**Production Planning and Directionality in External Sandhi**  
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**Introduction.** Variability has increasingly become a focus in phonological theory, leading to models designed to not only handle variability, but also predict it (e.g. Boersma 1997; Johnson 2002). While it has increasingly become evident that variability is an important part of speech, it is less clear how much variability the phonological theories are responsible for predicting, as some variability may be a consequence of selecting different pronunciation options, while some may be the consequence of articulatory undershoot (e.g. hypospeech in Lindblom 1990) or of speech planning limitations (see Wagner 2012).

The Locality of Production Planning Hypothesis (PPH; e.g. Wagner 2012) seeks to explain why word-internal phenomena are less variable than similar cross-word phenomena. In this model, the reason is simple: word-internal processes only require phonological information that is already available when planning the word, while the phonological context required for a cross-word process may not yet have been planned. For example, flapping a word-final /t/ in English requires the speaker to have planned that the following word is vowel-initial. This means that factors associated with slower production planning (ex. lower lexical frequencies, lower conditional probability) will also lower process application rates because the phonological context may be planned too late.

The PPH’s focus on planning makes an important prediction that has not yet been tested: there should be a difference between sandhi processes that apply in word 1 based on word 2 compared to those that apply in word 2 based on word 1. This prediction results from the fact that, when producing word 1, word 2 may not yet have been planned at a segmental level, meaning that some variability in the process is expected to be due to the variability in whether word 2 was planned. When producing word 2, however, word 1 has necessarily been planned.

In this study, we test the predicted asymmetry between left-to-right and right-to-left external sandhi by examining vowel hiatus resolution in Spanish. Previous work has found that in VV sequences V1 or V2 could delete, with the primary consideration being preserving vowel identity rather than vowel position (e.g. Garrido 2012). Using a mixed-effects logistic regression predicting the automatic classification of VV sequences from spontaneous conversational speech, we test factors affecting the speed of lexical planning (word frequency, conditional probability) on predicting vowel deletion in Spanish, finding a notable directional asymmetry.

**Methods.** We examine 5000 cases of /a#e/ and /e#a/ sequences, chosen because of the preference for /a/ to be preserved in these sequences (Garrido 2012) and because having different vowels in each position allows us to determine which vowel was deleted. These cases, obtained from the Nijmegen Corpus of Casual Spanish (Torreira and Ernestus 2010), were categorised as [e], [a], [ea] or [ae] using a forced aligner augmented with optional phonological rules for vowel deletion in VV sequences. The aligner’s decision to align a vowel or to delete it was then analysed using mixed-effects logistic regression, testing the effects of lexical frequency and conditional probability in predicting vowel deletion associated with vowel identity preferences. We predict that /ea/ will be more sensitive to these planning factors because the speaker must know /a/ is upcoming in order to delete /e/, whereas in /ae/ sequences the preferred vowel is planned first and so by /e/ it is known that deletion is possible.
**Results.** We find that lexical frequency and conditional probability do not have significant main effects; an interaction with vowel order is found. There is, however, a strong preference for /a/ to be preserved over /e/, with /e/ deleted 83.5% of the time and /a/ only deleted 10.0% of the time (p<0.0001). This preference for /e/ to be deleted is modulated by lexical frequency, with /e/ deleting significantly more often when word 1 (p=0.024) or word 2 (p<0.0001; figure 1) is frequent. Looking at the conditional probabilities, we see that /e/ is significantly more likely to be deleted when there’s a high conditional probability (p=0.038). This effect crucially occurs in interaction with a positional effect, with /ea/ showing significant predictability-mediated deletion, but not /ae/ (p<0.001; figure 2).

![Figure 1: The vowel deletion rate based on vowel identity and word 2’s frequency.](image1)

![Figure 2: The effect of conditional probabilities on vowel deletion.](image2)

**Discussion.** We find that conditional probability and lexical frequency mediate vowel deletion rates in a manner consistent with the directionality effects predicted by the PPH. We propose that these effects are not simply the result of frequency-driven reduction alone, as lexical frequency does not have an effect on its own. We instead suggest that these results provide strong evidence for the PPH’s proposal that a speaker’s ability to plan the required phonological context plays a major role in these cross-word phonological processes. We additionally show that automatic classification, a relatively recent methodology in phonological work, can be used to facilitate large-scale studies to better understand variation in casual speech.

**References.**