stop rate is 63 % (Section 4.3.2)

The strong glottal stop rate in utterance-initial position (22b) may pave the way towards an answer. Recall from Section 4.3 that the two contexts with the highest glottal stop rate are known as the Strong Position {#,C.}__: utterance-initial (#__V, 63 %) and post-C (or rather, post-coda) when followed by H (C + H, 48.1 %).

The responsibility of the Strong Position in glottal stop insertion thus suggests that its two constitutive contexts share something. What could that be? Ségéral and Scheer (2001, 2008b) unify the two contexts in the Strict CV framework: both word-initial and post-coda consonants occur after a governed empty nucleus (whereas coda consonants __{#,C} are found before a governed empty nucleus, and intervocalic consonants have no adjacent empty nucleus). While this may be the syllabic identity of the Strong Position, it does not tell us why H generates glottal stops: the strong post-coda position alone has nothing to say about the difference between C + __V (glottal stop rate 1.4 %) and C + __H (glottal stop rate 48.1 %), where the insertion site occurs in the same Strong Position.

What we are looking for is thus a combination of two factors: the (strong) position of the insertion site and the effect due to H. That is, the Strong Position effect suggests that something *in addition to their syllabic position* must be shared by #__V and C + H. One candidate is H, but obviously the effect of #__V could not be attributed to H, since there is no: the utterance-initial insertion site is followed by V, not by H.

The only other candidate is #: the utterance-initial position is *initial*, i.e. initial of a computational domain (the word). Therefore, what could be shared by #__V and C + H is the fact that the insertion site is domain-initial in both cases: C + H is in fact C + [H]. In other words, H sets its word off into a separate domain. This is H-specific: C + V makes a single domain [C + V].

This conclusion, reached only on the grounds of the experimental data and the Strong Position effect, converges with a long-standing tradition in the analysis of H that is discussed in the following Section.

5.4.3 H creates syllable islands: it sets itself off into a separate domain

Since the 1970s, it was proposed that the specificity of H is to disallow syllabification of preceding segments with the initial vowel of H words. That is, H prohibits the first vowel of its word to have an onset consonant: the syllable always begins with this vowel.

The idea that H sets its word off into a distinct domain (of computation), thus blocking communication with the preceding word and disallowing resyllabification over the word boundary, appears in different guises in the literature: Morin (1974: 87f) and Schane (1978: 138f) propose that H words are vowel-initial and bear a syllable boundary to the left of H in the lexicon which cannot be altered during computation.

Cornulier (1978, 1981) argues that H induces a "separation" (French *disjonctivité*) and is marked for this property in the lexicon (see also Côté 2008: 92).

Tranel (1992, 1995b) has coined the term *syllable island* for this perspective on H.

The authors quoted concluded on this identity of H based on its general properties in liaison and elision, without considering glottal stop insertion. This increases the weight of the convergence mentioned since the conclusion that H sets itself off in a separate domain was reached on entirely independent grounds: liaison and elision then, glottal stop insertion now.

5.5 Glottal stop insertion is triggered by the strong position

5.5.1 Domain-initial position

The preceding discussion supports the conclusion made explicit under (23) below.

(23) context 1
glottal stop insertion is triggered by the strong domain-initial position [__V]. This position occurs

a. utterance-initially
#__V = [__V…]
b. utterance-internally when a word begins with H
1. C+H = C+[__H…]
2. V+H = V+[__H…]

Since H has the domain-creating virtue mentioned, it will create domains regardless of what precedes: this is shown under (23b) where H produces a separate domain both after V and after C. This domain is thus perfectly independent of the Strong Position: V + __H is a weak position, while C + __H is strong, but both C + [__H] and V + [__H] are strong.

This view offers a handle on the strong glottal stop rate in V + H (33.8 %), as opposed to V + V (4.8 %). Glottal stops in V + H are domain-initial V + [ʔH] (just as they are in C + [ʔH]), but there is no H to create a domain in V + V. Thus the prediction is that V + H is sometimes V + [H] (when H is present), but V + V is never V + [V], and therefore no glottal stop insertion occurs here. This makes the strong contrast between V + H and V + V. That glottal stops in fact do exist in V + V (4.8 %) then begs the question, which will be addressed in Section 5.6 (there is still another source of domains).

But this situation needs to be appreciated in the light of the intrinsic variation that H is known to produce: it may or may not be present (Section 5.1). We now have a phonological interpretation of what it means for H to be present or absent: it sets its word off in a separate domain when it is present, but no extra domain is created in its absence.

This intrinsic variation due to H thus produces the situation shown under (24) below.

(24) locus of variation in H words: H present / absent

		C+H	V+H
a.	H present	C+[__V]	V+[__V]
b.	H absent	C+__V	V+__V

In H words, the “presence of H” under (24a) translates as the creation of an extra domain, which makes the difference between H words (C + [__V], V + [__V]) and other words, which identify as C + __V, V + __V. In “absence of H” under (24b), though, there is no extra domain created and thus H words have the exact same phonological structure as other words: C + __V and V + __V.

Glottal stop insertion then occurs domain-initially (and only in this context), producing the H-related variation observed.

5.5.2 Post-coda position

The presence or absence of H and thus of the extra domain also accounts for the fact that the glottal stop rate in C + H is significantly higher than in V + H (Section 5.4.1). In presence of the extra domain (24a), the insertion site is domain-initial and thus experiences identical phonological conditions in C + [__H] and V + [__H]: the domain boundary bars communication with the preceding C or V.

The absence of the extra domain under (24b), though, puts the preceding C or V in the purview of the insertion site, which is then placed in strong post-coda position in C + __H, while it stands in weak post-vocalic position in V + __H.

Glottal stop insertion is thus driven by the Strong Position {#,C}__: it occurs in (domain-) initial and post-coda position. There are two domain-initial positions: utterance-initial #__V = [__V] and utterance-internal C [__H…] or V [__H…]. The other Strong Position, post-coda C + __V, of course only occurs utterance-internally.

This situation allows for a view where the glottal stop occurs *only* in Strong Position: the cases where it is observed after a vowel in fact identify as domain-initial V + [__H…]. No glottal stop is ever inserted in weak post-V position V + __H, i.e. when H is not creating a domain.

The advantage of C + H over V + H regarding glottal stop rate thus comes from the extra source for domain-internal glottal stops in the former context, as shown under (25) below.

(25) context 2
glottal stop insertion is triggered by the strong post-coda position when word 1 and word 2 occur in the same domain

	domain-initial		domain-internal	
	V+[__H…]	C+[__H…]	C+__V	V+__V
a. after C	–	ʔ	ʔ	–
b. after V	ʔ	–	–	–

Both C + H and V + H collect glottal stops domain-initially, i.e. when the H-created domain is present. But in case it is absent, i.e. in domain-internal position, only C + H benefits from additional glottal stops.

Finally, recall that glottal stop insertion is inherently optional: when all conditions for insertion are met, it still may or may not occur. This is why the glottal stop rate never reaches 100 %, even in Strong Position.

5.6 Domains created in absence of H

The last piece of data that remains unaccounted for are the contexts C + V and V + V. Although they produce very few glottal stops (1.4 % and 4.8 %, see Section 4.2), these cannot be discussed away. In C + __V, the insertion site is in strong post-coda position and thus a legitimate locus for glottal stop insertion. But in V + __V, the insertion site does not appear to qualify for a Strong Position in any way: it does not occur after a C, and there is no H that could create a domain.

If it is the case that glottal stop insertion only occurs in Strong Position, though, a domain must set off word 2 when V + __V is observed with a glottal stop: in these cases, V + __V in fact must identify as V + [__V…].

What could be the nature of such a domain, in absence of H? Section 6 introduces the idea that the domains at play in this case, but indeed also when H creates domains, identify as production planning domains.

6 Production planning domains

6.1 Domains created by interfaces

Domains in phonology are stretches of the linear string that are computed in one go. The regular instantiation of phonological domains is defined by morpho-syntactic divisions, which are reflected in the phonology either procedurally (cycles, phases) or representationally (items of the Prosodic Hierarchy). The influence of this kind of domain on liaison was discussed in Section 5.2.

It is obvious that the kind of domain which produces glottal stop insertion at its left edge is not of this morpho-syntactic type. For one thing, unlike in liaison where syntactic categories define domains (Adj., DET, PRO, N, V), no morpho-syntactic information of any kind contributes to the delineation of glottal stop-generating domains. Also, recall that the configuration PRO + V was selected because liaison occurs in 100 % of cases in this configuration, against only 55 % in Adj + N. Morpho-syntactic domains are at the origin of this variation. The fact that PRO + V does not oppose any barrier to liaison indicates that whatever domain is created by H in X_{PRO} + $[H]_V$, i.e. a pronoun followed by an H verb, is of a different kind.

There is thus reason to believe that phonological computation is sensitive to two types of quite different domains, one of morpho-syntactic origin, the other not. Where could the latter come from, then?

The literature offers a candidate with a good fit: production planning domains (Kilbourn-Ceron 2017a; Wagner 2012 and others, see below). These domains are created post-phonologically when speakers decide which items are grouped into chunks whose production is planned in one go. Production planning domains are inherently variable and decided "on the fly" in production upon every speech act. In this perspective, both kind of domains, morpho-syntactic and production planning, are a consequence of interfaces: with morpho-syntax in the former, with phonetics and production in the latter case.

The idea of the Production Planning Hypothesis (PPH, Wagner 2012 and following) is that online speech production is local. That is, only a certain chunk of the string to be pronounced is encoded for production in one go, and this chunk is intrinsically variable. Regarding the size of production planning domains, the psycho-linguistic literature suggests that it may not always encompass two successive words (Levelt et al. 1999).

Production planning especially affects phonological and phonetic phenomena that occur in external sandhi, i.e. when the computation of a property of word 1 depends on a property of word 2. Obviously, the computation of the word 1 property cannot be effected if word 2 is not available by the time word 1 is encoded. Word 2 being available means that it occurs in the same speech production chunk as word 1. Thus if the production planning domain spans over both words [word 1 + word 2], an external sandhi process may go into effect. In case the two words are placed in different chunks that are successively submitted to production [[word 1] [word 2]], though, external sandhi is blocked because the value of the word 1 property depending on word 2 cannot be computed in [word 1].

How is it then decided which items are included in production planning domains? Table (26) below mentions a number of factors that have been documented to influence external sandhi phenomena.

(26) external sandhi word 1 + word 2
Factors bearing on the size of production planning domains (word 2 is in the same or a different domain with respect to word 1)
- a. morpho-syntactic divisions
- b. length of word 1
- c. lexical frequency of word 2
- d. conditional probability of word 2 given word 1
- e. speech rate
- f. repetition of the stimulus

The influence of morpho-syntactic divisions (26a) on production planning domains is documented by the variable presence of *-g* in the pronunciation of /ŋg/ in English spoken in North West England (e.g. Manchester). Bailey (2019) has elicited pronunciations from natives in a reading task (like most other experimental studies discussed below), judging whether words like *sing* or *wrong* were pronounced with a final [ŋ] or a final [ŋg]. He contrasted four different morpho-syntactic divisions according to the greater or lesser distance at which they place word 1 and word 2 (in increasing order): i) NP-internal as in [the wrong shop]$_{NP}$, ii) VP-internal: in a double object construction, the indirect object ends in a /ŋg/ word, followed by the direct object [she gave [the ring]$_{IO}$ [a quick polish]$_{DO}$], iii) crossing an NP-VP boundary [[the sting]$_{NP}$ became painful], iv) crossing an intonational phrase boundary [[it's a traditional thing]$_{IP}$, Patricia said]. Results where /ŋg/ is followed by a consonant-initial word show that the more distant word 1 and word 2 are syntactically, the higher the rate of g-presence.

In the same way, Tamminga (2018) documented that coronal stop deletion in the Philadelphia Neighborhood Corpus (Labov and Rosenfelder 2011) (*she was jus[ø] calling her friend*) is significantly lower when the next word occurs across a stronger (matrix CP + high adjunct, high adjunct + matrix CP, matrix CP + conjunction, matrix CP + matrix CP) than across a weaker (verb + direct object) syntactic boundary (see also Tanner et al. 2017).

Kilbourn-Ceron et al. (2017) examined t/d-flapping in American English according to the presence (*if you plit, Alice will be mad*) or absence (*if you plit Alice, John will be mad*) of a clause boundary between word 1 and word 2 (here *plit* and *Alice*). They found that the flapping rate was significantly higher in absence of the clause boundary, as compared to its presence.

Finally, Wagner et al. (2020) have probed the liaison rate of the plural morpheme -*s* in French for Adj-pl + N (*elle discute avec les dernier-s élèves* 'she discusses with the last pupils') and N + Adj (*ils construisent des douche-s intérieures* 'they construct inside-showers'). Results showed that the liaison rate was significantly higher in the former than in the latter case. The pronunciation of LCs that belong to word 1 (the -*t* of *petit*, as opposed to the LC being a separate morpheme, pl -*s*) is traditionally held to be obligatory in Adj + N, but only optional in N + Adj. The stronger syntactic bonds between nouns preceded by an adjective, as compared to when they are followed by an adjective, are thus confirmed by Wagner *et al.*'s results.

In the same study, Wagner et al. (2020) also test the length of word 1 (26b). They found that short items (one or two syllables) produce a significantly higher liaison rate than longer words (three syllables). This is consistent with the PPH: given a stable size of the window that is planned in one go, shorter first words leave more space for integrating word 2 into the domain.

Another factor bearing on production planning windows is lexical frequency (26c). Based on the Buckeye Corpus of conversational speech, Kilbourn-Ceron et al. (2017) extracted tokens where word 1 ends in t/d and is followed by a vowel-initial word (~12 k tokens), then measured the occurrence of flapping. Results show that the lexical frequency of word 2 is a strong predictor of the likelihood of flapping: the more frequent it is, the more likely flapping occurs. Since lexical frequency enhances lexical access, the faster retrieval of a high frequency item increases its chances to slip into a production planning window shared with the preceding word: it is ready for encoding earlier than low frequency items.

In the same way, Kilbourn-Ceron (2017a: 131ff, 2017b) has found a positive effect of the lexical frequency of word 2 in French liaison. The study was based on the PFC corpus (Durand 2014) and concerned two configurations: N-pl + Adj (*des pas enjoués* 'cheerful steps', ~13 k potential liaison sites) and Adj + N (*un petit enfant* 'a little child', ~2.5 k potential liaison sites).

A better estimate for the ease of accessing word 2 than lexical frequency may be the conditional probability of word 2 to occur given word 1 (26d). That is, the probability of word 2 to occur if word 1 is known, based on the occurrence of [word 1 – word 2] pairs in a reference corpus. Kilbourn-Ceron (2017a: 146) and Wagner et al. (2020) found that the conditional probability of word 2 increases liaison rate.

Other documented effects on external sandhi processes modulating the ease of access of word 2 are speech rate (26e) (the faster, the more likely the process) and repetition (if a word was pronounced previously (26f), its likelihood to undergo the process increases). Literature regarding these factors is discussed in Kilbourn-Ceron et al. (2017, 2020).

In all cases, production planning has a gradient effect: its influence on the phonological processes at hand is never categorical. This is because, recall, production planning is inherently variable (Kilbourn-Ceron et al. 2017).

6.2 Glottal stop insertion and production planning

Phonological processes in external sandhi that are studied in the literature on production planning include liaison, t/d-flapping, presence of g in the pronunciation of /ŋg/, coronal stop deletion and others not discussed above such as devoicing of high vowels in Tokyo Japanese (in C__#C contexts where both consonants are voiceless, Kilbourn-Ceron and Sonderegger 2018) or the reduction of *is* to *'s* in English (*Austria 's nice*).

In all cases save the reduction of *is*, the external sandhi processes studied concern the last item of word 1. And in all cases, including the reduction of *is*, the process is favoured by the inclusion of word 2 into the production planning window of word 1: [word 1 + word 2] will be conductive for the process, while [word 1] + [word 2] will have an inhibitory effect.

The case studied in the present article, glottal stop insertion in French, provides a new type of evidence for production planning domains in so far as the item undergoing the external sandhi process occurs at the beginning of word 2 and is favoured, rather than inhibited, when word 2 is planned in its own domain. It also introduces a case where a lexical property of words, H, has the virtue of setting off its word into a separate domain. As far as I can see, lexical marking of words is not among the factors bearing on production planning that have been documented to date.

Other factors known to influence production planning (26) are of course also expected to weigh on glottal stop insertion. The present study was not designed to control for them, but this is certainly something to be done in further investigation.[6]

7 Conclusions

On the preceding pages, experimental evidence regarding glottal stop insertion in French external sandhi was provided, speaking to properties of the pattern for which no data were available to date. This namely concerns the influence of the left context of the insertion site (Sections 4.2 and 4.3), but also the variation associated to H: lexical, inter- and intra-speaker (Section 4.1).

As a by-product, it was shown that glottal stop insertion takes into account preceding consonants, whether they are pronounced (C + H) or not (LC + H): the glottal stop rate of both contexts is statistically indistinguishable. By contrast, both groups show a significantly higher glottal stop rate than V + H. This suggests that the LC is present in the string submitted to phonological computation even when it remains unpronounced. This is incompatible with analyses where the LC is epenthetic and only inserted in order to break hiatus. It converges with the classical autosegmental analysis of liaison where the LC is lexically recorded at the end of word 1, i.e. where it comes from diachronically and where it is spelt.

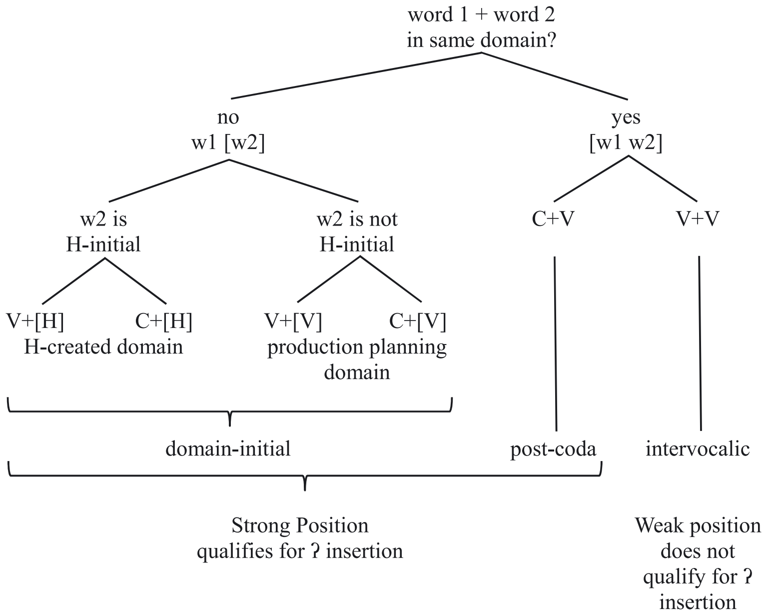
Another by-product of the experiment is the insight that when occurring as word 1 in liaison, function words (DET, PRO) create a closer bond with word 2 than content words (Adj.) (Section 5.2).

On the analytic side, it was argued that glottal stop insertion, despite its ramifying sub-patterns and multiple loci of variation, may be reduced to a single context: all instances of glottal stop insertion occur in the Strong Position {#,C}__, i.e. domain-initially or after codas. This generalization is based on the insight that H has the virtue to set its word off in a separate domain (a classical idea in the literature, Section 5.4.3), and that the domains in question are production planning domains, which also occur in absence of H.

6 Recall that the glottal stop rate of V + V is 4.8 % (23 of 476), against 1.4 % (7 of 503) in C + V. This difference is significant: $F(1,41) = 5.96$; $p = 0.019$; $\eta^2 = 0.059$). In V + V and C + V, domains can only be production planning domains (there is no H). Given the analysis discussed, this means that production planning is sensitive to whether word 1 ends in a consonant or in a vowel: the latter context V + V is more conductive for placing word 2 in a separate domain than is C + V. This factor in production planning needs further probing.

The decision tree summing up all aspects of the intricate glottal stop distribution (except the utterance-initial position, for expository reasons) appears under (27) below.

(27) distribution of the glottal stop



The missing context, the utterance-initial position #__V, is of course also domain-initial and thus a Strong Position. The action of two out of the three loci of variation is also shown under (27): domains may be due to H or to production planning. In case either creates a domain, the insertion site will be on the left branch of the tree, i.e. in domain-initial Strong Position. If on the other hand no domain is created by either means, the insertion site of C + V will be in strong post-coda position, while it occurs in weak intervocalic position in V + V.

The Strong Position {#,C}__ thus defines contexts that qualify for glottal stop insertion: all glottal stops appear in this position, and glottal stops appear nowhere else. But given the third locus of variation, the intrinsic variability of glottal stop insertion, positions that qualify for insertion may or may not actually receive a glottal stop.

The intricate puzzle of contexts where glottal stop insertion does or does not occur may thus be broken down to a complementary distribution whose contours are blurred by the three loci of variation: insertion occurs in Strong Position, and only in this context. This supports the idea that glottal stop insertion is a form of strengthening (Ségéral and Scheer 2001: 117 note 18; Pagliano 2003: 664f).

Appendix

1. Pilot study with H nouns

	LC + V probed in two configurations:	
	Adj + N	DET + N
1	un petit exposé	ce sont des évêques
2	un grand évier	ce sont des éditeurs
3	un gros enjeu	ce sont des examens
4	un long institut	ce sont des instituts
5	un faux atome	ce sont des annuaires
6	un excellent annuaire	ce sont des enjeux
7	un vilain abandon	ce sont des abandons
8	un soi-disant évêque	ce sont des éviers
9	un inquiétant examen	ce sont des exposés
10	un plaisant éditeur	ce sont des atomes

2. Main experiment with H verbs

a. X + H (CL, C, V followed by H)			
	CL + H	C + H	V + H
1	nous hantons nos ennemis	elle hache l'oignon	tu haches le persil
2	nous haïssons le chômage	elle harcèle sa copine	tu hais les dictateurs
3	nous heurtons la glissière	elle harponne le poisson	tu hantes tes voisins
4	nous hochons la tête	elle hausse la voix	tu harcèles le prof
5	nous huons l'attaquant	elle hisse le pavillon bleu	tu harponnes les requins
6	nous hâtons l'échéance	elle hurle au voleur	tu hausses le ton
7	vous hachez la viande	il hait les examens	tu heurtes la loi
8	vous harcelez le directeur	il hante le château	tu hisses le drapeau
9	vous harponnez la baleine	il heurte le bon goût	tu hoches la tête
10	vous haussez les épaules	il hoche les épaules	tu hues l'arbitre
11	vous hissez la voile	il hue le ministre	tu hurles à l'injustice
12	vous hurlez au loup	il hâte son départ	tu hâtes la guérison

b. X + V (CL, C, V followed by V)			
	CL + V	C + V	V + V
1	nous aimons le foot	elle aide sa mère	tu aides les clients
2	nous appelons le prof	elle apprend l'anglais	tu aimes le cinéma
3	nous entendons la rue	elle arrête la cigarette	tu appelles ta mère
4	nous envoyons des lettres	elle attend le bus	tu apprends un métier
5	nous essayons un plat exotique	elle occupe toute la place	tu arrêtes le café
6	nous ouvrons le livre	elle oublie le temps	tu attends les résultats
7	vous aidez les enfants	il aime les fraises	tu entends les chiens

(continued)

8	vous apprenez l'espagnol	il appelle son copain	tu envoies le document
9	vous arrêtez le sport	il entend le tram arriver	tu essaies le pantalon
10	vous attendez le train	il envoie un colis	tu occupes le créneau prévu
11	vous occupez peu d'espace	il essaie la nouvelle voiture	tu oublies les ennuis
12	vous oubliez vos obligations	il ouvre la porte	tu ouvres le garage

References

Abouda, Lotfi, Céline Dugua & Guillaume Enguehard. 2020. A propos de quelques exceptions aux règles de la liaison et de l'élision. *Congrès Mondial de Linguistique Française (CMLF) 2020 SHS Web of Conferences* 78. 09010.

Bailey, George. 2019. Ki(ng) in the North: Effects of duration, boundary and pause on post-nasal [g]-presence. *Laboratory Phonology* 10. 3.

Bermúdez-Otero, Ricardo. 2018. In defence of underlying representations: Latin rhotacism, French liaison, Romanian palatalization. *Probus* 30. 171214.

Boersma, Paul. 2001. Praat, a system for doing phonetics by computer. *Glot International* 5(9–10). 341–345.

Chomsky, Noam. 2001. Derivation by phase. In Michael Kenstowicz (ed.), *Ken Hale: A life in language*, 1–52. Cambridge, Mass.: MIT Press.

Clements, George & Samuel Keyser. 1983. *CV phonology. A generative theory of the syllable*. Cambridge, Mass.: MIT Press.

Cornulier, Benoît de. 1978. Syllables et suites de phonèmes en phonologie du français. In Benoît de Cornulier & François Dell (eds.), *Etudes de phonologie française*, 31–66. Paris: CNRS éditions.

Cornulier, Benoît de. 1981. H-aspiré et la syllabation: Expressions disjonctives. In Didier Goyvaerts (ed.), *Phonology in the 1980's*, 183–230. Ghent: Story-Scientia.

Côté, Marie-Hélène. 2005. Le statut lexical des consonnes de liaison. *Langages* 158. 66–78.

Côté, Marie-Hélène. 2008. Empty elements in schwa, liaison and h aspiré: The French Holy Trinity revisited. In Jutta Hartmann, Veronika Hegedüs & Henk van Riemsdijk (eds.), *Sounds of silence: Empty elements in syntax and phonology*, 61–103. Amsterdam: Elsevier.

Côté, Marie-Hélène. 2011. French liaison. In Marc van Oostendorp, Colin Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell companion to phonology*, 2685–2710. New York: Wiley-Blackwell.

Delattre, Pierre. 1966. *Studies in French and comparative phonetics*. The Hague: Mouton.

Dell, François. 1973. *Les règles et les sons*, 2nd edn. 1985. Paris: Hermann.

Durand, Jacques. 2014. Corpora, variation and phonology: An illustration from French liaison. In Jacques Durand, Ulrike Gutt & Gjert Kristoffersen (eds.), *The Oxford handbook of corpus phonology*, 240–264. Oxford: OUP.

Durand, Jacques, Bernard Laks & Chantal Lyche. 2014. French phonology from a corpus perspective. The PFC programme. In Jacques Durand, Ulrike Gutt & Gjert Kristoffersen (eds.), *The Oxford handbook of corpus phonology*, 486–497. Oxford: OUP.

Encrevé, Pierre. 1988. *La liaison avec et sans enchaînement: Phonologie tridimensionnelle et usages du français*. Paris: Seuil.

Encrevé, Pierre & Tobias Scheer. 2005. Autosegmental association is not automatic. *Paper presented at the 13th Manchester Phonology Meeting, Manchester, 26–28 May*.

Gabriel, Christoph & Trudel Meisenburg. 2009. Silent onsets? An optimality-theoretic approach to French h aspiré words. In Frank Kügler, Caroline Féry & Ruben van de Vijver (eds.), *Variation and gradience in phonetics and phonology*, 163–184. Berlin: Mouton de Gruyter.

Grammont, Maurice. 1914. *Traité pratique de prononciation française*. Paris: Delgrave.

Hillenbrand, James M. & Robert A. Houde. 1996. Role of F0 and amplitude in the perception of intervocalic glottal stops. *Journal of Speech and Hearing Research* 39. 1882–1190.

Kilbourn-Ceron, Oriana. 2017a. *Speech production planning affects variation in external sandhi*. McGill University PhD dissertation.

Kilbourn-Ceron, Oriana. 2017b. Speech production planning affects phonological variability: A case study in French liaison. In *Proceedings of the Annual Meeting on Phonology (AMP), USC*. Available at: http://journals.linguisticsociety.org/proceedings/index.php/amphonology/article/view/4004.

Kilbourn-Ceron, Oriana, Meghan Clayards & Andreas Wagner. 2020. Predictability modulates pronunciation variants through speech planning effects: A case study on coronal stop realizations. *Laboratory Phonology* 11. 5.

Kilbourn-Ceron, Oriana & Morgan Sonderegger. 2018. Boundary phenomena and variability in Japanese high vowel devoicing. *Natural Language & Linguistic Theory* 36. 175–217.

Kilbourn-Ceron, Oriana, Michael Wagner & Meghan Clayards. 2017. The effect of production planning locality on external sandhi: A study in /t/. In *Proceedings of the 52nd Annual Meeting of the Chicago Linguistic Society*, 313–326.

Kiparsky, Paul. 1982. From cyclic phonology to lexical phonology. In Harry van der Hulst & Norval Smith (eds.), *The structure of phonological representations I*, 131–175. Dordrecht: Foris.

Klausenburger, Jürgen. 1974. Rule inversion, opacity, conspiracies: French liaison and elision. *Lingua* 34. 167–179.

Labov, William & Ingrid Rosenfelder. 2011. *The Philadelphia Neighborhood Corpus of LING 560 studies, 1972–2010*. Philadelphia: University of Pennsylvania.

Ladefoged, Peter & Ian Maddieson. 1996. *The sounds of the world's languages*. Cambridge: Blackwell.

Levelt, Willem J. M., Ardi Roelofs & Antje S. Meyer. 1999. A theory of lexical access in speech production. *The Behavioral and Brain Sciences* 22. 1–75.

Malécot, André. 1975. The glottal stop in French. *Phonetica* 31. 51–63.

Morin, Yves Charles. 1974. Règles phonologiques à domaine indéterminé: Chute de cheva en français. *Cahier de Linguistique* 4. 69–88.

Morin, Yves Charles. 1987. French data and phonological theory. *Linguistics* 25. 815–843.

New, Boris, Christophe Pallier, Marc Brysbaert & Ludovic Ferrand. 2004. Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers* 36. 516–524.

Pagliano, Claudine. 2003. *L'épenthèse consonantique en français. Ce que la syntaxe, la sémantique et la morphologie peuvent faire à la phonologie*. Université de Nice Ph.D dissertation.

Paradis, Carole & Fatimazohra El Fenne. 1992. L'alternance C/ø des verbes français: Une analyse par contraintes et stratégies de réparation. *Revue Québecoise de Linguistique* 21. 107–141.

Priestly, Tom M. S. 1976. A note on glottal stop. *Phonetica* 33. 268–274.

Schane, Sanford. 1978. L'emploi des frontières de mot en français. In Benoît de Cornulier & François Dell (eds.), *Etudes de phonologie française*, 133–147. Paris: Editions du CNRS.

Scheer, Tobias & Pierre Encrevé. forth. Identity avoidance in French external sandhi.

Schwartz, Geoffrey. 2013. Vowel hiatus at Polish word boundaries – phonetic realization and phonological implications. *Poznań Studies in Contemporary Linguistics* 49. 557–585.

Ségéral, Philippe & Tobias Scheer. 2001. La Coda-Miroir. *Bulletin de la Société de Linguistique de Paris* 96. 107–152.

Ségéral, Philippe & Tobias Scheer. 2008a. Positional factors in lenition and fortition. In Joaquim Brandão de Carvalho, Tobias Scheer & Philippe Ségéral (eds.), *Lenition and fortition*, 131–172. Berlin: Mouton de Gruyter.

Ségéral, Philippe & Tobias Scheer. 2008b. The Coda Mirror, stress and positional parameters. In Joaquim Brandão de Carvalho, Tobias Scheer & Philippe Ségéral (eds.), *Lenition and fortition*, 483–518. Berlin: Mouton de Gruyter.

Selkirk, Elisabeth. 1981 [1978]. On prosodic structure and its relation to syntactic structure. In Thorstein Fretheim (ed.), *Nordic prosody II*, 111–140. Trondheim: TAPIR.

Selkirk, Elisabeth. 1996. The prosodic structure of function words. In James Morgan & Katherine Demuth (eds.), *Signal to syntax: Bootstrapping from syntax to grammar in early acquisition*, 187–213. Mahwah, NJ: Erlbaum.

Tamminga, Meredith. 2018. Modulation of the following segment effect on English coronal stop deletion by syntactic boundaries. *Glossa* 3. 86.

Tanner, James, Morgan Sonderegger & Michael Wagner. 2017. Production planning and coronal stop deletion in spontaneous speech. *Laboratory Phonology: Journal of the Association for Laboratory Phonology* 8. 15.

Tranel, Bernard. 1981. *Concreteness in generative phonology. Evidence from French*. Berkeley: University of California Press.

Tranel, Bernard. 1987. *The sounds of French. An introduction*. Cambridge: CUP.

Tranel, Bernard. 1992. The representation of French final consonants and related issues. In Jon Amastae, Grant Goodall, Marianne Phinney & Mario Montalbetti (eds.), *Contemporary research in Romance linguistics*, 53–78. Amsterdam: Benjamins.

Tranel, Bernard. 1995a. French final consonants and non-linear phonology. *Lingua* 95. 131–167.

Tranel, Bernard. 1995b. Current issues in French phonology: Liaison and position theories. In John Goldsmith (ed.), *The handbook of phonological theory*, 798–816. Cambridge (MA): Blackwell.

Tranel, Bernard. 2000. Aspects de la phonologie du français et la théorie de l'optimalité. *Langue Française* 126. 39–72.

Tyler, Matthew. 2019. Simplifying Match Word: Evidence from English functional categories. *Glossa* 4. 15.

Wagner, Michael. 2012. Locality in phonology and production planning. *McGill Working Papers in Linguistics* 22. 1–18.

Wagner, Michael, Josiane Lachapelle & Oriana Kilbourn-Ceron. 2020. Liaison and the localiy of production planning. *Paper presented at LabPhon 7, Vancouver, July 2020*.

Wetzels, Leo. 2002. Les adjectifs pré-nominaux du français: Formes longues et formes féminines. In Haike Jacobs & Leo Wetzels (eds.), *Liber amicorum Bernard Bichakjian*, 273–306. Maastricht: Shaker Publications.