(In)complete flapping through polysyllabic shortening in English

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Recent studies have shown that not only does the applicability of phonological rules vary but also their realization is gradient (English flapping: Eddington and Elzinga 2008). Unlike this trend, the present study reports an interesting counterexample that the application of English flapping is categorical in production, endorsed by the substantial confusability of flapped words with underlying intervocalic /t/ and /d/ in identification task. Fox and Terbeek (1977) show that duration of a flap consonant does not differ in the flapped words ('wr**i**[ɾ]ing' vs. 'r**i**[ɾ]ing'), but duration of the preceding vowel is significantly different. They suggest that the flapping rule follows the vowel lengthening induced by word-final voiced /d/. Additionally, Steriade (2000) shows an invariant allophonic [ɾ] across morphologically related words (Phonetic Uniformity paradigm: *cápit[ɾ]al*, *capit[ɾ]alístic*), whereas Riehl (2003) presents contradictory findings against phonetic paradigm for a flap. Given that, this study investigated whether flapping is incomplete in contemporary English with respect to a multitude of acoustic correlates of flaps in view of both production and word recognition, and attempted to testify to phonetic uniformity by exploring whether phonetic properties of underlying /t, d/ are preserved in the flapped words.

Fifteen native English speakers participated in a reading task with 24 minimal pairs of word-final /t, d/ words (e.g., 'bead' vs. 'beat') and 24 minimal pairs of (flapped) words (e.g., 'beading' vs. 'beating') as exemplified in (1). Additionally, word identification tests were conducted with eight English speakers with two types of listening stimuli: (i) the whole word recognition ('beating' vs. 'beating') and (ii) the 1st syllable recognition (audio input [bea] in 'beating' vs. [bea] in 'beading').

(1) a. underlying voicing contrast

*bea**d***	*bea**t***
*see**d***	*sea**t***
*be**d***	*be**t***

b. flapped words with underlying /t, d/

*bea**d**ing*	*bea**t**ing*
*see**d**ing*	*sea**t**ing*
*be**dd**ing*	*be**tt**ing*

First, as for production, we replicated the striking differences in the phonetic correlates of word final voicing contrast (2). There were significant differences in duration of the preceding vowel, duration of stop closure, duration of voicing during closure, and the rates of stop burst release. However, these contrasts were incompletely neutralized in flapped words as in (3). Specifically, there were significant differences in duration of the preceding vowel, flap closure duration, and duration of voicing perturbation whereas no differences were found for VOT and F0 of the preceding vowel.

(2) Phonetic correlates of word final voicing

UR cons.Type	Dur. of prec. V (ms.)	Stop clos.dur.(ms.)	Voicing dur.(ms.)	% of stop burst
/t/ words (*write*)	146	100	3.0	65
/d/ words (*ride*)	227	54	42.4	96
	F[1,28]=76.1, p<.0001	F[1,27]=3217, p<.0001	F[1,26]=43.7,p<.0001	F[1,28]=9.28, p=.005

(3) Phonetic correlates of flaps

UR cons.Type	Dur. of prec. V (ms.)	Flap clo. dur. (ms.)	Voicing Dur. (ms.)	VOT (ms.)	F0 of prec.V (Hz)
/t/ words (*writer*)	115	18	18	25	161
/d/ words (*rider*)	130	25	24	15	161
	F[1,27]=8.1, p=.008	F[1,27]=6.3,p=.01	F[1,27]=6.2,p=.01	F[1,27]=3.8, p>.05	F[1,27]=.0,p>.05

These findings are, to some extent, consistent with Fox and Terbeek' incomplete flapping in terms of duration of the preceding vowel. The results of our study provide interesting phonological implications. First, they imply that vowel lengthening seems to precede flapping in derived words with /t, d/ final bases. Of course, the duration of a vowel preceding a flap is markedly shortened in words with underlying /t, d/ to the level of short vowels, but the polysyllabic shortening does not utterly eliminate the length contrast. Accordingly, the opacity problem seems to be still alive for vowel lengthening because of keeping the trace of longer vowel of /d/ based words. In optimality theoretic approach, this opaque interaction can be

solved in many ways such as OO-correspondence (V-length contrast). Secondly, the results imply that the concept of phonetic uniformity between base words and derived words might vary depending on each phonetic property). This lack of phonetic uniformity involving flap closure duration, VOT and F0 for /t/-/d/ contrast provides additional evidence challenging phonetic uniformity and against connectionist models (Seidenberg 2005).

Additionally, identification test confirms the complete application of flapping as revealed in the production mode with 24 native speakers of English. Words with final /t/ and /d/ were more accurately and rapidly identified (with accuracy 98% and RT 1.65 sec.) than those that undergo complete flapping. That is, the rates of word recognition sharply decreased for flapped words. Words with underlying /t/ were recovered at chance level, whereas those with underlying /d/ were comparatively higher (50% vs. 67%).

(4) Recoverability of underlying /t, d/ words

	/t/ final (e.g., 'write')	/d/ final (e.g., 'ride')	Words with UR /t/ (e.g., 'writing')	Words with UR /d/ (e.g, 'riding')
Accuracy (%)	98	98	50	67
Reaction time (sec.)	1.6	1.7	2.0	1.9

This difference in recoverability is interesting, considering that there were no statistically significant differences in all the phonetic properties of vowels flanking flaps in words with underlying /t/ and /d/ as seen in (5). One possible source can be located in the average duration of the vowel preceding the flap. The vowel length was slightly longer (15 ms.) before flapped words with underlying /d/ than before those with underlying /t/. Overall results indicate that native English suffer substantial difficulty in recovering words that underwent incomplete flapping unless they are assisted with the broader contexts.

(5) Acoustic properties of listening word stimuli

UR C-Type	Dur. of prec. V (ms.)	Flap dur. (ms.)	Voicing Dur. (ms.)	VOT (ms.)	F0 of prec.V (Hz)
/t/ words (*writer*)	115	20	20	14	156
/d/ words (*rider*)	123	20	20	12	163
	p>.05	p>.05	p>.05	p>.05	p>.05

Finally, it was found that when listeners were presented solely with the first syllable preceding the flapped sound, they had difficulty in recovering the whole words with underlying /t/ and /d/ as in (6) (e.g., auditory input [bi]-> choose 'beading' or 'beating'). This also indicates that absence of contrast in the length of vowel preceding the flap accounts for the greatly low degree of identifiability of flapped words.

(6) Recoverability of underlying /t, d/ words based on the 1st syllable alone

	Words with UR /t/ (e.g., 'writing')	Words with UR /d/(e.g, 'riding')
Accuracy (%)	60	53
Reaction time (sec.)	1.8	1.8

In summary, our study revealed incomplete final devoicing and incomplete flapping along with polysyllabic shortening in English, along with suggestion that phonetic paradigm uniformity is not as typical as phonological paradigms and that phonological opacity still emerges for vowel lengthening.

Selected references

Fox, R.A., and D. Terbeek. (1977). Dental flaps, vowel duration and rule ordering in American English. *Journal of Phonetics* 5, 27-34.

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