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PHONETIC EFFECTS ON AMERICAN ENGLISH FLAPPING: THE ROLE OF CONSONANT REPETITION

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The American English phonological flapping rule results in the weakening of /t/ phonemes when isolated in onset position between stressed and unstressed syllables (obligatorily) or two unstressed syllables (optionally). The productivity of the flapping rule is already known to vary depending on several different factors. I present here a pair of phonetic production studies suggesting that consonant repetition is one of those factors. Flapping is dispreferred if a sequence of multiple flaps would result.

Key words: phonetics, English, flapping, repetition, OCP

In this paper I present a pair of production studies that demonstrate gradient variation in phonological rule application (North American English flapping). The use or non-use of the flapping rule depends partly on phonological goodness as measured by the degree of violation of the Obligatory Contour Principle (OCP).

Flapping is a characteristic rule of North American English in which /t/ phonemes are pronounced as flaps obligatorily when appearing as isolated consonants in onset position at the start of a syllable, when the preceding syllable is stressed and the syllable initiated by the flap is unstressed. An example is the /t/ phoneme in the word *water*. The orthographic /t/ must be pronounced as a flap rather than a full /t/. Flaps also are used optionally when they are isolated consonants in onset position between two unstressed syllables. An example is the /t/ phoneme in the word *quality*. The orthographic /t/ in this word may be pronounced as a full /t/ or as a flap. Flaps are much shorter in duration than full /t/ allophones, and voicing may continue throughout the production of the flap. Flaps are also typically retroflex. The following two spectrograms demonstrate the acoustic difference between full /t/ (Figure 1) and a flap

(Figure 2). The location of each flap is indicated with an arrow underneath. Notice that even on a smaller time scale, the duration of the full /t/ in Figure 1 is of considerably longer duration than the flap indicated in Figure 2. In addition, the voicing bar is hardly interrupted for the flap in Figure 2, whereas the whiter space (indicating less noise) during the arrow-indicated interval is much more prominent in Figure 1 for the full /t/.

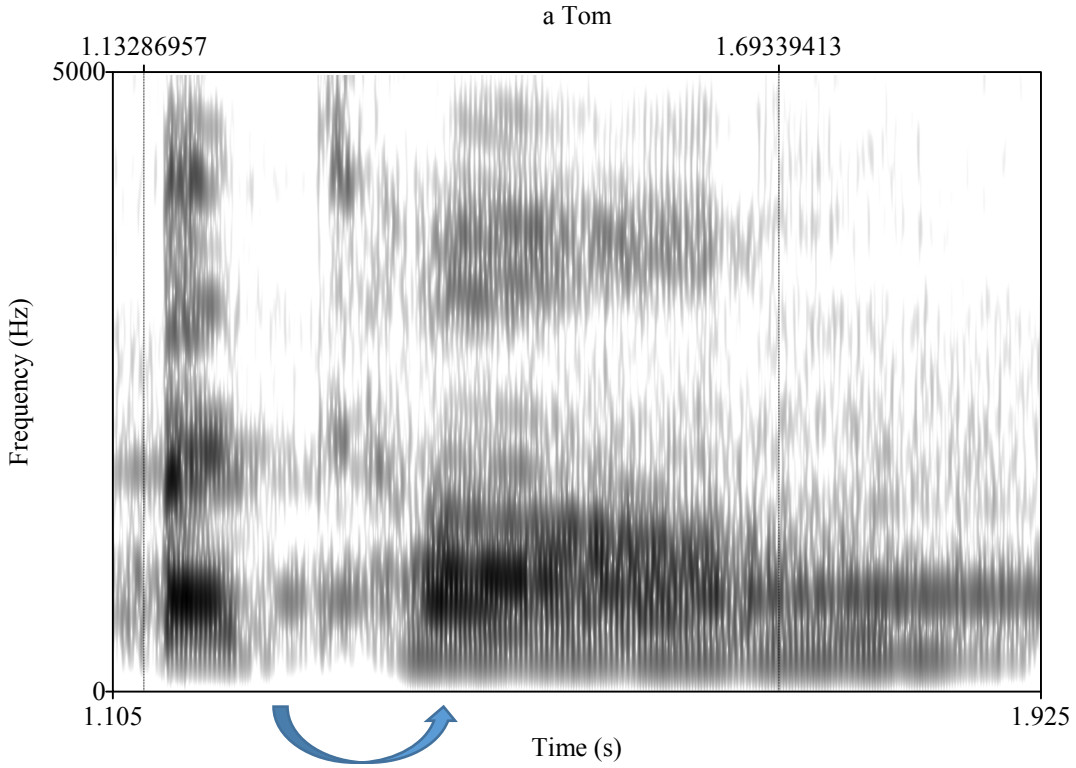

Figure 1. *Spectrogram of "a Tom," produced with full /t/*

Previous work has shown that American English speakers are alert to these cues and are highly reliable in identifying flapped versions of /t/ (Patterson and Connine, 2001). Such work has also identified several factors which influence the likelihood of flapping in optional contexts (between two unstressed syllables). In such contexts, flapping is sensitive to the presence of a morpheme boundary, lexical frequency, and speech rate (Patterson and Connine, 2001). Flapping is less likely when it coincides with a morpheme boundary within the word. Thus, all else being equal, /t/ is more likely to be flapped in the word *quality* (the /t/ is inside a single suffix) than in the word *auditor* (/t/ is at the boundary of the root *audit* and the agentive *–or* suffix). Flapping is also less likely in words that are less frequent. Thus, flapping of the /t/ is less likely for a word like

auditor than for a similar but more frequent word such as *editor*. Finally, flapping is less likely in slow and careful speech. The same speaker may flap or not flap the /t/ in the word *editor* depending on the formality and carefulness of his or her speech at a given moment.

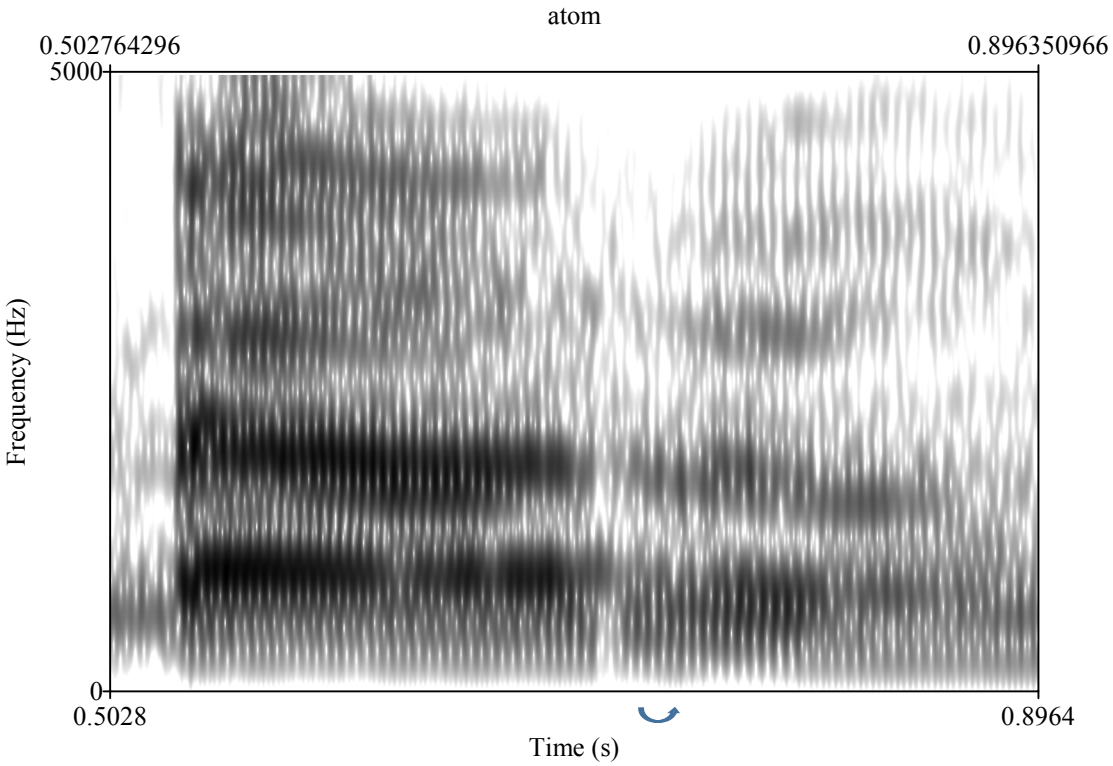

Figure 2. *Spectrogram of "atom," produced with flap*

It is the contention of this paper that the similarity of the preceding consonant to a potential flap is one of the factors affecting the rate of optional flapping application, and that flap sequences are avoided when possible. This type of repetition-sensitive behavior is often described under the umbrella of the OCP, or Obligatory Contour Principle. The OCP was introduced by Leben (1973) in relation to tonal phonology, in order to describe pitch sequences in languages with phonemic tone. Such languages often have rules which result in sequences of different tones/pitches rather than repetitions of the same one over and over. In its weak form, the OCP states that repetition of similar elements is dispreferred. Researchers quickly noticed that such repetition-avoiding rules frequently occur for other phenomena as well, particularly in relation to consonant repetition (Yip, 1988). Subsequent research showed that avoidance of repetition does not only motivate categorical phonological rules, but also influences the statistical likelihood of different combinations of consonants in the

lexicons of the world's languages (Frisch, Pierrehumbert, Broe, 2004). Thus, roots are less likely to contain identical or similar consonants in close proximity, compared to what is otherwise expected from random combination of consonants according to their individual frequency in the language. Something like the OCP is also known to influence optional allomorphy and lexical choice (Mondorf, 2009, Walter and Jaeger, 2008). Suffixes are used less often when similar to the preceding root consonants, as with the English comparative *–er* suffix. Berkley (1994) has shown that the *–ity* suffix applies less frequently to roots ending in consonants like /t/ and /d/, similar to the suffix consonant itself. And the optional English relativizer *that* is used less often in sentences when it would precede pronominal *that*, such as *I think (that) that is interesting*.

I argue that since OCP-like, repetition avoidance behavior is known to influence grammars in a gradient fashion, it may also influence the likelihood of optional rule application. The application of the flap rule in optional contexts is the perfect test case for this hypothesis. The two studies described in this paper examine whether flapping rates vary according to the degree of similarity between neighboring consonants.

In the first study, native American English speakers (n=8) recorded wordlists containing a sequence of first an obligatorily-flapped coronal stop, then an optionally flappable one.

The subject pool includes 4 females and 4 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psyscope software (Cohen, MacWhinney, Flatt, Provost, 1993). Additional nonce words were included in the stimulus set as distractors. Stimuli were read aloud in the inflecting frame sentence given below:

1) Stimulus sentence:
She kawdids a lot. She's a kawdider now.

Utterances were digitally recorded in a sound-proof booth and analyzed using the Praat software program for acoustic analysis (Boersma, Weeninck, 2013).

Stimuli consisted of disyllabic stress-initial non-words with full vowels in the initial syllable and the short lax [ɪ] vowel (possibly reduced schwa) in the second. The surrounding vocalic and consonantal segments

permuted according to place and quality among the segments shown below:

2) Stimuli (orthographic)

k p s	aw ee oo	d t	i	d t

3) Stimuli (IPA)

k^h p^h s	ɑ i u	d t	ɪ	d t
		C1	V	C2

A context involving repetition (REP) occurs when C1 and C2 share underlying phonemic identity (both [d] or both [t]). The number of stimulus types totals 36, each of which is produced twice per speaker (in different inflectional/derivational forms), resulting in a sample of 72 test items for each subject.

The C1 coronal occurs in an obligatory flapping environment in both forms (in a stressed-unstressed syllable sequence). Thus the orthographic representation supplies the only indication as to the C1 flap's underlying status as [t] or [d]. The C2 position, however, allows for variation in production both across and within forms. For the verbal form (*kawdids*), C2 must be pronounced faithfully as [t] or [d]. For the nominal *-er* suffixed form, however, C2 occurs in an environment for which flapping may occur. Flapping is optional in this context (between unstressed syllables). It is further inhibited by the presence of a morpheme boundary, and by its occurrence in a novel nonce word. Low lexical frequency is known to correlate with a lower flapping rate, and I assume that non-words are treated as maximally infrequent (Patterson and Connine, 2001). These factors, in addition to the formal setting of a laboratory environment, should be conducive to lack of a ceiling effect for flapping so that observable variation results in this environment.

The nominalized form, then, provides the crucial environment of interest to us: a series of two consecutive flappable segments. For this set

of 36 items, each C2 token was classified by the author as flapped or unflapped through auditory inspection. A dissimilation-type repair between identical consonants could manifest as lower flapping rates where such variation is possible. The duration of the flappable segments was also measured following the procedure of the duration measures in the previous experiments. Variation in duration is a potential correlate of the extent of flapping when it is unclear perceptually, especially for flapped [d].

This experiment constructs a context in which some dissimilation of the place gesture is permitted via an optional allophonic alternation (English flapping), to see if its optional application rate is modulated by the presence of a neighboring homorganic oral stop consonant. If repetition avoidance is motivating flapping likelihood, then flapping rates should be lower than normal after another flap. The second, optionally-flapped consonant should be less often flapped than otherwise expected.

This experiment yielded a positive result in the sense that flapping occurred significantly less often than normal, even when it should have been obligatory. Subjects showed extreme sensitivity to repetition in that they experience great difficulty in producing sequences of flaps at all, regardless of their underlying phonemic identity. This difficulty exists to such an extent that only two speakers, from the subject pool of 8, completed the task as instructed. Both subjects consistently flapped C2, so that no significant variation in flapping rate according to consonant identity is observed.

All subjects accurately produced two pre-test items in the desired fashion. Subjects 1 and 2 continued to do so for the full course of the experiment. However, Subject 3 immediately changed production type upon beginning experimental trials. Medial C1 [t] (koo**t**id) was consistently produced without flapping, even though the environment should make flapping obligatory. Subject 4 also produced stimuli in a 'compound'-type fashion from the very beginning. In addition, main stress is shifted to the second syllable for this speaker. Subjects 5 and 6 also produced unflapped C1 throughout the experiment. Subject 7 was not so consistent. The status of C1 as flapped or unflapped was unpredictable, but this variation still precluded experimental analysis of this subject's data. In addition, the vowel quality of the second syllable was anomalous for this subject, often being produced as a full tense [i] vowel. Finally, Subject 8 shifted stress rightward to the second syllable as Subject 4 did, with concomitant loss of the possibility of flapping C1. Subject 8 also joined Subject 7 in changing the quality of the vowel. The lax [ɪ] persists in some

cases, but more often it is rendered as tense [i]. Occasionally [u] surfaces instead, for stimuli in which this is also the vowel of the initial syllable.

Thus the most frequent response was for subjects to produce the disyllabic stimuli as compounds rather than as single stems. This results in equal stress assignment to the two syllables, and loss of the flapping environment for C1. Two subjects instead reassigned primary stress to the second syllable, with the same result as far as flapping is concerned. This strategy may have been inadvertently facilitated by the form of the stimuli, as the syllables sometimes are separable into independent English words (e.g. left-edge paw, saw, see; right-edge did, tit; non-orthographically, left-edge koo and soo).

Durational measures of both consonants similarly fail to vary.

	REP	**sd**	**non-REP**	**sd**
C1	32	9	32	9
C2	49	12	51	15

Figure 3. *Mean C1 and C2 durations and standard deviations (in milliseconds) by context*

Duration is much longer in a context for which flapping is optional (C2), despite the consistent percept of flapping in both environments. However, no durational change is associated with underlying identity of flaps. It is not the case that C2 is flapped less often or that it is less "flaplike" in contexts with identical consonant repetition than otherwise.

In sum, subjects showed extreme sensitivity to flap repetition in that they experienced great difficulty in producing sequences of flaps at all, to the extent that only two speakers completed the task as instructed. The remaining six subjects avoid potential double-flap sequences primarily by shifting stress so as to preclude flapping in one of the contexts.

In the second study described in this paper, American English speakers (n=8) were digitally recorded in a quiet room using the Praat software program for acoustic analysis (Boersma, Weeninck, 2013). All participants had vision normal or corrected to normal, and none reported hearing, language or neurological disorders. Informed consent was obtained from all participants. The recordings consisted of a wordlist of 100 English words. Sixty of the items were *–ity*-suffixed words, and the remaining 40 words were distractors of similar prosodic form. Stimuli were interspersed with distractors in random order, varied for each

participant. Participants read aloud the wordlist from a printed sheet two times – first in careful speech, second in casual speech.

The 60 *–ity*-suffixed words from a limited lexical frequency range, divided evenly into six groups according to stem-final consonant: [d n l r s labial (m/w/v)]. Example tokens include: *commodity, insanity, agility, seniority, ferocity, depravity/annuity/proximity*. All stimuli were quadrisyllabic with stress on the second syllable, and none contained syllable clusters at the pre-suffix boundary. All were attested in either the Kucera-Francis (Francis, Kucera, 1979) or Thorndike-L (Thorndike, Lorge, 1944) corpora of written English, with frequency values of up to 15 or 50, respectively. Distractors were also quadrisyllabic with second-syllable stress and fell within the same frequency range.

The crucial variable was the flapping rate of the /t/ in the *–ity* suffix. This consonant is optionally flapped in this environment. The working hypothesis was that flaps will be produced less often after consonants more similar to flaps. In this case, the four voiced coronal consonants [d n l r] are more acoustically and articulatorily similar to flaps than the voiceless fricative [s] or the labial consonants.

Overall flapping rates varied considerably between participants, ranging from one who flapped only 2% of flappable tokens, and one who flapped 100% of flappable tokens. Data from the 100% flapper was excluded from the analysis, as it was uninformative regarding variation on flapping rates depending on preceding consonant.

Analysis of the remaining 7 participants shows that the hypothesis concerning stem-final consonants and flapping rate is borne out. Flapping occurred least often after the four voiced coronal consonants [d n l r]. Flapping was more frequent after [s], and most frequent of all following one of the labial consonants [m w v]. Relative flapping rates averaged across subjects are shown in Figure 4 below.

Overall flapping rates range from barely over 10% after the coronal nasal, to one-third of all tokens (34%) after labial consonants. The special status of the coronal nasal may be due to the fact that American English also includes a flapped variant of /n/. However, the voiced coronal stop [d] appears not to have any special status with respect to flapping rates, despite the fact that it is obligatorily flapped in the stimulus set.

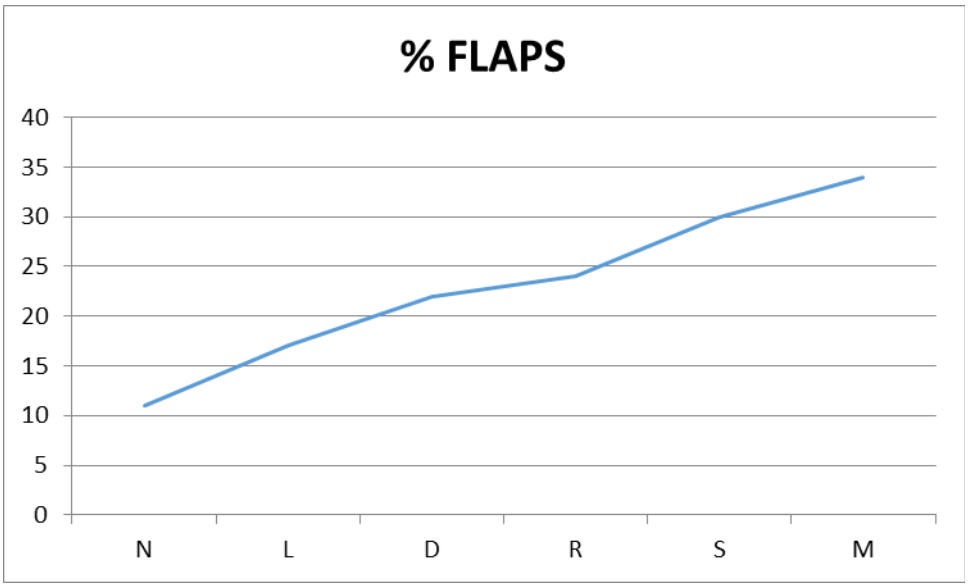

Figure 4. *Percentage of –ity flaps according to preceding consonant type*

Figure 5 displays the flap percentages in tabular form, below.

CONS	% FLAPS
N	11
L	17
D	22
R	24
S	30
M	34

Figure 5. *Percentage of –ity flaps according to preceding consonant type*

Within-subject analysis reveals behavior consistent with the averages. For example, the participant who flapped only 2% of flappable tokens (4 items), produced these 4 flaps only for /s/-final and /m/-final roots.

Subjects flapped most often after labial consonants, somewhat less for /s/, and least of all for the other four coronal consonants. Thus, flapping is avoided next to consonants which are more similar to flaps. In sum, flapping increases as similarity with the preceding consonant decreases.

The studies reported in this paper demonstrate that flapping joins the large number of phonological patterns enforcing a lack of phoneme or featural repetition (so-called “OCP effects”).

Berkley's (1994) previous work showed that likelihood of *–ity* affixation in the first place is related to the nature of the final stem consonant. Derrick and Gick (2009) have shown that when flap sequences do occur, they are articulatorily distinguished from one another such that only one is produced as a retroflex consonant. These phonetic studies show that similarity may also be avoided by flapping only one consonant in a potential flap sequence. Alternatively, as in Study 1, phonological repairs may be undertaken so as to eliminate the context for a potential flap sequence. Taken together, these findings constitute an example of OCP-driven probabilistic variation in rule application. They also identify a new factor influencing the (non-)application of the American English flapping rule.

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