A phonetic and phonological analysis of palatalization as a trigger of sound change in the development of Vosgien

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A previous study (Chopinez, unpublished) investigated the developments of certain Vosgien (a Romance language) phonemes from Latin. This study attempts to describe these various sound changes, through a mixture of literature review, bidirectional phonological and phonetic modelling, and experimental methods. Particular attention is paid to the role of palatalization as a trigger for sound change. It is found that all Latin segments under investigation underwent assibilation, triggered by articulatory palatalization. Some segments, motivated by the retention of palatal cues, remain articulated at the palatal area, and eventually dorsalize. Certain details remain unclear as to their mechanisms, and warrant further study.

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Table of Contents

1 Introduction

The Lorrain language is an Oïl language native to eastern France and southern Belgium. Eastern varieties of the language (specifically: Vosgien) stand out for having a dorsal fricative phoneme, other than a rhotic. This phoneme corresponds with French /ʃ/, or more rarely /s/. However, French /ʃ/ and /s/ sometimes correspond with Vosgien /ʃ/ and /s/. In a previous study (Chopinez, unpublished), a comparative method was used to determine the origins of these phonemes and of their distribution. It was found that different phonological environments in Latin could predict the presence of /ʃ/, /s/, or /x/ in Vosgien words. The relevant sound changes are summarized below:

1) $O^C j \rightarrow x$ / VO_V (O^C = coronal obstruent)

2) s → x / _e

3) k → x / _jV

4) a) ka → xV / _lV^F (V^F = front vowel)
   b) ka → xV / _NV^F: (N = nasal stop)
   c) ka → ʃV / elsewhere

5) a) ska → ʃV / V_V
   b) ska → xV / elsewhere

The broad pattern is that when a coronal or dorsal obstruent is next to a palatal glide or a front vowel, the consonant evolves into /x/, while /ka/ evolves into /ʃ/ (as in French and most other Oïl varieties). Both of these patterns are linked to palatalization. When a /ka/ is followed by a sonorant and a front vowel, it evolves into /x/ and not /ʃ/, suggesting that a reinforcement of the palatal context is what differentiates the two outcomes. Likewise, when /a/ is preceded by a cluster /sk/, the cluster develops into /x/; but if /ska/ is preceded by a vowel then the /s/ is treated as a coda for a previous syllable, and the /ka/ develops into /ʃ/. That a simple palatalization causes assibilation is not to be unexpected, however for a reinforced palatal context to cancel this assibilation and cause simple frication is unexpected. In this study, phonological and phonetic modeling, alongside experimental data, will be used in order to explain how this unusual development may have occurred, and to describe the specific mechanisms involved.

Although the overall phonological development observed in Vosgien is unusual, some of the individual sound changes feature parallel developments (or sound laws, or dialectal variation) in other languages. For example, $O^{C}j \rightarrow x \ / \ VO\_V$ (1.b) has a parallel in Swedish. Swedish features a phoneme spelt ‘sj’, which is pronounced, depending on the dialect, either as [sj] [ɕ] [ç] or [ɧ] (Asu, Ewald & Schötz, 2015). This suggests an older coronal segment followed by a palatal glide, which in most dialects (with the exception of Estonian Swedish) evolved into a single palatalized segment, and in some dialects even dorsalized. A similar pattern exists in the Swedish sound spelled ‘tj’, which in Estonian Swedish is pronounced [tj], but in most other Swedish varieties is realized as a [ɕ] (Asu, Ewald & Schötz, 2015), showing that, as appears to be the case in Vosgien, this development targeted coronal obstruents as a phonological class. Although palatalization does not appear to have been involved, Assamese features a historical sound change */s/ → /x/* (Sarma & Sarma, 2014), further showing that the dorsalization of coronal sounds is an attested shift which may be modelable. If so, $s \rightarrow x \ / \ \_e$ (2) may also be modelled in the same fashion.

ka → ʃV (4c) is likewise attested, although in a more limited scope. This sound shift is common in Gallo-Romance languages, most notably in most Oïl languages (with the exception only of Picard and Norman) (Recasens, 2020). Vosgien is unsurprisingly no exception to this rule, and it can be expected that the well described mechanisms for the change in French also apply to it. However, this pattern of sound change - palatalization triggered by a low vowel - is largely unattested outside of a few Latin descended branches. This reinforces the notion that this development is the same as attested in French, as the probability that a cross-linguistically rare sound change would happen in a contextually independent manner in many closely related speech varieties is low. This, in turn, implies that the change should have happened in a manner that was not dependent on other Vosgien developments not shared with its relatives. The developments described above will be explored and modelled in detail in section 2.

ska → xV (5b) finds parallels in some West-Germanic (WG) varieties (e.g. Dutch), within which /s/ causes the frication of following /k/ (Hall, 2021). In other WG varieties (e.g. English), however, the cluster becomes /ʃ/ instead, paralleling *ska → ʃV* (5a). In some WG varieties, there are even positionally motivated differentiations in the evolution of proto-Germanic /sk/ (Hall, 2021), mirroring the discrepancy in Vosgien. However, while the evolution of Latin /ska/ could be analogized to the evolution of Germanic /sk/ when these sound changes are taken into isolation, the simultaneous palatalization of Latin /ka/ means that the factors involved in causing the shift *ka → ʃV* (5a) may also be involved in the evolution of /ska/. The fact that all of these consonantal developments occur in onset position followed by /a/ reinforces this notion. The evolution of Latin /ska/ will be explored and modelled in detail in section 3, with explicit reference to the evolution of /ka/ explored in section 2.

k → x / _jV (3) has parallels in Irish (Martinet, 1952) and Liverpool English (Watson 2007), both of which underwent a historical frication of their /k/ phoneme. However, in neither language can the shift be explained through a palatal process/context, and seems to happen to /k/ more generally (intervocalically, in the case of Irish) as opposed to the specific palatal context of the Vosgien development. However, the shift could be connected to the development of /ska/ in Vosgien, as both feature initial palatalizing contexts resulting in a frication of /k/. This development will be explored and modelled in detail in section 3.

Modelling will be conducted through a bidirectional phonetics and phonology model, through an optimality theoretic interface. This is hereby referred to as BiPhon-OT, and conducted in accordance with Boersma 2009. Two levels will be relevant for the analyses in sections 2 & 3. The phonological surface form will be represented with dashes “/ /”. Rules pertaining to its structure in Latin and Vosgien (and intermediary stages) will be represented in the form of structural constraints. The phonetic form will be represented with brackets “[ ]”. The differentiation between the auditory and articulatory forms (and the interface connecting them) is not necessary, so the phonetic form will stand in for both of these simultaneously. Articulatory factors affecting the phonetic form will be represented in the form of articulatory constraints. The interface connecting the surface and phonetic forms together will be represented in the form of cue constraints.

Given what has been discussed so far, a potential explanation for the strange patterns of development in Vosgien is that a first round of palatalization caused all relevant dorsal sounds to assibilate, as most directly exemplified by *ka → ʃV* (4c). A second round of palatalization may then have caused another shift, which ultimately resulted in a dorsalization of the segments with stronger palatal cues.

Section 2 will cover sound changes which are well attested and described in the literature. Section 3 will make use of the phonological and phonetic grammar developed in section 2, alongside a small amount of literary backing, in order to describe sound changes which are not well attested and described in the literature. Section 4 will attempt to describe sound changes which are not well supported, either by the model developed in sections 2 & 3, nor in existing linguistic literature. Section 5 will attempt to investigate the proposal made in section 4 through experimental methods. Section 6 will summarize and discuss the findings of the previous sections, and the success or lack thereof of the model developed in this study.

2 Well attested sound changes

This section will primarily cover two sound laws, *ka → ʃV* (4c) and $O^{C}j \rightarrow x \,/\, VO\_V$ (1). The mechanisms involved in these are relatively well attested and described in linguistic literature, such that it is possible to confidently extract phonetic and phonological principles and model them in the form of various ranked constraints. Section 3 will then take these ranked constraints and see whether they can successfully predict the remaining sound changes.

2.1 The assibilation of Latin /ka/

The *ka → ʃV* (4c) sound change is not well attested anywhere outside of Gallo-Romance languages. Despite this, due to the prevalence of some of these languages (most particularly French), the causes and mechanisms of the development have been extensively described and discussed in previous works. Walker (1981), among others, suggests that this phenomenon can be linked with the palatalization of /k/ before front vowels found commonly cross-linguistically, and particularly so in Romance. He argues that in early varieties of Gallo-Romance, /a/ was likely fronted such that the same mechanisms for palatalization were present. This account suggests that the vowel would later lose its frontedness, or in some cases shift to become a different vowel entirely, such that the only remaining evidence of its former quality is the prior palatalized consonant. Cox (1975) disagrees with such accounts, arguing that since fronted /a/ is both the proposed cause of palatalization, and supported exclusively by the fact that palatalization occurs, the explanation is thus circular. He further points out that the development of the vowel systems of modern Gallo-Romance tongues from Latin cannot well be explained if an intermediate stage with a fronted /a/ is assumed. Finally, he points to the fact that the palatalization of Latin /ke/ and /ki/ typically results in Gallo-Romance /se/ and /si/, whereas the palatalization Latin /ka/ results in either /ʃa/, /t͡ʃa/, or /t͡sa/ (depending on the variety), but rarely /sa/. If the palatalization of /ka/ came as a result of /a/ being fronted (and thus had the relevant phonological and phonetic properties of front vowels), then it would be expected that the development of /ka/ should mirror than of /ke/ and /ki.

Recasens (2020) agrees with Cox's criticism of the fronted /a/ explanation. He points out that the palatalization of /ka/ occurs even in environments wherein it is likely that /a/ was distinctively backed, for example when followed by /u/ (e.g. Latin 'causa' /kausa/ → French 'chose' /ʃoz/). He additionally notes that certain Gallo-Romance varieties (notably: Normano-Picard, Arpitan, northern Occitan, and certain Catalan dialects) feature fronted /a/ (modernly or historically) only after palatalized /k/, suggesting that the palatalized consonant triggered fronting and not the other way around.

Recasens (2020) offers an alternative account of the palatalization of Latin /ka/. He points out that articulatory strengthening, when applied to velar fricatives, can cause palatalization. This is because strengthening is achieved by applying greater pressure of the tongue towards the dorsum. This pressure causes the tongue to be squished more strongly against the velum, such that the point of contact is spread over a larger part of the dorsal region, bleeding into the palatal region. Thus, in attempting to articulate [k͈] (a strengthened velar plosive), something akin to a palatal plosive [c] is uttered instead. Only [k͉] (a non-strengthened velar plosive) can be realized as fully velar. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[HighVelarPressure, PreciseClosure]**. This constraint eliminates any candidate for the phonetic form which contains an articulatory strengthened velar stop with a precise velar point of closure. This articulatory mechanism, however, would suggest that either all velar stops ought to be palatalized regardless of the following vowel, or none at all, depending on whether or not a given language defaults on a strengthened articulation for its stops.

Recasens (2020) argues that velar strengthening can be blocked, however, if the tongue dorsum is involved in the production of a following vowel. If the dorsum is involved in the production of a following vowel, then it will be anticipating this role during the articulation of the velar stop, and as such applying maximal pressure with it becomes articulatorily more difficult. Since low vowels, as opposed to all other vowels, make minimal use of the tongue dorsum, they would not block velar strengthening (and the resulting palatalization), whereas other vowels would block it and thus not trigger palatalization. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[TongueDorsum, HighVelarPressure]**. This constraint eliminates any candidate for the phonetic form which contains both a vowel requiring a particular use of the tongue dorsum and an articulatory strengthened velar stop.

Recasens (2020) justifies this account by pointing out that in certain Romance varieties, word final /k/ is also systematically palatalized, without regard for any vowel segment. Such a development can only be explained through the strengthening phenomenon described above, and gives credence to the notion that this is also why /ka/ can undergo palatalization. The only remaining factor to consider is what determines whether or not a given language prefers its velar stops to be strengthened. This can be described as a language-specific account of which cues are associated with velar stops. If a language associates /k/ with a relatively high acoustic intensity, then it may mandate that /k/ be articulated as [k͈] rather than [k͉], whenever possible. If a language makes no such association, then it may be fine with [k͉] as the default realization of /k/. This can also be contextually specified, such that /kV/ is associated with high intensity, but not /k#/, thus explaining why certain Romance varieties palatalize word-final /k/ whereas others (such as Vosgien) do not. This correspondence between certain phonological segments and particular acoustic cues can be encoded in BiPhon-OT with the cue constraint ***/kV/[lowIntensity]**. This constraint eliminates any candidate for the phonetic form which contains a low intensity [k͉], if the corresponding /k/ in the surface form input is followed by a vowel. It also eliminates any candidate for the surface form which contains /kV/, if the corresponding [k] in the phonetic form has low intensity.

These constraints are put to test in tableaus 1 through 3. An additional positively formulated cue constraint is added: **/velar/[velar]**[1]. This constraint mandates the association of a velar phonological segment with cues emerging from a sound articulated at the velum area, whether that be in perception or production. Although the constraint does not have any direct effect on the outcome of the tableaus, it serves instead to illustrate the fact that an input /k/ can only have as its optimal candidate [c] as a result of the other factors described above (represented as the 3 more highly ranked constraints), and that this phenomenon could thus not exist as a random occurrence.

/ka/	***[TongueDorsum, HighVelarPressure]**	***[HighVelarPressure, PreciseClosure]**	***/kV/ [lowIntensity]**	**/Velar/ [velar]**
[k͉a]			*!	
[k͈a]		*!		
☞[ca]				*

Tableau 1: /ka/→[ca]

[1] BiPhon-OT typically makes use only of negatively formulated constraints. For the purposes of this analysis, positively formulated constraints are also used, which can be thought of as the amalgamation of several negatively formulated constraints.

In tableau 1, ***[TongueDorsum, HighVelarPressure]** does not eliminate any candidate, since none of the candidates contain a vowel which requires a particular use of the tongue dorsum. Strengthened [k͈] is eliminated first due to its articulatory difficulty. Non-strengthened [k͉] is eliminated second, due to its failing to correspond to the association of /kV/ with high intensity. This leaves [ca] as the optimal candidate. This is because the lack of correspondence between palatal acoustic cues and phonologically velar segments is regarded as less problematic than the non-correspondence between low intensity cues and phonologically prevocalic velar segments, and fulfilling either correspondence is treated as secondary to articulatory ease.

/ku/	***[TongueDorsum, HighVelarPressure]**	***[HighVelarPressure, PreciseClosure]**	***/kV/ [lowIntensity]**	**/Velar/ [velar]**
☞[k͉u]			*	
[k͈u]	*!	*		
[cu]	*!			*

Tableau 2: /ku/→[k͉u]

/ke/	***[TongueDorsum, HighVelarPressure]**	***[HighVelarPressure, PreciseClosure]**	***/kV/ [lowIntensity]**	**/Velar/ [velar]**
☞[k͉e]			*	
[k͈e]	*!	*		
[ce]	*!			*

Tableau 3: /ke/→[k͉e]

In tableaus 2 & 3, ***[TongueDorsum, HighVelarPressure]** eliminates both [k͈e]/[k͈u] and [ce]/[cu]. The reason it eliminates [k͈e] and [k͈u] is clear, since these feature simultaneously a vowel involving the tongue dorsum and a high amount of velar pressure. Since [ce] and [cu] result from an attempt at applying high pressure in the velar region, they are also eliminated despite not being strictly velar in their articulation. Since articulatory ease is considered to be more important than the association of surface form /k/ with high acoustic intensity (in this early Romance variety, at least), [k͉e] and [k͉u] are thus the most optimal candidates for /ke/ and /ku/.

The tableaus above thus show how phonological rules and phonetic principles can be encoded as ranked constraints in BiPhon-OT to model real sound changes. Of course, the analysis is as of yet incomplete, since Latin /ka/ does not become Vosgien /ca/, but rather /ʃV/. Recasens (2020) argues for /ca/ as an intermediary stage in a multi-step process, viewing the sound change *ka → ʃV* (4c) as resulting from the accumulation of several successive sound changes. The full process is argued to be palatalization (/ka/ → /ca/), then assibilation (/ca/ → /t͡ʃa/), then fricatization (/t͡ʃa/ → /ʃa/).

Recasens (2020) shows that tongue placement for palatal segments is varied and unstable, such that there is typically an extended zone of contact between the tongue and hard palate. Upon the burst, the release is then not instant but gradual as different points of the tongue body each release in imperfect coordination, creating a period of frication between start of release and full release. Thus, this articulatory mechanism causes palatal stops to frequently be articulated as affricates. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[Palatal, PreciseClosure]**. This constraint eliminates any candidate for the phonetic form which contains both a palatal obstruent and a highly precise place of articulation. This includes eliminating any candidate containing a palatal stop. The full effect of this constraint goes beyond palatal stops, this will be explored in section 2.2. As seen in the initial palatalization of /ka/, imprecise closure can result in a change in place of articulation, such that [ta] or [ka] could in principle be the outcome of /ca/, rather than [t͡ʃa].

Correspondences between segments and cues can be used to explain why one of these outcomes is the one which occurs. First, /c/ should be associated with the cues that are produced by articulating at and around the hard palate, notably the raising of the second formant at the transition period between the palatal phone and surrounding phones. This correspondence between palatal segments and a raised F2 can be encoded in BiPhon-OT with the constraint **/Palatal/[HighF2]** (Ladefoged, 2012). This constraint eliminates any candidate for the phonetic form which does not contain a high F2 transition cue, if the corresponding segment in the surface form input is palatal. It also eliminates any candidate for the surface form which does not contain a palatal segment, if the corresponding phone in the phonetic form contains a raised F2 transition cue. Second, /c/ should be associated with the cues that are produced when articulating a stop consonant. Specifically, it should contain a burst, but no frication. This second non-correspondence can be encoded in BiPhon-OT with the constraint ***/stop/[frication]**. This constraint eliminates any candidate for the phonetic form which contains frication, if the corresponding segment in the surface input is a stop. It also eliminates any candidate for the surface form which contains a stop segment, if the corresponding phone in the phonetic form contains frication. These constraints are put to test in tableau 4.

/ca/	***[Palatal, PreciseClosure]**	**/Palatal/[HighF2]**	***/stop/[frication]**
[ca]	*!		
[ka]		**!	
[ta]		**!	
☞[t͡ʃa]		*	*

Tableau 4: /ca/→[t͡ʃa]

In tableau 4, ***[Palatal, PreciseClosure]** must be the highest ranked constraint, to represent the difficulty of precisely articulating [ca], and the fact that a speaker must articulate a different (albeit similar) phone. If this articulatory constraint is not ranked above the cue constraints, then [ca] would be the optimal candidate, matching most correctly the cues associated with /ca/. It is less evident that **/Palatal/[HighF2]** should be ranked higher than ***/stop/[frication]**, since both of these represent the association of surface form /c/ with the cues realized during its production. However, following Recasens (2020)'s analysis, it is reasonable to assume that retaining palatal cues is treated as more important than the absence of frication. The postalveolarly articulated form [t͡ʃa] violates **/Palatal/[HighF2]**, since its F2 is not as high as that of patataly articulated phones, but higher than that of velarly or dentoalveolarly articulated phones (Ladefoged, 2012).

The final step in Recasens (2020)'s analysis, frication of an affricate, is cross-linguistically common (Bybee & Easterday, 2019). Recasens (2002) argues that aerodynamic simplicity is the source of this. The burst of an affricate requires more intensity and a more strongly disrupted airflow, all of which requires greater articulatory effort. Eliminating the burst and its preceding closure thus renders the sound easier to articulate. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[burstEffort]**. This constraint eliminates any candidate for the phonetic form which contains a burst.

Cue associations can be made for affricates, in order to render the analysis complete. Affricate segments are associated with frication. This correspondence can be encoded in BiPhon-OT with the constraint **/affricate/[Frication]**. This constraint eliminates any candidate for the phonetic form which does not contain frication, if the corresponding segment in the surface form input is an affricate. It also eliminates any candidate for the surface form which is not an affricate, if the corresponding segment in the phonetic form is not an affricate. Affricate segments are also associated with the presence of a burst. This correspondence can be encoded in BiPhon-OT with the constraint **/affricate/[Burst]**. This constraint eliminates any candidate for the phonetic form which does not contain a burst, if the corresponding segment in the surface form input is an affricate. It also eliminates any candidate for the surface form which is not an affricate, if the corresponding segment in the phonetic form is not a burst. These constraints are put to test in tableau 5.

/t͡ʃa/	***[burstEffort]**	**/affricate/[Frication]**	**/affricate/[Burst]**
[t͡ʃa]	*!		
[ta]	*!	*	
☞[ʃa]			*

Tableau 5: /t͡ʃa/→[ʃa]

In tableau 5, ***[burstEffort]** must be the highest ranked constraint, so that stop and affricate candidates are eliminated and only frication can occur. If the cue constraints were more highly ranked, that would mean that the affricate status would take precedence over articulatory ease, as can be observed in Walloon (a close relative of Vosgien). The cue constraints do not have a particular internal ordering that is discernible on the basis of this analysis.

2.2 The dorsalization of Latin palatalized coronals

Although not directly attested, cross-linguistic evidence for $O^{C}j \rightarrow x\ /\ VO\_V$ (1) can be found in Swedish, in which the segment spelled 'sj' can be realized as [sj], [ç], [ɕ] or [ɧ], depending on the dialect; and in which the segment spelled 'tj' can be realized as [tj] or [ɕ], also depending on the dialect. This suggests, at the very least, a connection between coronal obstruents followed by a palatal glide, palatal fricatives, and dorsal fricatives. Given the spelling, it can be hypothesized that the [sj] and [tj] realizations were the historic norm, before certain dialects (all except for Estonian Swedish) underwent palatalization, and in some cases dorsalization (Asu, Ewald, Schötz, 2015). No example nor analysis could be found showing a direct shift from coronal to dorsal (or vice-versa), however analyses do exist presenting an indirect shift with an intermediate palatal stage. This is particularly common in various Romance varieties (Recasens, 2020).

The palatalization of coronal obstruents in presence of a front vocoid is well attested cross-linguistically, including multiple independent examples in most Indo-European branches (Recasens, 2020). Bateman (2007) and Recasens (2020) both give an articulatory account of this phenomenon. The successive articulation at two entirely distinct places can be difficult, as it requires a rapid and drastic movement of the tongue. However, since anterior coronal and (pre-)palatal sounds make use of different parts of the tongue, coarticulation, wherein there is simultaneousness in the articulation of two segments, is possible. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[RapidTongueMovement]**. This constraint eliminates any candidate for the phonetic form which contains distinctly articulated phones one after the other with overly different tongue placement. In some cases, coarticulation can cause the tongue to be preemptively moved posteriorly, such that the place of release is between the anterior coronal and palatal regions, and the movement's (partial) simultaneousness with the release causes frication. This results in /sj/ → [ʃ] and /tj/ → [t͡ʃa] (Bateman, 2007). This outcome can be ruled out, however, since this would predict a merger with palatalized Latin /ka/.

Recasens (2020) describes another similar mechanism, with a slightly different end point. Instead of dragging the tongue backwards, coarticulation takes the form of positioning the tongue at both places of articulation simultaneously. Since the distance between the alveolar ridge and the hard palate is not more than the distance between the tongue tip and the anterior tongue body, dual-place articulation is possible. This position is awkward for the tongue, however, as it is difficult to press with the tongue tip hard enough to articulate an obstruent, while the tongue body hovers at a slightly greater distance from the palate to articulate a glide. As a result, there is a tendency for the pressure applied with the tongue to be generalized to both places of articulation, resulting in a alveolo-palatal fricative or affricate, [ɕ] or [t͡ɕ]. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[coronalContact, palatalApproximation]**. This constraint eliminates any candidate for the phonetic form which contains a coronal obstruent with a secondary palatal articulation.

As with the sound changes described in section 2.1, it is important to consider and account for the relevant cues associated with the segments under analysis. The constraint **/Palatal/[HighF2]** proposed in section 2.1 is relevant here, to account for the cues (raised F2 in transition with neighboring phones) associated with /j/. A similar association can be made between dentoalveolar obstruent segments and the cues produced by dentoalveolar articulation, namely the presence of a high spectral center of gravity (Ladefoged, 2012; Boersma & Hamann, 2008). This association can be encoded in BiPhon-OT with the constraint **/Dentoalveolar/[HighCoG]**. This constraint eliminates any candidate for the phonetic form which does not contain a high center of gravity, if the corresponding segment in the surface form input is dentoalveolar. It also eliminates any candidate for the surface form which is not dentoalveolar, if the corresponding segment in the phonetic form contains a high center of gravity.

These constraints are put to test in tableaus 6 through 8. An additional constraint is added: **/twoSegments/[cueTransition]**. This constraint mandates the association of two phonological segments with two sets of cues separated (or linked) by a transitional period, whether that be in perception or production. Although the constraint does not have any direct effect on the outcome of the tableaus, it serves instead to illustrate the fact that a phonological input in production containing two segments can only have as its optimal candidate a single phone as a result of the tendency towards coarticulation in the particular context described above (represented as the more highly ranked ***[RapidTongueMovement]** constraint).

/sj/	***[RapidTongue Movement]**	***[coronalContact, palatalApproximation]**	**/palatal/ [HighF2]**	**/dentoalveolar/ [HighCoG]**	**/twoSegments/ [cueTransition]**
[sj]	*!				
[sʲ]		*!			*
[sʃ]	*!				
[s]			**!		*
☞[ɕ]				*	*
[ʃ]			*!	**	*

Tableau 6: /sj/→[ɕ]

In all three tableaus, the necessary ordering is that the articulatory constraints be ranked higher than the cue constraints, and that the cue constraint **/Palatal/[HighF2]** be ranked above **/Dentoalveolar/[HighCoG]**. The constraint ***[RapidTongueMovement]** prevents both forms in tableau 6 containing two distinct articulatory movements. Its role as the initial trigger of sound change is reflected in the fact that, without it, [sj] would be the optimal candidate for tableau 6. The constraint ***[coronalContact, palatalApproximation]** prevents the use of [sʲ] as a repair strategy, forcing the outcome to be a plain sibilant. Since [ɕ], as a result of its articulation with the tongue body against the hard palatal, is the only one of these to feature a fully raised F2 in its transitional cues, it does not get eliminated. **/Dentoalveolar/[HighCoG]** does not play a role in tableau 6, nor in tableau 7, however its role becomes evident in tableau 8.

/tj/	*[RapidTongue Movement]	*[coronalContact, palatalApproximation]	/palatal/ [HighF2]	/dentoalveolar/ [HighCoG]	/twoSegments/ [cueTransition]
[tj]	*!				
[tʲ]		*!			*
[t]			**!		*
☞[t͡ɕ]				*	*
[t͡ʃ]			*!	**	*

Tableau 7: /tj/→[t͡ɕ]

/se/	*[RapidTongue Movement]	*[coronalContact, palatalApproximation]	/palatal/ [HighF2]	/dentoalveolar/ [HighCoG]	/twoSegments/ [cueTransition]
[se]	*!				
[sʲe]		*!			
[sʃe]	*!				
☞[ɕe]				*	
[ʃe]				**!	

Tableau 8: /se/→[ɕe]

Tableau 8 differs somewhat from tableaus 6 & 7, in that its input does not contain /j/. However, since [e] requires a similar tongue positioning as [j], ***[RapidTongueMovement]** has the same effect, eliminating [se]. Since the articulatory constraints eliminate most candidates, the only other potential candidate evaluated by cue constraints is [ʃe], which violates **/Dentoalveolar/[highCoG]** (the only relevant cue constraint in the tableau) more strongly than [ɕe], since the CoG of [ɕ] is somewhere between that of [ʃ] and [s] (Boersma & Hamann, 2008). Importantly, this tableau shows that s → x / _e (2) can be explained through the same mechanisms and ranked constraints as $O^{C}j \rightarrow x\ /\ VO\_V$ (1).

Latin /tj/ /sj/ and /se/ all become Vosgien /x/, meaning the obstruents should merge at some point in their development, however two outcomes are found in tableaus 6 through 8: [ɕ] and [t͡ɕ]. In section 2.1, de-affricatization was shown with /t͡ʃa/ → /ʃa/, in tableau 5. When putting

/t͡ɕ/ through the same ranked constraints as in tableau 5, the same effect occurs. This is shown in tableau 9.

/t͡ɕ/	*[burstEffort]	/affricate/[Frication]	/affricate/[Burst]
[t͡ɕ]	*!		
[t]	*!	*	
☞[ɕ]			*

Tableau 9: /t͡ɕ/→[ɕ]

Now that the palatalization of alveolar obstruents (in certain phonological contexts) has been explained and modeled, the next step in this analysis is the dorsalization of /ɕ/. This process is not well described in existing literature, however simple attested principles can be combined to derive a solution. First, articulatory ease can be used to motivate sound change. [ɕ] is articulated at two places simultaneously, requiring a greater tongue effort to realize as compared to phones articulated as a single place only. Much like with the processes represented by ***[RapidTongueMovement]** and ***[coronalContact, palatalApproximation]**, seeking greater articulatory ease is an important trigger of sound changes both cross-linguistically, and in the development of Vosgien specifically. It can therefore be proposed that articulatory ease led to an attempt as articulating phonological /ɕ/ at a single place. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[MultipleClosurePoints]**. This constraint eliminates any candidate for the phonetic form which contains more than one place of obstructed articulation.

Second, cue constraints can be used to highlight which cues are associated with /ɕ/, to see which sounds best match with it. There are two important cues not yet introduced, associated with alveolopalatal fricatives, as described by Shadle (1989). The first of these is the higher intensity associated with fricatives produced by directing the post-obstruction air-stream into an oral obstacle. Fricatives with these phonetic features are typically classified phonologically under the category 'sibilant'. This correspondence between certain phonological segments and particular acoustic cues can be encoded in BiPhon-OT with the constraint **/sibilant/[highIntensity]**. This constraint eliminates any candidate for the phonetic form which does not have high intensity, if the corresponding segment in the surface form input is a sibilant. It also eliminates any candidate for the surface form which is not a sibilant, if the corresponding phone in the phonetic form has high intensity. The second of these is the well defined spectral peak associated with fricatives produced by placing the tongue in a wall-like position such that air must rise above it in order to reach the place of obstruction. Fricatives with these phonetic features are classified phonologically, for the sake of this study, under the category ‘palatodorsal’. This correspondence between certain phonological segments and particular acoustic cues can be encoded in BiPhon-OT with the constraint **/palatodorsal/[DefinedPeak]**. This constraint eliminates any candidate for the phonetic form which does not have a well defined spectral peak, if the corresponding segment in the surface form input is a palatal or dorsal fricative. It also eliminates any candidate for the surface form which is not a palatal or dorsal fricative, if the corresponding phone in the phonetic form has a well defined spectral peak. These constraints are shown in tableau 10.

/ɕ/	***[multipleContactPoints]**	**/palatodorsal/[DefinedPeak]**	**/sibilant/[highIntensity]**
[ɕ]	*!	*	*
☞[ç]			**
[ʃ]		**!	
[s]		**!	

Tableau 10: /ɕ/→[ç]

In tableau 10, **/palatodorsal/[DefinedPeak]** is ranked higher than **/sibilant/[highIntensity]**. This represents the prioritizing of palataodorsal cues over sibilant cues, and causes [ç] to be selected as the optimal candidate, despite not being a sibilant, over [s] or [ʃ] which are sibilants but are not palatal nor dorsal. Since the cues referred to by these constraints are linked to mutually exclusive places of articulation, it is not possible for a phone which is not articulated at multiple points simultaneously to feature both cues (or, more specifically, intermediary cues). Thus, as a result of the most highly ranked articulatory constraint, one cue or the other must necessarily be lost in the final output.

The process of dorsalization is as of this point not complete, however. /ç/ backing to /x/ can be explained using mechanisms described in section 2.1: the articulatory instability of palatal sounds. Articulatory instability, as described by Recasens (2020), makes it difficult for palatal obstruents to be systematically articulated at a precise place of articulation. Instead, the tongue is spread over a broader area of closure, which may not average at an ideal palatal placement, and which may therefore be slightly dorsal or slightly coronal instead. This is represented by the previously introduced articulatory constraint ***[Palatal, PreciseClosure]**. Given the cue preference proposed just above, a tendency towards the slightly dorsal may be preferred. This is shown in tableau 11.

/ç/	***[Palatal, PreciseClosure]**	**/palatodorsal/[DefinedPeak]**	**/sibilant/[highIntensity]**
[ç]	*!		
[ʃ]		*!	
☞[x]			

Tableau 11: /ç/→[x]

2.3 Summary of the current phonological and phonetic grammar

Figure 1 is a map of the ranking between all constraints introduced so far. Upward constraints outrank downward constraints with which they are linked. Brackets separate groups of constraints which have no set ranking in relation to one another. No set ranking does not mean that a full phonological and phonetic grammar of Latin or Vosgien (or any intermediary form) would not feature a defined ranking, but rather that no ranking can be established on the basis of the analysis performed in section 2 of this study.

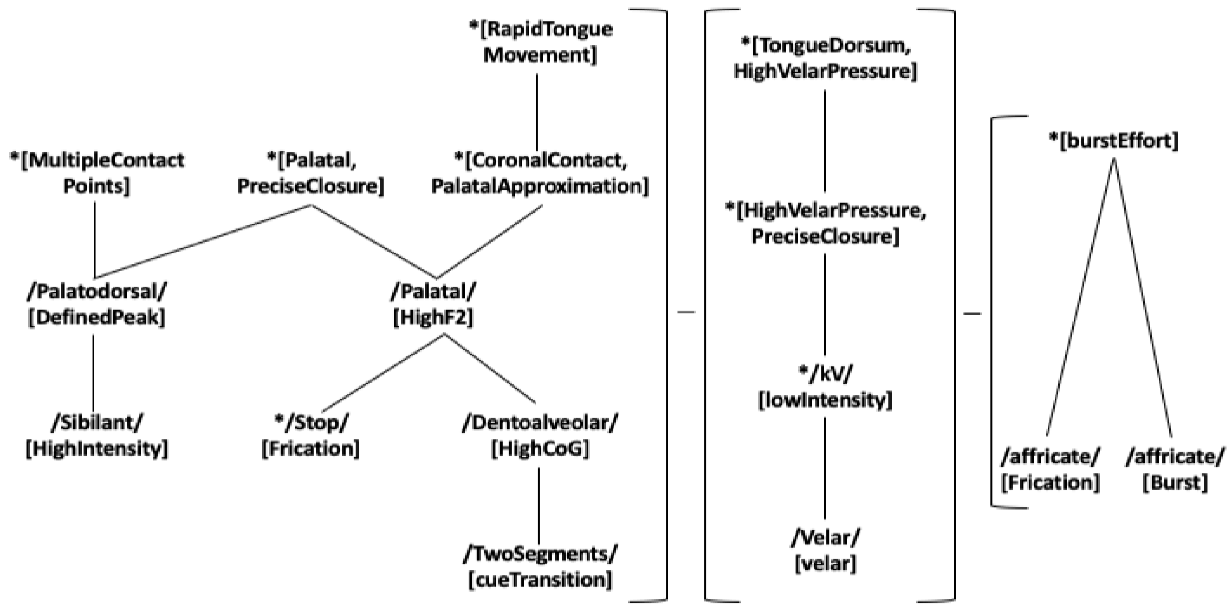

Figure 1: Summary of the constraints and ranking thereof, in the phonological and phonetic grammar introduced in section 2

3 Poorly supported sound changes

This section will primarily cover three sound laws, *ska → ʃV / V_V* (6a), *ska → xV* (6b), and *k → x / _jV* (7). The mechanisms involved in these are not as well attested and described in linguistic literature as compared to the sound laws covered in section 2. However, the BiPhon-OT grammar presented in section 2 may be used, with the aid of a few additional phonological and phonetic principles described in linguistic literature, to describe and model the sound laws which will be explored in this section. This additionally serves as a test for the analysis already done. Since the rules shown in (6) and (7) occur in the same language as (1) (2) and (3c) (described in section 2), the phonological and phonetic system presented above should not predict incorrect sound changes, and should be able to (when supported by additional principles which had not been relevant previously) predict the relevant sound changes correctly.

3.1 The split in Latin /ska/

ska → xV (5b) and *ska → ʃV* (5a) are attested cross-linguistically, both being found in different West-Germanic varieties (such as Dutch and English, respectively) (Hall, 2021). However, it differs from them by its vowel specificity. Indeed, WG features these sound changes for any /sk/ cluster, not only when followed by /a/. In the development of Latin into Vosgien, however, /sk/ without /a/ does not undergo such a change, meaning that /a/ is a trigger for the sound change. This suggests that the mechanisms responsible for causing *ka → ʃV* (4c) may also be responsible for the particular development of Latin /ska/ into Vosgien. This possibility is logical, since, as explained above, the same phonological and phonetic grammar which developed in section 2 should be capable of adequately describing the development explored in this subsection. To see if this is the case, the ranked constraints used in tableaus 1-3 (which describe the first step in the development of /ka/) can be used in a tableau with input /ska/. This is done in tableau 12. Since *ska → xV* (5b) applies by default, regardless of surrounding phonological context, it will be explored first. After, it will be investigated how the presence of a vowel prior to the cluster leads to a different outcome in ska → ʃV / V_V (6a).

/ska/	***[HighVelarPressure, PreciseClosure]**	***/kV/[lowIntensity]**	**/Velar/[velar]**
[sk͉a]		*!	
[sk͈a]	*!		
☞[sca]			*

Tableau 12: /ska/→[sca]

Tableau 12 behaves identically to tableau 1. The constraints predict that /k/, when followed by /a/, becomes realized as [c]. The function of the constraints is not impacted by the presence of /s/ in the surface form nor of [s] in the candidates. This same method can be employed for the next step in the analysis, mirroring tableau 4. This is shown in tableau 13.

/sca/	*[Palatal, PreciseClosure]	/Palatal/[HighF2]	*/stop/[frication]
[sca]	*!		
[ska]		**!	
[sta]		**!	
☞[st͡ʃa]		*	*

Tableau 13: /sca/→[st͡ʃa]

As in tableau 12 with tableau 1, tableau 13 behaves identically to tableau 4, successfully modelling the affricatization of /c/ as a result of articulatory instability, and the prioritizing of place cues over manner cues. As in tableau 12, the presence of /s/ in the surface form and of [s] in the candidate does not affect the effect of the ranked constraints. However, it is evident that an identical development cannot continue, as this would predict a merger of Latin /ska/ and /ka/ in all conditions, which is not what can be observed to have happened in the evolution of Vosgien.

This issue can be resolved by observing that [st͡ʃa] is in discordance with a principle established in section 2.2. As explained by Bateman (2007) and Recasens (2020), rapid movement of the tongue between overly distinct positionings can lead to coarticulation, wherein two distinct segments are realized as one single segment with phonetic properties of both. This articulatory factor is encoded in BiPhon-OT with the constraint ***[RapidTongueMovement]**. This constraint, when dealing with an input /st͡ʃa/, should predict coarticulation of the two consonantal segments. The cue constraint **/twoSegments/[cueTransition]**, demanding that the segments be produced distinctly but failing to have effect due to a lower ranking, can also be included in this analysis. Other cue constraints must be invoked, as to specify the cue requirements for each of the phonological segments. First, **/Dentoalveolar/[HighCoG]** can be used to represent the cue correspondences of /s/. /t͡ʃ/, however, is associated with a low spectral center of gravity, as compared to /s/ (Ladefoged, 2012; Boersma & Hamann, 2008). This can be encoded in BiPhon-OT with the cue constraint **/Postalveolar/[LowCoG]**. This constraint eliminates any candidate for the phonetic form which does not contain a low center of gravity, if the corresponding segment in the surface form input is postalveolar. It also eliminates any candidate for the surface form which is not postalveolar, if the corresponding segment in the phonetic form contains a low center of gravity. This constraint, while new, is based on the cue to segment correspondences described in section 2.2. In tableaus 6 through 8, the constraint **/Dentoalveolar/[HighCoG]** was violated singularly by [ɕ] and doubly by [ʃ], and this was explained by the fact that dentoalveolar articulation produces a high spectral center of gravity, alveolopalatal articulation produces a medium spectral center of gravity, and postalveolar articulation produces a low spectral center of gravity. This last cue to segment correspondence is the one now being formalized with the constraint **/Postalveolar/[LowCoG]**.

One final cue constraint is to be used for this next step in development, **/affricate/[Burst]**. This mandates that the affricate segment must not become a fricative. Its use does not affect the outcome of this current step in the analysis, however its importance will become evident when examining ska → ʃV / V_V (6a), later in this subsection. All of these constraints are brought together with the same rankings specified in section 2.3, in tableau 14.

/st͡ʃa/	***[RapidTongue Movement]**	**/postalveolar/ [LowCoG]**	**/dentoalveolar/ [HighCoG]**	***/twoSegments/ [cueTransition]**	**/affricate/ [Burst]**
[st͡ʃa]	*!				
[sʃa]	*!				*
[t͡ʃa]			**!	*	
[sta]		**!			
☞[t͡ɕa]		*	*	*	

Tableau 14: /st͡ʃa/→[t͡ɕa]

Tableau 14 functions similarly to tableaus 6 through 8. The articulatory constraint eliminates the two most faithful candidates, such that only an affricate, or two segments articulated dentoalveolarly, are possible candidates. The following two cue constraints determine the optimal candidate. It is important that these are equally ranked. Since [st] contains a high spectral center of gravity, and [t͡ʃ] contains a low spectral center of gravity, each satisfies its respective cue constraint but strongly violates the other. Although [t͡ɕ] does not contain standard cues for either place of articulation, it approximates either cue types more closely than [st] does for postalveolar cues and [t͡ʃ] for dentoalveolar cues. This is represented by assigning two violations for a full non-correspondence, and assigning one violation for a partial correspondence. Although an ordering is necessary in the visual presentation of the tableau, these two constraints should be regarded as applying at the same time, each simultaneously eliminating the least optimal candidate (the one with the most violations), such that [t͡ɕ] is the only remaining candidate before either constraint can eliminate it in favor of the candidate that does not violate it at all. Thus, [t͡ɕ] is the optimal candidate because it violates the cue constraints to a lesser degree than [st] and [t͡ʃ], and candidates better matching the surface form in terms of cue structure are eliminated earlier due to articulatory pressures.

Crucially, Latin /ska/ has at this stage merged with Latin /sja/ and /tja/, as is known to happen in the development of Vosgien. Thus, the phonological and phonetic principles established in section 2 appropriately model the development of /ska/. The next step, deaffricatization, is identical to what has been shown in both sections 2.1 and 2.2. This is shown in tableau 15.

/t͡ɕa/	***[burstEffort]**	**/affricate/[Frication]**	**/affricate/[Burst]**
[t͡ɕa]	*!		
[ta]	*!	*	
☞[ɕa]			*

Tableau 15: /t͡ɕa/→[ɕa]

Then, dorsalization also happens identically as to what has been shown in section 2.2. This is shown in tableaus 16 & 17.

/ɕa/	***[multipleContactPoints]**	**/palatodorsal/[DefinedPeak]**	**/sibilant/[highIntensity]**
[ɕa]	*!	*	*
☞[ça]			**
[ʃa]		**!	
[sa]		**!	

Tableau 16: /ɕa/→[ça]

/ça/	***[Palatal, PreciseClosure]**	**/palatodorsal/[DefinedPeak]**	**/sibilant/[highIntensity]**
[ça]	*!		
[ʃa]		*!	
☞[xa]			

Tableau 17: /ça/→[xa]

Thus, *ska → xV* (5b) can be explained and modelled purely on the basis of the analysis and modelling conducted for other sound laws in section 2. The next part of this section is to show why, when preceded by a vowel, the outcome of Latin /ska/ is not dorsal but postalveolar. As explained above, the tableaus used in section 2.1, when applied to /ska/, predict the same palatalization as with Latin /ka/. This applies here too, as shown in tableaus 18 & 19.

/Vs.ka/	***[HighVelarPressure, PreciseClosure]**	***/kV/[lowIntensity]**	**/Velar/[velar]**
[Vsk͉a]		*!	
[Vsk̤a]	*!		
☞[Vsca]			*

Tableau 18: /Vs.ka/→[Vsca]

/Vs.ca/	***[Palatal, PreciseClosure]**	**/Palatal/[HighF2]**	***/stop/[frication]**
[Vsca]	*!		
[Vska]		**!	
[Vsta]		**!	
☞[Vst͡ʃa]		*	*

Tableau 19: /Vs.ca/→[Vst͡ʃa]

The following step is where the two phonological contexts develop distinctly from one another. For Latin /ska/, when not preceded by a vowel, coarticulation was the source of the differentiation from /ka/, and of the merger with /tja/ and /sja/. ska → ʃV / V_V (6a), therefore, could be explain if it is assumed that the previous vowel prevent coarticulation. This is possible, since coarticulation is the result of two phones with overly distinct articulatory movements being articulated in rapid succession. Cheng & Zhang (2015) provide evidence that syllabic position (onset, coda, or nucleus) has an effect on certain phonetic details of consonants. Specifically, they note that a vowel phone preceding a consonant may help the consonant be more distinctly emphasized. This could possibly cause a slower transition between [s] and [t͡ʃ]. If this is the case, then the articulatory constraint ***[RapidTongueMovement]** would no longer have an effect, as it specifically prohibits complex tongue movements occurring too quickly, but not the same movement occurring at a slower speed. If this is the case, then the next step in the analysis would look as shown in tableau 20.

/V.st͡ʃa/	***[RapidTongue Movement]**	**/postalveolar/ [LowCoG]**	**/dentoalveolar/ [HighCoG]**	***/twoSegments/ [cueTransition]**	**/affricate/ [Burst]**
☞[Vst͡ʃa]					
[Vsʃa]					*!
[Vt͡ʃa]			**!	*	
[Vsta]		**!			
[Vt͡ɕa]		*	*	*	

Tableau 20: /s.t͡ʃa/→[st͡ʃa]

In tableau 20, the syllable boundary causes the outcome to be entirely different, as the first two candidates are not eliminated at the start. The candidates which competed in tableau 14 are now all eliminated by the top two cue constraints. Whereas before the least problematic of these was found to be the optimal candidate, now the imperfectness of these candidates causes them all to be eliminated. The cue constraint **/affricate/[Burst]** prevents deaffrication from occurring at this stage, and thus [Vst͡ʃa] is preserved as the optimal candidate. Thus, the same constraints causing /st͡ʃa/→[t͡ɕa] do not cause any sound change when a vowel segment is present before /s/. As with all sound changes explored so far, deaffricatization is then caused by the valuing of articulatory ease over correct cue correspondence. This is shown in tableau 21.

/Vs.t͡ʃa/	***[burstEffort]**	**/affricate/[Frication]**	**/affricate/[Burst]**
[Vst͡ʃa]	*!		
[Vsta]	*!	*	
☞[Vsʃa]			*

Tableau 21: /Vs.t͡ʃa/→[Vsʃa]

Again, the grammar developed in section 2 (and elaborated upon in section 3) predicts other developments in Vosgien. This shows that there is indeed a consistent process of sound change, which implicated a number of phonological contexts in Latin, such that the particular direction of development towards Vosgien can be observed.

3.2 The frication of Latin /kj/

The fricatization of /k/, as seen in $k \rightarrow x$ / _jV (3), is attested cross-linguistically, for example in Irish (Martinet, 1952) and Liverpool English (Watson 2007). However, the sound change in the development of Vosgien from Latin is specifically found before /j/, which is far less well attested. Better attested is the assibilation of /k/ in front of a front vocoid (/i/, /e/, /j/), which can be found in all Latin varieties other than Sardinian, certain Mayan varieties, certain Bantu and Dravidian languages, and English (Recasens, 2020; Hall, 2021), among others.

Recasens (2020) describes the mechanism for this development. The cause, he argues, is coarticulation. Due to the palatal articulation of [j] (as well as [i] and [e]), it is complicated to articulate a velar stop followed, in quick succession, by the vowel. This is the same process described in section 2.2 and 3.1, encoded in BiPhon-OT by the constraint ***[RapidTongueMovement]**. In this case however, this articulatory process does not necessarily lead to a merger of two phones, but simply in a change in the place of articulation of the stop segment, such that /k/ is realized as [c]. This intermediary step in the assibilation of velar stops is the same as described in sections 2.1 and 3.1. Hall (1997) explains that it is not possible for palatal consonant segments to be secondarily palatalized, and shows that /cj/ (among other combinations) is cross-linguistically rare. This is because it is not possible not to have the tongue body raised towards the hard palate while articulating a palatal consonant, and it is not possible to avoid a fluid movement of the tongue away from the hard palate when transitioning from articulating a palatal consonant to articulating a vowel. This would suggest that /kj/ becomes /c/, rather than /cj/. This articulatory phenomenon can be encoded in BiPhon-OT with the constraint ***[Palatal + j]**. This constraint eliminates any candidate for the phonetic form which contains a palatal consonant followed by [j].

However, this would predict a merger with Latin /ka/, such that Latin /kj/ should become Vosgien /ʃ/. It is thus necessary to assume that this intermediate stage was in fact /cj/. Although this is rare, if a phonological grammar insists on the presence of cues associated specifically with a distinctively articulated [j] phone, [c] and [j] may remain distinctly articulated segments. This insistence can be encoded in BiPhon-OT with the constraint ***/j/[Ø]**. This constraint eliminates any candidate for the phonetic form which does not contain a time window with cues produced specifically by [j], if the surface form input contains a segment /j/. It also eliminates any candidate for the surface form which contains /j/, if the corresponding phonetic form input does not feature matching cues in a distinct time window. If ***/j/[Ø]** outranks ***[Palatal + j]**, the outcome would be to preserve [j] even after [c]. These ranked constraints are shown in tableau 22.

/kjV/	***[RapidTongueMovement]**	***/j/[Ø]**	***[Palatal + j]**
[kjV]	*!		
☞[cjV]			*
[cV]		*!	

Tableau 22: /kjV/→[cjV]

In tableau 22, the rapid tongue movement of [kjV] eliminates it as a viable candidate, despite the fact that it otherwise would have been the optimal candidate. ***/j/[Ø]** outranking ***[Palatal + j]** represents the fact that the grammar prefers, in this particular instance, adherence to the cues which are expected to be produced as a result of the surface form, over articulatory ease.

The next step, in accordance with Recasens (2020)'s analysis, is the affricatization of /c/. This process happens nearly identically to what has been shown in sections 2.1 and 3.1, and all of the constraints employed earlier are employed here. However, the newly created constraints ***/j/[Ø]** and ***[Palatal + j]** are also present, as to ensure the continued preservation of [j]. This is shown in tableau 23.

/cjV/	***[Palatal, PreciseClosure]**	**/Palatal/[HighF2]**	***/stop/[frication]**	***/j/[]**	***[Palatal + j]**
[cjV]	*!				*
[cV]	*!			*	
[kjV]		**!			
[kV]		**!		*	
[tjV]		**!			
[tV]		**!		*	
☞[t͡ʃjV]		*	*		
[t͡ʃV]		*	*	*!	

Tableau 23: /cjV/→[t͡ʃjV]

In tableau 23, as before, the articulatory instability of palatal obstruents causes a different place of articulation to be selected, and the prioritization of place cues over manner cues leads to a postalveolar affricate being selected rather than a velar or dentoalveolar stop. The second to last constraint ensures that [j] is present, although since [t͡ʃ] is not palatal, ***[Palatal + j]** would not have had effect to prevent the presence of [j] even if it had outranked ***/j/[Ø]**.

A final step in this development can be proposed, to demonstrate the merger of Latin /kj/ with Latin /sj/ and /tj/ (and when followed by the right vowel, with /ska/ or /se/ as well). As described at multiple points during this analysis, coarticulation can be invoked to suggest that the palatal glide of /t͡ʃjV/ should cause another sound change. The articulatory constraint ***[RapidTongueMovement]** can have this effect. The cue constraint **/Palatal/[highF2]** is also invoked, as to account for the cues expected to be found given a surface form containing /j/. This is shown in tableau 24.

/t͡ʃjV/	*[RapidTongueMovement]	/Palatal/[highF2]	*/twoSegments/[cueTransition]
[t͡ʃjV]	*!		
[t͡ʃV]		**!	*
☞[t͡ɕV]		*	*

Tableau 24: /t͡ʃjV/→[t͡ɕV]

In tableau 24, the expected outcome could have been [t͡ʃʲV], rather than [t͡ɕV]. However, Hall (1997) argues that these phonetic forms are in fact identical to one another, as the way in which the tongue body is raised while articulating primarily at the postalveolar area necessarily causes palatal frication. Importantly, this is not a mere tendency but rather, according to Hall (1997), a universal rule such that any differentiation between the phones is purely a matter of theoretical notation and not of a difference attested in any language.

4 A problematic sound change

Two sound changes remain unexplained in the development of Vosgien from Latin, *ka → xV / _lV^F* (6a) and *ka → xV / _NV^F:* (6b). No parallels to this could be found cross-linguistically. Given the development of Latin /ka/ into Vosgien /ʃV/, the particular phonological and phonetic mechanisms that are likely to have caused it, and the manner in which has been modelled in BiPhon-OT earlier in this paper, the developments of (6a) and (6b) are entirely unexpected. Indeed, if segmental sequences such as /kani:/ or /kale/ were to be inserted into the grammar which has been uncovered in sections 2 & 3, the correct outcome would not successfully be predicted (as was done in section 3.1), nor could this failure be resolved by introducing well supported additions to the grammar (as was done in section 3.2). This section will focus on an attempt to model these remaining sound changes, similar to sections 2 & 3, but differs from them in its increased speculativeness.

One important pattern in the development of Vosgien explored in section 3 is the fact that the sound changes featuring a fricatization of /k/ were in actually a series of sound changes, involving palatalization, then assibilation with retention of a palatal feature, then dorsalization. The /ka/ segments in (6a) and (6b) are known to, on their own, palatalize then assibilize, but once in the sibilant stage they do not retain an distinctly palatal feature and as a result do not dorsalize. The contexts for /ka/, /_lV^F/ and /_NV^F:/, can therefore be assumed to trigger an additional palatalization, such that upon reaching the sibilant stage in its development, Latin /k/ retains or regains a palatal feature, and is then able to dorsalize as observed. Such a development may happen prior to the initial palatalization of /ka/, such that it becomes /kja/ and from there behaves identically to $k \rightarrow x$ / $\_jV$ (3), or it may happen once the initial palatalization has already occurred, such that there is an intermediate sound shift /ʃ/ → /ɕ/. For the purposes of this analysis, the second of these will be assumed. However, both are possible, and there is no good way to know with any amount of certainty which is correct, since they both rely on the same mechanism and result in the same outcome.

The specific aspects of the palatalizing contexts around /ka/ which can be presumed to be responsible for this additional stage of palatalization are the front vowels. As discussed in section 3.2, Recasens (2020) shows that front vocoids (and especially front vowels) are a common trigger of palatalization, as a result of coarticulation. No feature of /l/ or nasal consonants (specifically: /n/ and /m/), however, is attested as a cause of palatalization in linguistic literature. However, the front vowel's distance from the consonant it palatalizes is problematic. A simple assumption that can be made is that the front vowel palatalizes the sonorant just before it. This is an easily explainable development, which is attested in most Romance varieties, and which may be modellable within the grammar developed in sections 2 & 3. If this assumption is correct, then a cue transfer through the vowel /a/ can possibly occur.

Ní Chiosáin & Padgett (2012) study palatalization in Irish. Irish features phonemic differentiation between plain (or velarized) consonants and secondarily palatalized consonants. They investigate the acoustic differences between plain-palatal pairs, and do a perception study. They find that palatalized consonants cause the F2 of neighboring vowels to be raised, and that this F2 raising is an important cue in identifying that a consonant is palatal rather than plain. Importantly, they find that in production this F2 raising effect applies most strongly to the following vowel, but also applies to a significant degree on the previous vowel. If /l/ /m/ or /n/ have been palatalized by the following front vowel, they may thus in turn raise the F2 of the preceding /a/. Upon perceiving this, listeners may interpret that the raised F2 as signaling that the preceding consonant, rather than the following one, is palatalized. Since the F2 raising effects are stronger towards a following vowel than a preceding one, the cue association between raised F2 and the previous consonant will be stronger than the cue association between raised F2 and the following consonant, making cue misinterpretation possible.

This can be encoded in BiPhon-OT. The initial palatalization can be explained as caused by coarticulation, using the articulatory constraint ***[RapidTongueMovement]**, similar to how it was used in section 3.2. This is shown in tableau 25.

/ʃali/	***[RapidTongueMovement]**
[ʃali]	*!
☞[ʃa̹lʲi]	

Tableau 25: /ʃali/→[ʃa̹lʲi]

In tableau 25, there are only two candidates, one of which has palatalized [lʲ] and [a̹] with a raised F2, and the other of which has plain [l] and [a]. Since the change in the quality of /a/ is a direct result of the change in the articulation of /l/, neither cue constraints nor articulatory constraints could map the relation between the two, and as such it is not possible for a candidate to have one but not the other. The next step is perceptual. Two constraints are needed, to represent the association between a palatalized consonant and the raised F2 cue of either vowel around it. The first of these is **/CʲV/[RaisedF2]**. This constraint eliminates any candidate for the phonetic form which does not contain a vowel with a raised F2, if the surface form input is a palatalized consonant followed by a vowel. It also eliminates any candidate for the surface form which does not contain a palatalized consonant followed by a vowel, if the corresponding vowel phonetic form does not have a raised F2. The second of these is **/VCʲ/[RaisedF2]**. This constraint eliminates any candidate for the phonetic form which does not contain a vowel with a raised F2, if the surface form input is a palatalized consonant preceded by a vowel. It also eliminates any candidate for the surface form which does not contain a palatalized consonant preceded by a vowel, if the corresponding vowel phonetic form does not have a raised F2. This is shown in tableau 26.

[ʃa̪lʲi]	**/CʲV/[RaisedF2]**	**/VCʲ/[RaisedF2]**
/ʃa̪li/	*!	*
/ʃa̪lʲi/	*!	
☞/ɕa̪lʲi/		
/ɕa̪li/		*!

Tableau 26: [ʃa̪lʲi]→/ɕa̪li

In tableau 26, /ɕ/ is proposed as the palatalized version of /ʃ/, in accordance with Hall 1997, as initially explained in section 3.2. Upon reaching this stage, Latin /ka/ has merged with Latin /sja/, /tja/, /ska/, and /kja/. One issue remains in the analysis, however, and this is the issue of vowel length. In *ka → xV / _lV^F^* (6a), the length of the front vowel which triggers palatalization is not relevant. In *ka → xV / _NV^F^:* (6b), however, palatalization only occurs if the vowel is long. There is no clear explanation for this. It can be speculated that since nasal consonants don't involve passing an airstream directly through the vocal tract, less pressure is placed on the various articulators, decreasing the need for articulatory easing through mechanisms such as coarticulation. This, however, cannot be substantiated. More broadly, the analysis presented in this section is merely a hypothesis, as it is not supported well by existing linguistic literature nor by the phonological and phonetic grammar created to account for other sound changes.

5 Experiment

The hypothesized effect discussed in section 4 can be tested experimentally. If stimuli are created containing a palatalized nasal or lateral consonant, it can be observed whether or not listeners perceive the preceding vowel as more fronted. The stimuli must be articulated by a speaker of a language with the appropriate sounds, ideally a language closely related to Vosgien in order to most closely imitate the original phonological and phonetic context. The listeners must be speakers of a different language, which does not contain palatal sonorants, since native speakers of such a language might automatically recognize a raised F2 in a vowel as being a cue from the following palatal sonorant. In order to detect this effect, listeners can give a listening judgement linking the stimuli vowel to one of two vowels differentiated by F2 in the listener's native language. Catalan and Dutch are good candidates for this. Catalan has a palatal nasal stop and a palatal lateral approximant, and is closely related to Vosgien. Dutch does not have palatal sonorants. Catalan has a vowel /ɔ/, with an F2 value around 1200 Hz for males (Recasens & Espinosa, 2006). Dutch (from the Netherlands) has the vowels /a/ and /ɑ/, differentiated in large part by F2 (Adank, van Hout & Smits, 2004). /a/ has an F2 value around 1300 Hz for males, /ɑ/ has an F2 value around 1000 Hz for males (Adank, van Hout & Smits, 2004). Catalan is also selected because it has enough speakers that this experiment can practically be realized, but is not so well known that participants are likely to be very familiar with its sound. Dutch is also selected for its convenience in accessing participants, since this study is conducted in Amsterdam.

5.1 Method

Stimuli

Thirty-two fake-words in adherence to Catalan phonology are created. All are monosyllabic, with a vowel [ɔ]. 8 words end in [n], 8 in [ɲ], 8 in [l], and 8 in [ʎ]. The words within each group are differentiated by their initial consonants. A male native Catalan speaker pronounces these words in a sound booth. The duration of each of these vowels is manipulated to be around 150ms. Manipulation is done in a Praat (Boersma & Weenik, 2025), using a Praat script (Appendix 3). This manipulation is done so that the major non-F2 differentiating cue of the vowels, duration, is between that of (and therefore ambiguous for) Dutch /a/ and /ɑ/ (Adank, van Hout & Smits, 2004).

For each Catalan fake-word, two more fake words in adherence to Dutch phonology are created. These have an equivalent word initial consonant, and a dental equivalent of the word final consonant. One of the words has a vowel [a], the other has a vowel [ɑ]. Two male native Dutch speakers from South Holland record these stimuli using a Neumann TLM103 cardioid condenser microphone set-up within a sound treated room. It is important that all the recorders be of the same sex so that formant values between languages are not too misaligned as a result of differences in the voice qualities of the recorders.

Thirty-two additional Catalan stimuli are made and recorded, as well as an accompanying two Dutch stimuli for each. These are used as filler items. They do not follow the same sound correspondences as above. Target stimuli can be found in Appendix 1. Filler stimuli can be found in Appendix 2.

Participants

6 native Dutch speakers from the Netherlands are recruited. None of them have studied or been significantly exposed to any Romance language. None of them have a second native language. None of them have a hearing or language impairment.

Procedure

An XAB design is used. Participants first listen to a Catalan stimulus. They are told this is a real word in a language they are told is called ‘Choomah’. They then listen to both of the associated Dutch stimuli. They are told this is a recording of a Dutch speaker’s attempt at pronouncing the initial ‘Choomah’ language word. Participants are then asked to determine which of the two Dutch stimuli constitutes a better attempt at pronouncing the foreign-language stimulus. They are told the experiment is aimed at understanding speech perception, without further detail.

Analysis

A logistic regression model is used. The dependent variable is the binary choice between the Dutch fake-word containing /a/ and the Dutch fake-word containing /ɑ/. There are two binary independent variables, both relating to the final consonant of the Catalan fake-word. First, whether the consonant is palatal or dental (place). Second, whether the consonant is lateral or nasal (manner). These are independently analyzed, although any interaction effect is also reported. Participants are accounted for as a random variable. This analysis is conducted in RStudios (2025), with the help of the lme4 library (Bates et. al, 2015).

Predictions

For the place variable, it is predicted that palatal stimuli will have a greater [a:]/[ɑ] ratio than dental stimuli, by a factor significantly greater than 1. For the manner variable, it is predicted that lateral stimuli will have a greater [a:]/[ɑ] ratio than nasal stimuli, by a factor significantly greater than 1. It is also predicted that the effect of the place variable will be greater than the effect of the manner variable.

5.2 Results

For a given item in the experiment, there are odds of 3.91 of choosing the short vowel item over the long vowel item, across all conditions. The 95% confidence interval runs from 1.93 odds to 7.89 odds, thus the preference of short vowel item over long vowel item is significantly different from 1 times greater (p-value = 0.000108, z-value = 3.873), and this preference can be generalized to the broader population. The odds of a participant choosing the long vowel item when hearing a palatal stimulus are 1.33 times greater than the odds of a participant choosing the long vowel item when hearing a dental stimulus. The 95% confidence interval runs from 0.63

times to 2.81 times, thus the difference in the odds of choosing the long vowel item when hearing a palatal stimulus versus when hearing a dental stimulus is not significantly different from 1 times greater (p-value = 0.452175, z-value = 0.752), thus the difference in odds cannot be generalized to the broader population. The odds of a participant choosing the long vowel item when hearing a lateral stimulus are 1.20 times greater than the odds of a participant choosing the long vowel item when hearing a nasal stimulus. The 95% confidence interval runs from 0.57 times to 2.54 times greater, thus the difference in the odds of choosing the long vowel item when hearing a lateral stimulus versus when hearing a nasal stimulus is not significantly different from 1 times greater (p-value = 0.625668, z-value = 0.488), thus the difference in odds cannot be generalized to the broader population. The increase in the odds that a participant chooses the long vowel item when hearing a palatal stimulus rather than a dental stimulus is 2.21 times greater if the stimulus is nasal rather than lateral. The 95% confidence interval runs from 0.49 times to 9.93 times greater (p-value = 0.291230, z-value = -1.055), thus this interaction effect cannot be generalized to the broader population.

Power analyses are used to calculate the probability of finding a significant effect, if there is one, based on the quantity of collected data. The place of articulation variable yields a power of 0.48, given its current estimate and a significance threshold of 0.05. The manner of articulation variable yields a power of 0.23, given its current estimate and a significance threshold of 0.05. The interaction between the place and manner of articulation variables yields a power of >0.99, given its current estimate and a significance threshold of 0.05. Power analysis is conducted in RStudios (2025), with the help of the pwr library (Champely, 2020).

5.3 Discussion

One limitation of this design was in accounting for cues other than F2 which might affect the judgement of participants. Duration was the main of these. While it was accounted for as described above, the manipulation resulted in slight deviations in the formant values of the Catalan stimuli as well as a reduction in the sound quality thereof. Furthermore, F1 is also a confounding cue in this regard, and could not be accounted for. This is because manipulating F1 values causes other formant values to be shifted by amounts which would defeat the purpose of the experiment, and additionally requires resampling of the stimuli to 10,000Hz (for males, 11,000Hz for females) such that acoustic signal above 5,000Hz is lost and the sound quality of the stimuli is thus drastically lowered. It was therefore determined that having F1 remain as a confounding factor was less problematic to the experimental design than the consequences of F1 manipulation in the Catalan stimuli. This technological limitation renders the XAB design less effective, particularly if the languages being tested serve as stand-ins rather than being themselves the subject of investigation. However, given the historical nature of the sound changes under investigation in this study, the use of stand-in languages remains a necessary experimental tool in spite of its limitations.

Due to the very low number of participants who could be recruited and from whom usable data could be gathered, very little information was able to be gathered from the experiment. What has been gathered is as follows. First, the Catalan vowel was consistently heard as being more similar to the Dutch short/back /ɑ/ than to the Dutch long/fronted /a:/. This fact may have been a problem with the experiment even if there had been a greater number of participants. This is because this may have hidden a real effect, and made it impossible to interpret the data in a useful manner. If having a palatal consonant in coda position does make the vowel sound more fronted than if the coda is a dental consonant, but both fronted and non-fronted versions of the vowel sound closer to /ɑ/ than /a:/, then the experiment would be unable to identify the effect despite there indeed being an effect. Second, although no significant interaction effect was found, power analysis confirms that the collected dataset was large enough such that an effect of the size suggested by the estimate had a greater than 99% chance of being identified as significantly different from 1 (within a 95% confidence interval). This means that it is likely that there is either no interaction effect to be found, or that the real effect would be very different to that suggested by the estimate. However, it must be noted that, as with any non-significant results, no strong conclusions can be derived other than the fact that no effect was found, and it is still a possibility that a real effect similar to that suggested by the estimate does exist. Third, both individual effect estimates of place of articulation and manner of articulation of the coda consonant in the Catalan words were in alignment with the predictions. However, these estimates were highly insignificant, and it is impossible to know whether they hinted at real effects or were a result of random change. This is further confirmed by the power analyses, which show that the probability of confirming, with at least 95% confidence, that the estimates reflect real effects, is less than half for the place variable and less than a quarter for the manner variable.

Although unsuccessful, this experiment can be treated as a pilot. Despite not yielding many results which can be used to draw conclusions, it did reveal a flaw in the methodology, which can lead to improvements in future attempts to make such a design, whether to answer this same question or for the sake of another area of study. Languages must be selected very carefully when attempting to stand in for non-present variables. Ideally, the X language would be a true non-language, with stimuli being technologically synthesized in order to match the ideal conditions as perfectly as possible. Until such technology becomes available, however, experiments of the kind attempted here are limited in their ability to reveal desired information, as at the moment they rely on the possibility that real languages, with an accessible pool of speakers, happen to line up with the desired experimental conditions.

6 General Discussion

The aim of this study has been to understand the manner in which a series of sound changes linking Latin to Vosgien, an Oïl language descended from Latin. These sound changes were discovered in a previous study (Chopinez, unpublished), and represented a challenge both due to their relative unattestedness, as well as the disconnect between expectation and reality. All of the contexts in which these sound changes occurred appeared to be linked with palatalization. However, only a few of them resulted in assibilation, a common result of palatalization, while most resulted in dorsalization. This was particularly problematic, as certain contexts, such as *ska → xV* (5b), $ka \rightarrow xV / \_lV^{F}$ (7a), and $ka \rightarrow xV / \_NV^{F}\!:$ (7b), appeared similar to *ka → ʃV* (7c) in terms of their initial context in Latin, but with additional context which would suggest a greater trigger for palatalization, but instead (7a) (7b) and (8) all exhibit frication. The proposed hypothesis for this was that all Latin segments did indeed assibilate as a result of palatalization, but that in some cases, the association of certain cues with palatal features caused the specific resulting sibilant to be alveolopalatal, rather than postalveolar. The alveolopalatal fricative, through independent processes, would then dorsalize, leading to the outcome found in Chopinez (unpublished).

This hypothesis was mostly correct. In section 2, two sets of sound changes were described, on the basis of pre-existing literature describing the same, or similar, sound changes. Notably, *ka → ʃV* (7c), $O^{C}j \rightarrow x$ / *VO_V* (1), and *s → x / _e* (2) all featured two characteristics facilitating their descriptions. First, they were the sound changes which were best described, and therefore could be appropriately grounded in existing research on the phonetic and phonological mechanics of sound change. Second, they were the most straightforward, since they involved either coronal segments dorsalizing, or dorsal segments assibilizing, both of which can intuitively be linked with palatalization, since the palatal area serves as a transition between segments of dorsal feature and segments of coronal feature. The simultaneous description of these sounds also served as a guide in attempting to identify specific intermediary steps in the development of the Vosgien phonemes. Specifically, the dorsalization of palatalized coronals ($O^{C}j \rightarrow x$ / *VO_V* [1], and *s → x / _e* [2]) involved, as can be discerned from cross-linguistic parallels as well as known articulatory and acoustic triggers for sound change, an intermediary posterior sibilant stage. Which specific phoneme this entails was not obvious, however, as the same phonological and phonetic context could lead to various slightly distinct developments. However, since Latin /ka/ does not merge with /tj/, /sj/, and /se/ in Vosgien, it could be assumed that the intermediary form was more likely to be /ɕ/ rather than /ʃ/. This assumption ended up making the next stage, full palatalization and then dorsalization, easier to explain. This highlights the manner in which this apparent inversion of dorsal and coronal phonemes in the evolution of Latin into Vosgien can have taken place, and thus confirms that the sound changes proposed in Chopinez (unpublished) can indeed have taken place within a single evolving language.

The phonological and phonetic grammar, encoded in BiPhon-OT, which was proposed as the mechanism through which the sound changes *ka → ʃV* (7c), $O^{C}j \rightarrow x$ / *VO_V* (1), and

$s \rightarrow x$ / _e (2) may have all occurred, demonstrated its correctness by describing with ease most of the remaining sound changes. The principles which caused (7c) (1) and (2) not only allowed for, but directly predicted that the sound changes *ska* → *xV* (5b), *ska* → *ʃV / V_V* (5a), and *k* → *x* / _*jV* (3) should occur on the basis of the original phonological and phonetic context in Latin. This confirmed, again, that the sound changes proposed in Chopinez (unpublished) can indeed have taken place within a single evolving language. It also confirms that the specific explanations given for the sound changes, both in terms of intermediary stages and in terms of the phonetic and phonological causes thereof, were largely correct, since incorrect descriptions are unlikely to successfully predict seemingly independent phenomena. Finally, it attests to the efficacy of BiPhon-OT as a system of phonetic and phonological modelling, since it was able to adequately depict and predict sound changes which took place over the course of several hundred years.

The largest shortcoming of this study has been the description of two sound changes, *ka* → *xV* / _lV^F (7a), and *ka* → *xV* / _NV^F: (7b). While an explanation was proposed and modelled in section 4, the lack of clear theoretical backing, as well as its limited overlap with the other mechanisms of sound change proposed in this study, render it highly speculative. Although an experiment was designed and performed in the hopes of confirming or denying the theoretical proposition of section 4, a lack of enough participants, alongside certain methodological issues, made it so that its results cannot be used to draw any conclusions. Further attempts at testing this experimentally in the future, however, could still yield interesting results. Furthermore, the identification of this particular phenomenon could open the door to exploring similar phenomena in other languages, and possibly establish the existence of new triggers and mechanisms of sound change.

It is important to note that the failure to adequately explain *ka* → *xV* / _lV^F (7a), and *ka* → *xV* / _NV^F: (7b) does not bear consequence on the rest of the analysis in this study. The nature of the issue is such that Latin /ka/ must have been impacted in some manner by the following syllable, such as to change its developmental trajectory. Whether or not the rest of the analysis constitutes a correct description of the development of Vosgien from Latin, this issue remains. It is possible that an error in the original study, in which Vosgien phonemes were mapped onto their Latin origins, is the source of this issue, however, As such, a revisitation of that research may be warranted.

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Appendices

Appendix 1: target stimuli

	Catalan 1	Catalan 2	Dutch 1	Dutch 2
1.1	/pɔn/	/pɔɲ/	/pan/	/pɑn/
Spelling	**pòn**	**pòny**	**paan**	**pan**
1.2	/pɔl/	/pɔʎ/	/pal/	/pɑl/
Spelling	**pòl**	**pòll**	**paal**	**pal**
2.1	/tɔn/	/tɔɲ/	/tan/	/tɑn/
Spelling	**tòn**	**tòny**	**taan**	**tan**
2.2	/tɔl/	/tɔʎ/	/tal/	/tɑl/
Spelling	**tòl**	**tòll**	**taal**	**tal**
3.1	/kɔn/	/kɔɲ/	/kan/	/kɑn/
Spelling	**kòn**	**kòny**	**kaan**	**kan**
3.2	/kɔl/	/kɔʎ/	/kal/	/kɑl/
Spelling	**kòl**	**kòll**	**kaal**	**kal**
4.1	/fɔn/	/fɔɲ/	/fan/	/fɑn/
Spelling	**fòn**	**fòny**	**faan**	**fan**
4.2	/fɔl/	/fɔʎ/	/fal/	/fɑl/
Spelling	**fòl**	**fòll**	**faal**	**fal**
5.1	/nɔn/	/nɔɲ/	/nan/	/nɑn/
Spelling	**nòn**	**nòny**	**naan**	**nan**
5.2	/nɔl/	/nɔʎ/	/nal/	/nɑl/
Spelling	**nòl**	**nòll**	**naal**	**nal**
6.1	/mɔn/	/mɔɲ/	/man/	/mɑn/
Spelling	**mòn**	**mòny**	**maan**	**man**

6.2	/mɔl/	/mɔʎ/	/mal/	/mɑl/
Spelling	**mòl**	**mòll**	**maal**	**mal**
7.1	/jɔn/	/jɔɲ/	/jan/	/jɑn/
Spelling	**yòn**	**mòny**	**jaan**	**jan**
7.2	/jɔl/	/jɔʎ/	/jal/	/jɑl/
Spelling	**yòl**	**yòll**	**jaal**	**jal**
8.1	/lɔn/	/lɔɲ/	/lan/	/lɑn/
Spelling	**lòn**	**lòny**	**laan**	**lan**
8.2	/lɔl/	/lɔʎ/	/lal/	/lɑl/
Spelling	**lòl**	**lòll**	**laal**	**lal**

Appendix 2: filler stimuli

	Catalan	Dutch 1	Dutch 2
F1	/pit/	/pit/	/pɪt/
Spelling	**pit**	**piet**	**pit**
F2	/fim/	/fim/	/fɪm/
Spelling	**fim**	**fiem**	**fim**
F3	/sik/	/sik/	/sɪk/
Spelling	**sic**	**siek**	**sik**
F4	/min/	/min/	/mɪn/
Spelling	**min**	**mien**	**min**
F5	/lis/	/lis/	/lɪs/
Spelling	**lis**	**lies**	**lis**
F6	/rip/	/rip/	/rɪp/
Spelling	**rip**	**riep**	**rip**
F7	/sip/	/sip/	/sɪp/

Spelling	**sip**	**siep**	**sip**
F8	/pik/	/pik/	/pɪk/
Spelling	**pic**	**piek**	**pik**

F9	/sup/	/sup/	/zup/
Spelling	**sup**	**soep**	**zoep**
F10	/set/	/set/	/zet/
Spelling	**sét**	**seet**	**zeet**
F11	/zul/	/zul/	/sul/
Spelling	**zul**	**zoel**	**soel**
F12	/zej/	/zej/	/sej/
Spelling	**zéy**	**zej**	**sej**
F13	/fus/	/fus/	/vus/
Spelling	**fus**	**foes**	**voes**
F14	/fem/	/fem/	/vem/
Spelling	**fém**	**feem**	**veem**
F15	/ʃot/	/ɕot/	/ʑot/
Spelling	**xót**	**sjoot**	**zjoot**
F16	/ʒep/	/ʑep/	/ɕep/
Spelling	**jép**	**zjeep**	**sjeep**

F17	/ret/	/ret/	/ʀet/
Spelling	**rét**	**reet**	**reet**
F18	/rop/	/rop/	/ʀop/
Spelling	**róp**	**roop**	**roop**
F19	/ram/	/ram/	/ʀam/
Spelling	**ram**	**raam**	**raam**

F20	/rut/	/rut/	/ʀut/
Spelling	**rut**	**roet**	**roet**
F21	/rom/	/rom/	/ʀom/
Spelling	**róm**	**room**	**room**
F22	/rɛl/	/rɛl/	/ʀɛl/
Spelling	**rèl**	**rel**	**rel**
F23	/raɲ/	/ran/	/ʀan/
Spelling	**ran**	**raan**	**raan**
F24	/roʎ/	/rol/	/ʀol/
Spelling	**róll**	**rool**	**rool**

F25	/ʒam/	/zam/	/ʑam/
Spelling	**jam**	**zaam**	**zjaam**
F26	/ʒit/	/zit/	/ʑit/
Spelling	**jit**	**ziet**	**zjiet**
F27	/ʃuf/	/suf/	/ɕuf/
Spelling	**xuf**	**soef**	**sjoef**
F28	/ʃel/	/sel/	/ɕel/
Spelling	**xél**	**seel**	**sjeel**
F29	/xop/	/χop/	/ɦop/
Spelling	**khóp**	**goop**	**hoop**
F30	/xɛj/	/χɛj/	/ɦɛj/
Spelling	**khèy**	**gej**	**hej**
F31	/xɛf/	/χɛf/	/ɦɛf/
Spelling	**khèf**	**gef**	**hef**
F32	/xuk/	/χuk/	/ɦuk/
Spelling	**khuc**	**goek**	**hoek**

Appendix 3: Praat script

```
;; Script: editing vowels F1 and duration and verifying results
; 1 - Preparation
writeInfoLine: "Item; Version; F1; F1 Bandwidth; F2; F2 Bandwidth"
folder1$ = "OldSounds" ; change for final
sstrings = Create Strings as file list: "list1", folder1$ + "/*.wav"
numberOfSounds = Get number of strings
folder2$ = "Textgrids"
tstrings = Create Strings as file list: "list2", folder2$ + "/*.TextGrid"
numberOfFiles = Get number of strings
for ifile to numberOfSounds
	selectObject: sstrings
	fileName1$ = Get string: ifile
	fullsound = Read from file: folder1$ + "/" + fileName1$
	selectObject: tstrings
	fileName2$ = Get string: ifile
	textgrid = Read from file: folder2$ + "/" + fileName2$
	selectObject: textgrid
	numberOfIntervals = Get number of intervals: 1
	for interval to numberOfIntervals
		word$ = Get label of interval: 1, interval
		if word$ = "v"
			ostart = Get start time of interval: 1, interval
			oend = Get end time of interval: 1, interval
		endif
	endfor
	selectObject: fullsound
	plusObject: textgrid
	invowel = Extract non-empty intervals: 1, "no"
; 4 - Duration edit
	nstart = Get start time
	nend = Get end time
	nduration = Get total duration

	selectObject: invowel
	manipulation = To Manipulation: 0.0001, 75, 600

	durationtier = Extract duration tier
	Add point: nstart, 0.15/nduration
	Add point: nend, 0.15/nduration

	selectObject: manipulation
	plusObject: durationtier
	Replace duration tier
	selectObject: manipulation
	newsound = Get resynthesis (overlap-add)
; 5 - Replacing the old vowel with the new vowel within the full word
	selectObject: newsound
	View & Edit
		editor: newsound
		newvisend = Get end of visible part
```

```
			Select: 0, newvisend
			Copy selection to Sound clipboard
		endeditor
		selectObject: fullsound
		View & Edit
			editor: fullsound
			Select: ostart, oend
			Paste over selection
			Close
		endeditor
; 6 - saving the new sound
		selectObject: fullsound
		Save as WAV file: "/Users/tristanchopinez/Desktop/MA Linguistics/Thesis/Stimuli/Manip/NewSounds/" +
fileName1$
; 7 - Remove all but initial and final
		selectObject: textgrid
		plusObject: invowel
		plusObject: newsound
		plusObject: manipulation
		plusObject: durationtier
		Remove
; 8 - Check formants
		selectObject: fullsound
		View & Edit
			editor: fullsound
			Select: ostart, oend
			ogfone = Get first formant
			ogfoneband = Get first bandwidth
			ogftwo = Get second formant
			ogftwoband = Get second bandwidth
			Close
		endeditor
		fend = ostart + 0.15
		selectObject: fullsound
		View & Edit
			editor: fullsound
			Select: ostart, fend
			newfone = Get first formant
			newfoneband = Get first bandwidth
			newftwo = Get second formant
			newftwoband = Get second bandwidth
			Close
		endeditor
		appendInfoLine: ifile, "; ", "Old", "; ", ogfone, "; ", ogfoneband, "; ", ogftwo, "; ", ogftwoband
		appendInfoLine: ifile, "; ", "New", "; ", newfone, "; ", newfoneband, "; ", newftwo, "; ", newftwoband
endfor
```