

Locality and variability in cross-word alternations: a production planning account

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Summary. The alternation in English between coronal stops /t,d/ and alveolar flap when intervocalic is nearly categorical when the VTV sequence is within a word, but is variable when a word boundary intervenes and occurs only rarely across a large boundary such as a clause edge. This pattern is common across many processes cross-linguistically – but *why* are segmental processes at word edges often more variable, and what influences the rate of variability? Previous literature that addressed phonological variability has proposed that phonological rules have to make reference to syntactic structure [6] or that phonological processes are tied to certain prosodic domains [8]. In contrast, we propose that phonological variability is only indirectly influenced by syntax and prosody through the **locality of production planning** (LPP). This hypothesis is motivated based on psycholinguistic models of speech production, and we test its predictions for English flapping in a corpus study and a production experiment. Results show that syntax may have an effect above and beyond prosodic boundary strength, and that the lexical frequency of the *following word* has a significant influence on rate of flapping, consistent with the LPP hypothesis.

Background. The syntactic relationship between two words has an influence on the phonological processes that apply at their juncture. Prosodic Phonology [8] holds that the effects of syntax on phonological phenomena are mediated through prosodic structure. Prosodic phrasing may be variable, and is not necessarily isomorphic to syntactic structure, so variability can be explained by indexing phonological alternations to apply only within certain prosodic domains. This approach predicts that phonological variability will be more closely correlated with prosodic than syntactic boundaries.

Current influential models of speech production suggest that planning may proceed incrementally [7,15]. That is, a word can be planned and uttered without full information about upcoming words. We propose that phonological alternations that rely on information in upcoming words are variable because they cannot ap-

ply if the conditioning environment in the next word has not yet been retrieved and encoded. For example, at the time that a word-final coronal segment is being phonologically encoded, flapping can only occur if the phonological form of the following vowel-initial word that triggers flapping has already been retrieved.

The likelihood of two words being phonologically encoded within the same planning window will be affected by anything that influences the scope of production planning: syntactic, morphological and phonological complexity [12], non-linguistic cognitive load [5], lexical frequency and predictability, and potentially many other factors. Incorporating these effects through production planning rather than as part of the phonological process's description could allow us to maintain a strictly linear description of flapping while still accounting for syntactic, prosodic and frequency effects observed in cross-word phonological alternations.

Hypotheses. Our hypothesis predicts that the more likely that the following word has been planned, the more likely cross-word alternations are to occur. We test three factors that we predict should affect the flapping:

- (1) **Strength of prosodic boundary** - stronger boundary between the stop and the following vowel should reduce the probability of flapping;
- (2) **Strength of syntactic break** - higher level syntactic boundaries should delay planning of the upcoming word and reduce flapping;
- (3) **Frequency of the following word** - higher frequency words should be retrieved more easily and so should increase flapping.

Production experiment. Subjects read aloud sentences containing a nonce word ending in [t] as the verb of an embedded clause. We manipulated whether the nonce word was followed by a vowel- or consonant-initial word, and whether or not a clause boundary followed the target word. Here we analyse only the intervocalic tokens of [t]. Duration of the vowel preceding the [t] was used as a proxy measure for prosodic boundary strength. Panel (A) in Figure 1 shows the empirical correlation between flapping and vowel duration for the two conditions of the syntactic manipulation (following syntactic boundary or not).

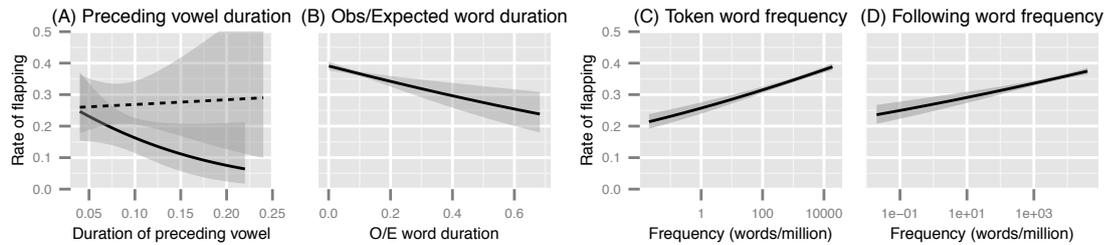


Figure 1: Empirical plots showing correlations with tapping for (A) Preceding vowel duration by *Syntax* (solid = ClauseBoundary, dashed = NoClauseBoundary) in the production exp., (B) O/E duration (see text), and (C) frequency of token word and (D) following word in the corpus study.

Mixed-effects logistic regression with full random effects by participant and item found that *Syntax* significantly predicted flapping ($\beta = 0.98$, $p = 0.032$) and that vowel duration was in the expected direction ($\beta = -0.919$, $p = 0.18$). The interaction was not significant ($p = 0.23$). The two factors were correlated ($r = -0.16$, $p = 0.002$) but model comparison suggested *Syntax* was the better predictor.

Corpus study. To test for effects of lexical frequency we examined flapping in the Buckeye Corpus [11] of conversational speech. We extracted 11,738 tokens of words which end in a vowel then /t/ or /d/ and were followed by a vowel-initial word (34.93% were transcribed as flaps). Word frequencies were retrieved from SUBTLEX-US (words per million) [1]. We tested both the token’s word frequency (Fig. 1 panel C) and the following word’s (panel D). Final lengthening of the token-containing word was measured as a ratio of observed to expected (O/E) duration, calculated by adding together the by-speaker mean duration of each phone for each word. Panel B in Figure 1 shows correlation between lengthening and rate of flapping.

Frequency, Next Word Frequency and *O/E Duration* were analysed as main effects in a mixed-effects logistic regression with random intercepts by speaker and lexical item, plus control predictors. In this model, the probability of flapping is negatively correlated with degree of final lengthening ($\beta = -0.39$, $p < 0.001$), positively correlated with frequency of the word ($\beta = 2.39$, $p = 0.015$), and also positively correlated with the frequency of the *following* word that forms the flapping environment ($\beta = 0.24$, $p < 0.001$).

Discussion. These results show that both spontaneous and lab-elicited speech exhibit patterns of variability that are predicted by the locality of production planning hypothesis. The production experiment results suggest that syntactic boundaries have an effect beyond at least

one of the correlates of prosodic boundaries, and may not be reducible to prosodic domain effects. The LPP provides an interpretation of syntactic effects that maintains strict modularity while accounting for variability within and across syntactic contexts.

The corpus study study showed a positive effect of the *following word’s* frequency. This is straightforwardly predicted by the LPP, while it is not clear that prosodic domain-based theories make any predictions about how word frequency should affect variability.

These results are consistent with studies of variability in word-internal alternations (e.g. [9] for English flapping), and with models that tie reduction directly to predictability, frequency, or conditional probability [10, 2], based on the information-structural intuition that less signal is needed when information content is lower [13, 14]. The proposal here suggests a very different cognitive mechanism for the observed effects, but since condition probability presumably facilitates production planning the predictions are similar. But the production planning hypothesis predicts that same locality and variability should be observed for non-reductive processes – an empirical prediction that will be tested in future work.

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