Gestural Alignment Constraints and Unstressed Vowel Devoicing in Andean Spanish

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1. Introduction

This paper applies the gestural alignment constraint schema proposed by Gafos (2002) to unstressed vowel devoicing in Andean Spanish. I will argue that this approach successfully addresses several characteristics identified in novel data from Cusco, Peru that depart from cross-linguistic trends in vowel devoicing and cannot be readily explained in terms of more traditional Articulatory Phonology phasing terminology. The discussion is organized as follows: Section 2 provides a description of vowel devoicing patterns in Andean Spanish and compares them with the characteristics of vowel devoicing in other languages. Section 3 develops an account of the Andean data in terms of timing patterns expressed as inter-segmental and intra-segmental gestural alignment constraints while Section 4 concludes and summarizes.

2. The unusual characteristics of vowel devoicing in Andean Spanish

2.1. Cross-linguistic characteristics of vowel devoicing

Vowel devoicing has been documented in a number languages including Japanese (Kondo 1997, Tsuchida 1997 and Varden 1999, *inter alia*), Korean (Jun & Beckman 1993), Modern Greek (Dauer 1980), Montreal French (Cedergren 1986) and Turkish (Jannedy 1995). Gordon (1998) presents information about vowel devoicing patterns in many less well-studied languages. In the vast majority of these cases, vowel devoicing is described as a variable, gradient and non-contrastive phenomenon that primarily affects high vowels adjacent to voiceless consonants. The process is typically attributed to two universal phonetic properties of high vowels: their limited duration and the high tongue position involved in their production. Because high vowels are inherently shorter than low or mid vowels in all languages (Lehiste 1970), there is a greater probability that the glottal abductions of adjacent voiceless consonants will prevent full realization of the glottal adductions required for their voicing. Also, the close oral constriction associated with the production of high vowels raises air pressure in the oral cavity which inhibits transglottal air flow and therefore makes them more susceptible to devoicing than those articulated with lower tongue positions (Jaeger 1978). The relationship between duration and devoicing is underscored by the fact that, in languages with contrastive vowel length, only short high vowels are affected, while in languages with stress accent, high vowel devoicing is limited to unstressed syllables.

Duration and aerodynamics are also the basis for two other factors that condition vowel devoicing in many languages: prosodic position and speech rate. Gordon (1998) reports that the final position of large prosodic domains is particularly conducive to devoicing, presumably due to the drop in subglottal pressure that occurs over the course of an utterance. With the notable exception of Japanese, in which vowel devoicing appears to be relatively independent of speech rate (Kondo 1997, Varden 1999), the process occurs primarily in rapid speech. This effect is attributed to the temporal compression that occurs as speech rate increases and further reduces the already short duration of high vowels, thus making them even more likely to be overwhelmed by contiguous voiceless consonants.

* I thank the WCCFL audience and Travis G. Bradley for their comments.

2.2. Vowel devoicing in Andean Spanish

Based on conversational speech samples collected in Cusco, Peru, vowel devoicing in Andean Spanish is also a gradient and variable effect that targets vowels in unstressed syllables adjacent to voiceless consonants.[1] As in most other languages, the partially and completely devoiced vowels produced by this process do not contrast with fully voiced vowels. However, in this dialect, the effect is not limited to the high vowels. Word internally (1) and in sandhi (2),[2] the front mid-vowel /e/ is devoiced in a proportion similar to that of the high vowels /i/ and /u/.[3]

(1)	/u/	[ku̥skéɲa]	*Cusqueña*	'Cusqueña brand beer'
	/i/	[paɾti̥sípa]	*participa*	'participates'
	/e/	[aɾte̥sanía]	*artesanía*	'crafts'
(2)	/i/	[kási̥ tóðo]	*casi todo*	'almost all'
	/e/	[tɾáxe̥ típiko]	*traje típico*	'typical costume'

Furthermore, in word-final syllables closed by an /s/ (3), the majority of which are plural morphemes, all five Spanish vowels are affected to an approximately equal degree including the low vowel /a/ which should be especially resistant to devoicing as a result of its longer duration and manner of production.

(3)	/u/	[kóɾpu̥s kɾísti]	*Corpus Cristi*	'Corpus Cristi'
	/i/	[aɾkoíɾi̥s]	*arcoiris*	'rainbow'
	/e/	[dosénte̥s]	*docentes*	'teachers'
	/o/	[mútʃo̥s]	*muchos*	'many'
	/a/	[alpákḁs]	*alpacas*	'alpacas'

The prosodic patterns associated with word final unstressed vowel devoicing in Andean Spanish also differ somewhat from cross-linguistic trends. Firstly, as unstressed vowels in this context are placed in the final position of progressively larger prosodic domains, devoicing rates actually decrease. Secondly, the syllabic affiliation of a following /s/ has a significant effect on devoicing. As seen in (4), vowels that precede a tautosyllabic /s/ are much more likely to devoice than those followed by an /s/ that forms the onset of the next syllable. This statistically significant difference (χ^2 $p<.05$) in devoicing rates occurs both word medially and word finally when a final /s/ may become the onset of a subsequent vowel initial word.

(4a)	/s/ in onset: devoicing may occur but is less likely (~12% devoicing rate)		
	[pɾo.fe̱.sóɾ]	*profesor*	'teacher'
	[kó.sa̱.sin.te.ɾe.sán.tes]	*cosas interesantes*	'interesting things'
(4b)	/s/ in coda: devoicing is more likely (~40% devoicing rate)		
	[ek.si̥s.tíɾ]	*existir*	'to exist'
	[kwán.tḁs.pa.lá.bɾas]	*cuántas palabras*	'how many words'

Finally, as in the case of Japanese, Andean vowel devoicing does not exhibit a strong correlation with speech rate. Unstressed vowels are frequently devoiced in slow, careful speech and even in text reading tasks.

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[1] For the present study, 16,581 unstressed vowels (1,648 devoiced) in ten minute samples of conversational speech selected from individual interviews with 16 residents of Cusco, Peru (14 men and 2 women) ranging in age from 25 to 90 were examined via spectrographic analysis.

[2] This comparison refers to non-clitics. Thus the frequent devoicing of /e/ is not a result of its reduction in the context of common Spanish clitics such as *que* and *se*. /e/ is also often devoiced in these function words as might be expected based on their high rates of usage.

[3] In Spanish, /i/ and /u/ are rarely found in absolute word-final position. In this corpus, no occurrences of /u/, voiced or devoiced, were encountered in sandhi.

3. Explaining unstressed vowel devoicing in Andean Spanish

3.1. The gestural overlap approach

Several studies (Beckman 1994, Jannedy 1995, Jun & Beckman 1993) develop accounts of high vowel devoicing within the theoretical framework of Articulatory Phonology (Browman & Goldstein 1989 *et seq*), which takes gestures, or the formation and release of constrictions in the vocal tract, to be the basic units of phonology. Articulatory Phonology has successfully explained a diverse array of intermittently occurring phenomena associated with fast speech as the result of increases in the amount of overlap between adjacent gestures. Under this approach, high vowel devoicing is also ascribed to a rate-based decrease in the distance between articulatory gestures that causes the glottal abductions of voiceless segments to impinge upon the adduction gestures of adjoining vowels. Thus, the gradience and variability of the process, as well as its association with rapid speech and its tendency to affect high and therefore short vowels are all accounted for.

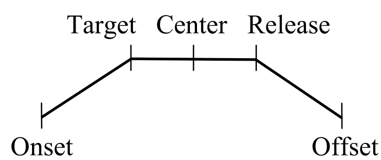
Vowel devoicing in Andean Spanish, however, is incompatible with the gestural overlap approach applied to prototypical devoicing patterns in several ways. As it occurs in slow speech when, presumably, there is ample time to produce all requisite articulatory gestures and affects non-high and therefore not particularly short vowels, it cannot be attributed to the interaction of a speed-induced decrease in the temporal distance between gestures and the duration of affected vowels. In addition, the behavior of word-final syllables ending in /s/, including the influence of /s/'s syllabic affiliation on the probability of devoicing as well as the decrease in devoicing rates that occurs when these syllables are placed in the final position of progressively larger prosodic domains, is not easily explained in terms of the durational or aerodynamic factors thought to motivate vowel devoicing in other languages. However, as gradience and variability are essential features of Andean vowel devoicing, it nonetheless appears that this process would be most successfully addressed by an approach that makes explicit reference to the relative timing of adjacent articulatory gestures.

3.2. Gestural alignment constraints

While unspecified increases in gestural overlap based on the phonetic characteristics of high vowels fail to account for vowel devoicing patterns in Andean Spanish, the gestural alignment schema recently proposed by Gafos (2002), which translates the principles of Articulatory Phonology (AP) into Optimality Theoretic terms, makes it possible to explain the process as a result of gestural phasing. Gafos expresses the temporal relationships between gestures with more precision than previous AP representations through reference to a set of hypothetical "landmarks", or points at which one gesture can be coordinated with another (5), and by formulating phasing as alignment constraints (McCarthy and Prince 1993) as shown in (6).

(5) Gafos' Gestural Landmarks

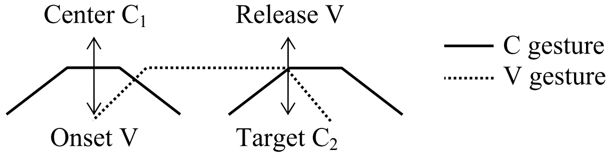
(6) ALIGN (G^1, landmark^1, G^2, landmark^2):
Align landmark^1 of G^1 to landmark^2 of G^2



The greater specificity of constraints composed according to this schema permits the expression of fine-grained non-contrastive differences in gestural phasing between languages and dialects which, although minute, have significant acoustic consequences, being the type of distinctions that make "English sound like English and German sound like German" (Ladefoged 1980). And, of course, as no faithfulness constraints need be proposed in an analysis consisting of output oriented alignment constraints, it is possible to refer to a wide range of phonetic detail without predicting the existence of unattested contrasts (Kirchner 1997).

Gafos focuses on cross-linguistic disparities in the relative timing of consonant clusters expressed as variants of the constraint CC COORD, which he uses to model the phasing of clusters timed to allow for an acoustic release between the two segments as well as those with close transitions. However, based on previous work by Browman and Goldstein (1990), he also indicates that coordination constraints CV COORD and VC COORD govern the relationships between vowels and consonants, as seen in (7).

(7) Canonical CV, VC Coordination (Browman & Goldstein 1990; Gafos 2002:281)
CV COORD: ALIGN (C, Center, V, Onset)
VC COORD: ALIGN (V, Release, C, Target)

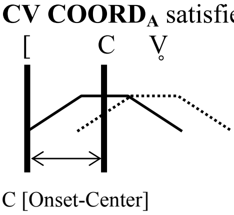


I propose that, like CC COORD, CV and VC COORD may also exhibit cross-linguistic variation and that unstressed vowel devoicing in Andean Spanish can be effectively modeled by assuming that the CV and VC COORD relationships present in this dialect allow for greater than typical overlap between adjacent consonant and vowel gestures. It has been suggested that, unlike the majority of Spanish dialects which are described as syllable-timed, Andean varieties may be stressed-timed (Hundley 1986); more overlapped consonant-vowel phasing relationships suggest one means of modeling such differences in speech rhythm.

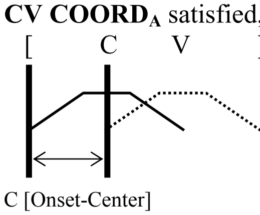
Of course, static coordination relationships cannot adequately represent the gradient nature of devoicing or the fact that unstressed vowels are most often produced as fully voiced in Andean Spanish. In order to accurately model the process, I follow Davidson (2003) and express CV and VC COORD in terms of phase windows (Byrd 1996) which allow a range of points within one gesture's cycle to be phased with another gesture. (8) depicts hypothetical CV and VC COORD constraints for Andean Spanish expressed in terms of ranges associated with phase windows. The least overlapped relationships allowed by these windows correspond to the canonical phasing schemes in (7) and thus account for the occurrence of fully voiced unstressed vowels. (9) shows phasing relationships that would either violate or satisfy these hypothetical constraints, with the edges of the phase windows represented by bold vertical lines. (9a) and (9c) satisfy CV and VC COORD$_A$, respectively, and produce devoiced vowels. (9b) and (9d), on the other hand, both satisfy the relevant alignment constraints for Andean Spanish and represent the canonical configurations shown in (7), thus producing fully voiced vowels. [4]

(8a) **CV COORD$_A$**: ALIGN (C, [Onset-Center], V, Onset)
Align any point ranging from C Onset to C Center with V Onset.
(8b) **VC COORD$_A$**: ALIGN (V, [Target-Release], C, Target)
Align any point ranging from V Target to V Release with C Target.

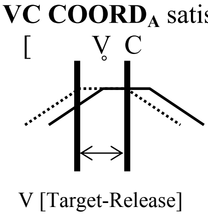
(9a) **CV COORD$_A$** satisfied, vowel devoicing



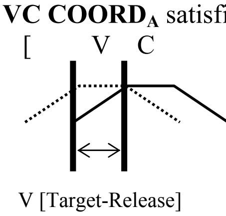
(9b) **CV COORD$_A$** satisfied, no devoicing



(9c) **VC COORD$_A$** satisfied, vowel devoicing



(9d) **VC COORD$_A$** satisfied, no devoicing



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[4] Brett Hyde (p.c.) suggests that the following alternative constraint formulations based on McCarthy (2003) could also be adapted to model the gradience and variability of these data:
CV COORD$_A$: *C Center/C Onset_V Onset (V Onset may coincide with or occur to the left of C Center)
VC COORD$_A$: *V Release/V Target_C Target (C Target may coincide with or occur to the left of V Release).

3.3. The devoicing of /e/: consonant-vowel homorganicity

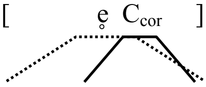
The reader will recall that, word internally and in sandhi, the front mid-vowel /e/ exhibits devoicing rates similar to those of the high vowels /i/ and /u/ while the other mid-vowel /o/ is rarely affected in these contexts. As the mean durations of unstressed /e/ and /o/ are 58.82 and 58.95 milliseconds respectively (Marín Gálvez 1994), intrinsic length cannot account for the different devoicing rates of these two vowels; some other factor must interact with CV and VC COORD$_A$ to produce this pattern.

Given that a study of phoneme frequency in conversational speech (Quilis & Esgueva 1980) indicates that the most commonly occurring voiceless consonants in Spanish are the coronals /s/ and /t/, the characteristic that sets /e/ apart from the other high vowels and underlies its tendency to devoice may be its anterior place of articulation. Clements and Hume's (1995) conclusion, based on consonant-vowel interactions in a variety of languages, that front vowels appear to form a natural class with coronal consonants and should therefore be considered [+coronal] supports the hypothesis that the high devoicing rate of /e/ is a result of this anterior vowel's interaction with voiceless consonants articulated in the same general region of the oral cavity. Furthermore, Lipski's (1990) feature geometry account of unstressed vowel reduction in Andean Spanish specifically attributes the frequent devoicing of /e/ to its [+coronal] status and consequent articulatory similarity to /s/.

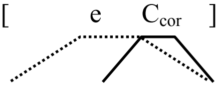
The idea that the degree of similarity between adjacent segments may influence their relative phasing is quite compatible with Gafos' model. In a recent study of svarabhakti phenomena employing the gestural alignment framework, Hall (2004) proposes that, since consonant-vowel homorganicity affects the occurrence of vowel fragments in some languages and influences the probability of metathesis in others, gestural overlap is more limited in heterorganic consonant-vowel combinations than in homorganic pairs. Following this line of reasoning, I propose that /e/ is more frequently devoiced than /o/ as a result of the greater degree of overlap permitted between this front vowel and homorganic (coronal) voiceless consonants. This hypothesis is expressed in the constraint *OVERLAP V//C$_{HET}$ shown in (10). As shown in (10a), this constraint allows overlap between the coronal consonants and /e/ sufficient to cause devoicing. However, the same degree of overlap between coronal consonants and the back vowel /o/ (10c) results in a violation of *OVERLAP V//C$_{HET}$. In (10b,d), the constraint is vacuously satisfied.

(10) ***OVERLAP V//C$_{HET}$**:
The plateau of a consonant may not overlap the plateau of an adjacent heterorganic vowel.[5]

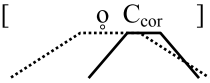
(10a) ***OVERLAP$_{HET}$** satisfied
[e̥ C$_{cor}$]



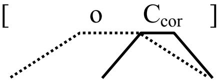
(10b) ***OVERLAP$_{HET}$** satisfied:
[e C$_{cor}$]



(10c) ***OVERLAP$_{HET}$** violated
[o̥ C$_{cor}$]



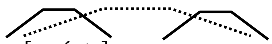
(10d) ***OVERLAP$_{HET}$** satisfied
[o C$_{cor}$]



Tableaux 1 through 3 illustrate the interaction of *OVERLAP V//C$_{HET}$ with CV and VC COORD$_A$. In the first tableau, we see that many different degrees of overlap permitted by CV and VC COORD$_A$, illustrated by candidates (a), (b) and (c), fail to violate *OVERLAP V//C$_{HET}$ since /e/ and the surrounding consonants are homorganic. Only candidate (d) is ruled out because its overlap is insufficient to satisfy CV COORD$_A$ and VC COORD$_A$.

[5] Gafos defines the plateau of a gesture as the interval between achievement of its target and its release.

Tableau 1. Overlap and the unstressed mid-vowel /e/

/sesánte/ ‘retired’	*OVERLAP$_{HET}$ V//C	CV COORD$_A$	VC COORD$_A$
☞ a.  [se̥sánte]			
☞ b.  [sesánte]			
☞ c.  [sesánte]			
d.  [sesánte]		*!	*

In Tableau 2, the only candidate produced with overlap sufficient to cause devoicing, candidate (a), runs afoul of *OVERLAP V//C$_{HET}$ as the plateaus of coronal C_1 and C_2 overlap that of the back vowel. Candidates (b) and (c) with voiced /o/ both satisfy all coordination constraints. Voiced candidate (d) is ruled out by CV COORD$_A$ and VC COORD$_A$ due to insufficient overlap.

Tableau 2. Overlap and the unstressed mid-vowel /o/

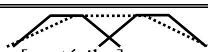
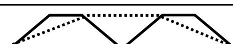
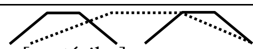
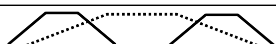
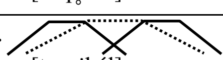
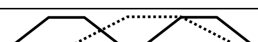
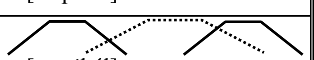
/esotéɾiko/ ‘esoteric’	*OVERLAP$_{HET}$ V//C	CV COORD$_A$	VC COORD$_A$
a.  [eso̥téɾiko]	*!		
☞ b.  [esotéɾiko]			
☞ c.  [esotéɾiko]			
d.  [esotéɾiko]		*!	*

Tableau 3 demonstrates that the interaction between vowel duration and the CV, VC coordination constraints suffices to cause the devoicing of high vowels. Devoiced candidate (a) is ruled out by *OVERLAP V//C$_{HET}$ as the front vowel /i/ is located between two non-coronal consonants. However, due to the limited duration of /i/ a devoiced candidate (b) can be produced by a degree of overlap that fails to violate *OVERLAP. Voiced candidate (c) is also acceptable to all constraints but candidate (d) is eliminated due to insufficient overlap between the vowel and the adjacent consonants.

Tableau 3. Overlap and the unstressed high vowels

/tropikál/ ‘tropical’	*OVERLAP$_{HET}$ V//C	CV COORD$_A$	VC COORD$_A$
a.  [tropi̥kál]	*!		
☞ b.  [tropi̥kál]			
☞ c.  [tropikál]			
d.  [tropikál]		*!	*

No tableau is provided for the low vowel /a/ due to space considerations. However, it is assumed that /a/ would pattern like /o/, with any candidate sufficiently overlapped to produce devoicing being eliminated due to violations of *OVERLAP.

3.4. Intra-segmental coordination and the coda /s/ effect

We have seen that all vowels, including the back mid vowel /o/ and the low vowel /a/, are frequently devoiced in word final syllables closed by /s/. Since, under the present analysis, *OVERLAP$_{\text{HET}}$ V//C prevents coronal voiceless consonants from overlapping these non-front vowels to the extent that would cause devoicing, this pattern requires further explanation.

As the majority of word final syllables ending in /s/ are plural desinences, it could be argued that the high devoicing rate associated with this context is a consequence of its morphological function (e.g. predictability or frequency). However, this supposition is undercut by the finding that unstressed vowels followed by an /s/ in coda rather than in the onset position of the following syllable are more likely to be devoiced word internally as well as word finally.

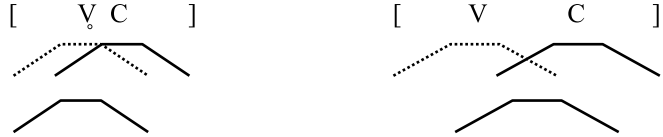
I propose that the asymmetry between devoicing rates associated with coda and onset /s/ in this dialect can plausibly be attributed to the articulatory pattern known as the syllable position effect. Several studies on English nasals, stops and the lateral /l/ (reviewed in Krakow 1999) demonstrate that these consonants exhibit a different type of organization when in coda; the timing relationships between their component gestures becomes less stable and there is an overall tendency for secondary articulatory gestures, such as movements of the velum, tongue dorsum or changes in glottal aperture to occur earlier in relation to the sounds' primary oral gesture than when in onset position. As vocal fold abduction normally occurs simultaneously with /s/'s oral gesture (Silverman 1997), the syllable position effect might cause a regressive shift in the sound's glottal opening and thus devoice the preceding unstressed vowel (11a).

Evidence in favor of this explanation comes from the decline in devoicing rates that occurs as word-final syllables ending in /s/ are placed in the final position of progressively larger prosodic domains. It seems reasonable to attribute this decrease in devoicing to phrase final lengthening, or the stretching out and pulling apart of articulatory gestures that has been observed at the boundaries of larger prosodic units (Beckman, Edwards & Fletcher 1992). Such a lengthening of gestures could counteract the syllable position effect by increasing the duration of vowels and moving them farther away from the glottal opening associated with /s/, therefore preventing their devoicing at the ends of intonational phrases and utterances (11b).

(11) a. Word-final [V̥ C] b. Intonation Phrase-final [V C]

Oral Gestures

Glottal Gestures



As the syllable position effect may not occur in all languages and its specific characteristics appear to exhibit cross-linguistic variation (Kochetov 2006), it is appropriately expressed in terms of coordination constraints. However, in this case, the constraints must refer to intra-segmental rather than inter-segmental gestural coordination. While Gafos does not propose any intra-segmental level constraints, he does lay the groundwork for them by noting that the primary oral gesture of a sound should be considered its 'head' gesture with which all other component gestures must be phased. Based on this proposal, HS COORD (12a) expresses the default coordination relationship between the head and secondary gestures associated with a segment. Presumably, in the case of /s/, this relationship would be one of simultaneity as shown in (13a). OG COORD$_{\text{CODA}}$ (12b) represents a head-secondary gesture relationship that might be associated with the syllable position effect. In (13b), we see that this constraint is satisfied when the secondary, glottal opening gesture precedes the head gesture. As in the case of the constraints expressing inter-segmental coordination, OG COORD$_{\text{CODA}}$ is formulated in terms of a phase window in order to accurately represent the gradience and variability of the devoicing process. It is assumed that, in Andean Spanish, OG COORD$_{\text{CODA}}$ outranks HS COORD.

(12a) **HS COORD**: Within a segment, align the Onset of the head (oral) gesture with the Onset of the secondary gesture. (default scheme)

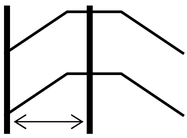
(12b) **OG COORD$_{\textbf{CODA}}$**: Within a segment associated with coda position, align any point ranging from glottal Onset to glottal Center with oral Onset. (context-specific coordination scheme)

(13a) **HS COORD** satisfied
OG COORD$_{\textbf{CODA}}$ violated

[V s]

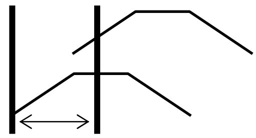
Oral

Glottal



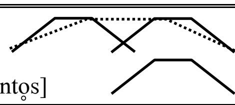
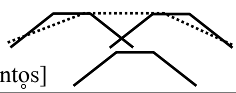
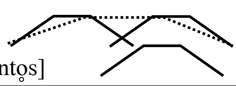
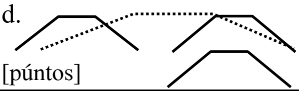
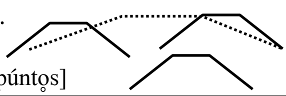
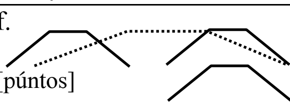
(13b) **HS COORD** violated
OG COORD$_{\textbf{CODA}}$ satisfied

[V̥ s]



In Tableau 4, we see how OG COORD$_{\text{CODA}}$ causes the devoicing of /o/ in a word final syllable. In candidates (a), (b) and (c), adjacent voiceless coronal consonants overlap the vowel sufficiently to cause devoicing, rendering the intra-segmental coordination of the following /s/ irrelevant. However, as all three violate *OVERLAP$_{\text{HET}}$, they are ruled out. Voiced candidate (d) has acceptable inter-segmental relationships, but is eliminated as it violates OG COORD$_{\text{CODA}}$. Candidates (e) and (f) are co-optimal, with (e) producing a devoiced vowel due to the early glottal opening gesture of the following /s/ and (f) producing an acceptable voiced vowel. In the latter case, /s/'s glottal gesture is within the phase window of OG COORD$_{\text{CODA}}$ but still far enough away from the vowel to allow glottal adduction to occur.

Tableau 4. Devoicing of word-final /o/

/púntos/ 'stitches'	*OVERLAP$_{\text{HET}}$V//C	CV COORD$_{\text{A}}$	VC COORD$_{\text{A}}$	OG COORD$_{\text{CODA}}$	HS COORD
a.  [púnto̥s]	*!			*	
b.  [púnto̥s]	*!				*
c.  [púnto̥s]	*!				*
d.  [púntos]				*!	
☞ e.  [púnto̥s]					*
☞ f.  [púntos]					*

4. Conclusion

To summarize, I have argued that gestural coordination constraints based on the alignment schema proposed by Gafos (2002) successfully account for vowel devoicing patterns in Andean Spanish that are not explained by the interaction of rate-based decreases in the temporal distance between gestures and vowel duration. I have proposed that the frequent occurrence of devoicing in slow speech in this dialect follows from CV and VC alignments which permit extensive overlap and that the front mid-vowel /e/ is affected far more often than the back mid-vowel /o/ because degree of overlap is limited by the homorganicity of adjacent segments. High devoicing rates for unstressed vowels preceding coda /s/ are attributed to this consonant's intrasegmental organization. As these hypotheses are based on acoustic data, they of course await confirmation with articulatory measurements. However, according to the information currently available, the gestural alignment constraints proposed facilitate the explanation of this acoustically salient but non-contrastive process.

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