# PERCEPTUAL BIASES IN CONSONANT DELETION

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## ABSTRACT

We demonstrate that adult English speakers make use of perceptual principles in medial consonant cluster deletion. Cross-linguistically, consonant cluster simplification via deletion is more likely apply to the first consonant rather than the second consonant (if both consonants are of equal sonority). Adult native English speakers, were given a two-alternative forced-choice task in which either C1 or C2 of a C1C2 cluster was deleted. When C1 and C2 were of equal sonority, participants selected C1 significantly more often than chance, but when sonority of C1 was greater than C2, participants selected C1 at chance. These results support a theory in which biases towards phonetically grounded processes shape the cross-linguistic distribution of phonological processes.

**Keywords:** consonant deletion, grounded phonology, perception

## 1. INTRODUCTION

It is widely understood that the majority of phonological patterns share some form of phonetic grounding [1]. Phonological patterns that can be traced to a phonetic precursor, or are found to be phonetically natural tend to be more common cross-linguistically. Thus, the most frequent phonological patterns found in the world's languages are also the ones that are found in the greatest number of language families, and appear to persist diachronically.

However, it is unclear what mechanisms underlie the relationship between phonetics and phonology. Moreton [4] differentiates between two ways in which phonetic biases can infiltrate linguistic typology: channel bias and analytic bias. In channel bias, phonetically grounded phonological patterns emerge as cross-linguistically frequent due to misperception in the learning process. As languages are passed from one generation to the next, learners may misinterpret sounds, and reanalyze them to conform to phonetically natural patterns [2, 5]. In channel bias, the phonetically natural rules that emerge over time are not a psychologically real aspect of the speaker. In analytic bias, phonetic grounding emerges through psychologically real constraints on online language learning and processing. The exact nature of these constraints is still unknown, but include perceptual and grammatical constraints on language.

The present paper demonstrates the importance of phonetic grounding in phonological processes. If phonological processes show phonetic grounding, then listeners without specific knowledge of a particular phonological constraint will make use of perceptual constraints that govern phonologically natural instances of the phonological process. Listeners should therefore prefer the grounded variant to the ungrounded variant. We provide evidence for phonetic grounding in consonant cluster deletion; listeners make use of perceptual weakness when making decisions about consonant cluster simplification.

## 2. PHONETIC NATURALNESS IN DELETION

Wilson [9] makes the typological claim that: "Across languages, deletion processes that apply to intervocalic biconsonantal clusters consistently delete the first consonant (schematically, VCIC2V → VC2V)." (p. 148). This means that if a language deletes a consonant cluster, it is more likely to delete the first consonant, rather than the second consonant. For example, in Diola Fogny, when two consonants combine as a result of morphological concatenation, the first consonant will delete (e.g., /let-ku+jaw/ → [lekujaw] 'they won't go').

The main reason cited for deletion of the first obstruent consonant over the second obstruent consonant is perceptual. Given a consonant cluster in which one consonant is perceptually weaker than the other, speakers will prefer to modify the weaker consonant, to make it stronger (via assimilation) or to delete the consonant [7, 8]. One reason for this preference is diachronic (e.g., channel bias). Over time, consonants in weak position will be deleted or altered to be more perceptible, and the language will phonologize the

phonetically small changes into a phonological deletion pattern [2]. A second reason for the preference to delete weak consonants is based on real-time language-specific phonological repairs (e.g., analytic biases). If a language has a constraint against consonant clusters, there are several options for repairing the cluster to satisfy this constraint. If the language repairs illicit clusters via deletion, there must be a method for deciding which consonant to delete. This decision is based on perception: delete the perceptually weakest consonant. Wilson [9] formalizes this tendency into an Optimality Theoretic [6] constraint NOWEAKCONSONANT. This constraint helps to formalize the preference for deletion of the weakest consonant (C1) in a cluster.

Wilson's [9] formalization of consonant deletion focuses solely on obstruent-obstruent sequences, and ignores complications that arise when the two consonants are of differing sonority. Perceptual strength in syllable final position increases with sonority. Thus, if C1 is more sonorous than C2, C2 may be perceptually weaker than C1, meaning that C2 may actually be the preferred sound to delete. This is further complicated by the fact that an orthogonal constraint preferring obstruent onsets creates a preference for deletion of the more sonorous segment in a consonant cluster. This interaction suggests that in a language that uses perceptual weakness as a basis for consonant deletion, it is not necessarily clear what will happen the two consonants are of unequal sonority.

A good language to test the effects of perceptual weakness in consonant cluster deletion would be a language that deletes consonants in weak position, but not in word-medial clusters. English has precisely this property. English shows variable consonant deletion in word final position. For example, in many dialects (particularly in fast speech) the final stop (especially /t/) of a word will be deleted or reduced to a glottal stop (e.g., the /t/ in /kaet/) may be deleted, or the final /s/ of a plural form (e.g., the /s/ in /kaets/) may be deleted. In all cases, the consonant is in word final position, a weak position for obstruent consonants. Because deletion is not categorical, and does not apply to word-medial consonant clusters, English speakers will have knowledge of deletion of obstruents in weak position, but not necessarily consonant deletion in word medial clusters. In this situation, it is possible to test biases towards deletion of C1 versus C2 in a word-medial clusters, and control for effects of sonority. The present experiment demonstrates that English speakers are biased towards deletion of the initial consonant in word-medial clusters when both consonants are of equal sonority. However, this bias disappears when the first consonant is more sonorous than the second consonant.

## 3. THE EXPERIMENT

The present experiment explores English speakers' biases to consonant deletion, using a two-alternative forced choice task, choosing between deletion of C1 of a consonant cluster or C2 of a consonant cluster. If speakers prefer C1 deletion to C2 deletion when C1 and C2 are of equal sonority, it suggests that English speakers use perceptual weakness as a strategy for consonant cluster simplification.

### 3.1. Methods

#### *3.1.1. Participants*

Participants in Experiment 1 were adult monolingual English speakers from the University of Rochester community, and were paid $5 for their participation. No participant had participated in an experiment involving consonant deletion.

#### *3.1.2. Design*

Participants were given 28 two-alternative forced choice items with consonant deletion. One of the items deleted C1 of a consonant cluster (natural deletion), while the other item in the test item showed deletion of C2 of the consonant cluster (unnatural deletion). All stimuli items were drawn from Finley [3], in a previous experiment using an artificial grammar learning setting.

#### *3.1.3. Materials*

Each item in the two-alternative forced-choice task was a triple: CVC, CVC, CVCVC. Participants were told that they would hear two sets of three words where the third word was a combination of the first two (given *tooth*, *brush*, *toothbrush* as an example), and their job was to select which set of three non-words they preferred (they were told that there was no right or wrong answer).

All stimuli were designed so that the final consonant of the first CVC word was different from the first consonant of the second CVC word. For example, [pik ket] was not a possible pair of

words in the experiment because it would be impossible to tell which consonant was deleted.

All consonants were drawn from the set [p, t, k, b, d, g, s, f, z, v, m, n], and vowels were drawn from the set [a, i, e, o, u]. We included items in which both consonants were stops (SS), items in which both consonants were fricatives (FF), items in which the first consonant was a nasal and the second consonant was a stop, and items in which the first consonant was a fricative and the second consonant was a stop (FS). When the sonority of the two obstruents is equivalent (SS and FF items), the weak consonant should be the first consonant, and therefore undergo deletion. When C1 is a fricative and C2 is a stop, the relative weakness between consonants is less clear. Because fricatives do not rely on a burst for their place of articulation to be perceived, fricatives in coda position are less weak than stops in coda position. This means that the preference for deletion of C1 should decline when C1 is more sonorous than C2.

**Table 1:** Examples of Experimental Items

| Condition | C1 Deletion | C2 Deletion |
|---|---|---|
| SS | bek dab bedab | bek dab bekab |
| FF | fev sof fesof | fev sof fevof |
| FS | dis taf titaf | dis taf disaf |
| NS | zin baf zibaf | zin baf zinaf |

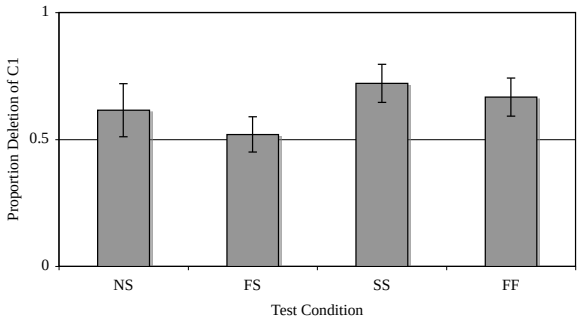
An adult female speaker of English recorded the stimuli used for the experiment in a sound-attenuated booth. The speaker was not aware of the purpose of the study, and was told to produce all sounds as clearly and accurately as possible. All stimuli were normalized to 70db.

If speakers use their knowledge of weakness the consonant in medial clusters, they should prefer deletion of C1 when both consonants are of equal sonority. When C1 has higher sonority then C2, we expect this bias to diminish, disappear, or even reverse. If speakers select C2 over C1, it suggests that speakers are more faithful to the onset of the input words.

### 3.2. Results

We recorded the number of times participants chose the natural (C1) deletion pattern over the unnatural (C2) pattern, as reported in Figure 1. Overall, when C1 was the same sonority as C2, participants selected C1 significantly greater than chance. When both consonants were fricatives, participants selected C1 66% of the time, which is significant by a one-sample t-test ($t(12) = 2.21$, $p < 0.05$). When both consonants were stops, participants preferred deletion of C1 72% of the time, which is significant by a one-sample t-test ($t(12) = 9.94$, $p < 0.05$).

**Figure 1:** Results: Means and Standard Errors




When C1 was more sonorant than C2, participants did not choose deletion of C1 significantly more often than expected by chance. While participants trended towards deletion of C1 to C2 (62%) when C1 was a nasal consonant, the difference was not significantly different from chance ($t(12) = 1.10$, $p = 0.29$). This is largely due to high variation and small number of test items. Of the 13 participants, four participants selected C1 less than 30% of the time. This suggests that this group of participants were relying on a constraint preferring deletion of weak obstruent consonants, while the majority of participants relied on the constraint preferring obstruents in onset position (one participant selected C1 50% of the time and therefore had no preference).

When C1 was a fricative and C2 was a stop, participants preferred deletion of C1 an average of 52% of the time, which was not significantly different from chance ($t(12) = 0.28$, $p = 0.79$).

### 3.3. Discussion

This paper demonstrated that adult English speakers are biased towards natural consonant deletion. When a consonant cluster is simplified through deletion, the first consonant is more likely to be deleted when both consonants are obstruents of equal sonority. When there is a mismatch in sonority between the two consonants, the perceptual constraints are more complex, as additional constraints on syllable structure and perceptual salience can reduce this bias. Participants were given a two-alternative forced-choice task between deletion of the first consonant of a cluster and deletion of the second consonant of a cluster. Participants chose deletion of the first consonant significantly more often than chance for

items in which both obstruents were of the same sonority. When sonority differed between the two stops, there was no difference, suggesting that speakers make use of phonetically grounded constraints in consonant deletion.

## 4. GENERAL DISCUSSION

The results of the present experiment demonstrate that English speakers extend their knowledge of partial consonant deletion in final position to medial clusters. These results support phonetically grounded constraints on medial consonant cluster neutralization. Because the preference for deletion of C1 to C2 is based on the fact that C1 tends to be perceptually weaker than C2, one should expect that in cases when C2 is perceptually weaker than C1 (i.e., there is a sonority difference), C1 is less likely to delete. This was the result we obtained: participants preferred deletion of C1 only when C1 and C2 were of equal sonority; when C1 was more sonorous than C2, the bias was reduced.

The results of the present experiment bear on the source for the preference of C1 over C2 in consonant deletion. The fact that adult speakers show a preference for deletion of C1 over C2 suggests that this preference is psychologically real, and part of the linguistic knowledge of adult speaker. Participants made their choices between C1 and C2 in real time, it supporting a model of phonology in which perceptual processes affect online phonological repairs.

While the present paper discusses the role of perception in consonant deletion, it is important to acknowledge that production can play an important role in consonant deletion. One question for future research is to extend the results to a production task, specifically teasing apart the roles of production and perception in biases for various phonological processes.

Another question for future research concerns the role prior knowledge of deletion in the present experiment. While English does not have cluster simplification of the type studied in this experiment, there are perceptually motivated deletion processes in English. It is unclear whether the results are a factor of the fact that English speakers have experience with deletion of perceptually weak consonants, or if preference for deletion of perceptually weak consonants is a result of universal preferences that would be found in languages with no deletion. Future research will test speakers of language with no deletion.

A final question for future research concerns the role of phonetic factors in learning. Finley [3] showed that learners are able to learn a general consonant deletion pattern, and generalize that pattern to different types of consonant classes. Participants were able to learn the phonetically unnatural deletion pattern (deletion of C2 over C1 in obstruent-obstruent pairs), suggesting that biases can be overcome if learning a relatively simple pattern like consonant deletion.

The present paper addressed the role of perceptual factors in consonant deletion. English speakers preferred deletion of perceptually weak consonants, suggesting an important role of perceptual factors in phonological processes.

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