Aspiration and the gradient structure of English prefixed words

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ABSTRACT

Building on work examining the phonetic properties of prefixed and pseudoprefixed English words (*mis-times* vs. *mistakes*), we investigate aspiration in 110 English words beginning with *mis-* and *dis-*, produced by 16 native speakers of American English. We find that some items show considerable cross-speaker variation, but most are stable. Aspiration can occur even before an unstressed syllable (*dis-[*p^h*]ossessed*), suggesting that not only word-initial but also some stem-initial voiceless stops are aspirated in English, either because of their prosodic position (prosodic-word-initial) or because of influence of the stem's freestanding pronunciation. Frequency factors correlate with an item's propensity to aspirate, supporting the view that whole-word and decomposed representations compete.

Keywords: English, aspiration, affixed words, variation, frequency

1. INTRODUCTION

In English, the voiceless stops /p, t, k/ aspirate when word-initial, regardless of whether they are in a stressed or unstressed syllable: *[*p^h*]otáto*, *[*p^h*]ásta* [8]. They also aspirate when initial in a stressed syllable: *po.[*t^h*]á.to*; but not when non-initial in the onset: *s[t]áte*. Ogden et al. [9] argue that morphological structure affects aspiration via syllabification: in prefixed *mis.-[*t^h*]ímes*, the morpheme boundary gives rise to a syllable boundary; /t/ is initial in a stressed syllable and thus aspirated. By contrast, in monomorphemic *mi.s[t]ákes*, /t/ shares its syllable onset with /s/.

Using 5 speakers of Southern British English, [2] and [11] examine in detail the phonetic properties of eight prefixed words like *mistimes*, *distrusts*, and eight pseudoprefixed words like *mistakes*, *displayed*. They find that prefixed words have longer voice onset time (VOT); longer duration for the prefix+VOT interval; a longer, fronter prefix vowel; a shorter prefix /s/; and, for *mis-*, higher amplitude of the following stop burst and aspiration. Moreover, [5] shows that these acoustic differences can be used by listeners in processing.

This study examines aspiration and VOT in a larger set of 110 words and using more speakers. The larger set of words allows us to include items whose prefixed status might be intermediate, and to test correlations of words' frequency properties with pronunciation. Our findings confirm [11]'s conjecture that frequency properties of words are correlated with aspiration in a way that supports the view that whole-word and decomposed representations compete [7]. A novel phonological observation here is that aspiration is possible even when the stem begins with an unstressed syllable; this cannot be accounted for by syllabification alone.

2. METHODS

2.1. Participants

Sixteen native speakers of American English participated (5 male, 11 female). Four of them had an additional native language: Hokkien, Vietnamese (2), or Tagalog. Age ranged from 19 to 46 years (median 21, standard deviation 7.8). Participants reported no known speech or hearing problems. They were paid for their time.

2.2. Materials

Disyllabic and longer lemmas beginning with *mis-* and *dis-* were extracted from CELEX [1]. We excluded a word if its COBUILD lemma frequency was zero (unless we expected it to be familiar to the participant population), or if we expected it to be unfamiliar to participants. We chose one wordform at random from each lemma, and a small number of wordforms substantially more or less frequent than expected based on lemma frequency (to aid in distinguishing effects of word and lemma frequency). We reduced the resulting set to 110 items by excluding semantically transparent suffixed forms of items already included (for example, we used only *dispense*, not *dispenser*).

We chose 330 fillers that also begin with prefixes (*re-, in-/im-/il-/ir-, con-/com-/col-/cor-, pre-*), sampled from CELEX to have the same frequency distribution as the target items, and the same distributions of stress pattern (which includes syllable count), and CELEX morphology code, eliminating a few items that we judged unfamiliar.

Stimuli consisted of a target or filler, preceded, to disambiguate part of speech, by a syntactically and pragmatically suitable word (*a, the, some, my, your, his, her, its, our, their, very, to, I, you, he, she, it, we, they, I'm, you're, he's, she's, it's, we're, they're, I've, you've, we've, they've*); for example, *a commandment* (filler), or *she disperses* (target). For each participant, the words preceding the targets and fillers were chosen randomly, and the stimuli were presented in a random order, except that the first and last items had to be fillers.

2.3. Procedure

Participants sat alone in a sound-attenuated booth, wearing a head-mounted microphone. They received written instructions to "read the word or phrase aloud", "try to speak naturally and casually—not too carefully", and "press the right arrow key (→) when you're ready for the next one". They were recorded reading the two-word stimuli from a computer screen, using Audacity or PCquirerX. When finished, they completed a questionnaire on age, sex, and language background.

3. RESULTS AND DISCUSSION

Forty-four stimulus recordings were excluded because the speaker said the wrong target word or preceding word, or was disfluent during the phrase. The resulting dataset consisted of 1,715 tokens. Using Praat [4], in each target token the interval from the stop release to the beginning of subsequent voicing was segmented.

Each token was judged by the first author, who is a native speaker of English, as *aspirated* (N=722), *unaspirated* (N=820), or *unsure* (N=171). This was performed in Praat by placing the cursor at the end of the [s], listening to the remainder of the word, and judging it as similar to an English word-initial voiced (i.e., unaspirated) or voiceless (aspirated) consonant. The same author and two research assistants measured each token's VOT, unless at least one of them failed to identify the stop release because the stop was judged to be fully or partly spirantized (N=227).

Target items tended to be consistently aspirated across participants or consistently unaspirated, but there were a fair number that varied (Appendix). Aspiration was possible even when the stem's first syllable was unstressed, as in *dis[p^h]osséssed*. Non-aspiration was possible even in a few words that clearly are prefixed, such as *displaced*.

We fitted two regression models: a logistic regression with presence of aspiration as dependent variable, and a linear regression with logarithm of VOT in milliseconds (raw VOT was skewed towards high values) as dependent variable. The logistic model excluded items coded *unsure*. Both models excluded stems beginning with /tɹ/ (N=204, of which 120 were already excluded from the VOT regression because of spirantization); these had a high rate of aspiration even when strongly unexpected, as in monomorphemic *distribution* (10 out of 16 tokens aspirated). Both models used the following factors:

- prefix (*mis-* or *dis-*)
- stem-initial consonant (/p, t, k/)
- initial stress of stem (primary, secondary, none)
- stem length, in syllables
- log COBUILD frequencies in CELEX: whole word, whole word's lemma, stem, stem's lemma
- whether stem exists as freestanding word
- whether stem has higher frequency than word
- whether immediately preceding item has same prefix; log number of previous stimuli with same prefix (to control for prefix priming)
- random intercepts for subjects
- random slopes for subjects by consonant and stem-initial stress

All predictors were centered and, if continuous, standardized. We did not use morphological structure as a factor, because of the difficulty of objectively identifying where each item falls on the continuum from prefixed to monomorphemic. In the future it would be beneficial to conduct experiments to assess the items' semantic transparency and other measures of prefixedness.

The software used was the MCMCglmm function [6] in R [10]. The results are summarized in Table 1 (overleaf). The MCMCglmm function's Monte Carlo *p* values are shown when less than 0.05.

These results show, first of all, that in stem-initial voiceless stops following prefixes *mis-* or *dis-*, the same factors tend to encourage longer VOT and perceived aspiration. The only contradictory result between the two models is that primary stress discouraged perceived aspiration but encouraged longer VOT. Moreover, there were two robust frequency effects. First, higher frequency of the target word is associated with less aspiration and lower VOT (word's own frequency and, as [11] found, lemma frequency). Second, there is more perceived aspiration, and VOT is longer, when the stem exists as a freestanding word, as in *misperceive* but not *discrepancy*.

We assume, following [3], that a prefixed word can have competing listed representations: a monomorpheme-like whole word (*misprint*) and a morphologically decomposed form (*mis+print*). If the speaker treats a word as prefixed, the stem-initial consonant will tend to be aspirated, whether because it is prosodic-word-initial, or through influence of the stem's pronunciation when freestanding (see [12] for a similar view of tapping in Tagalog).

Table 1: Regression results for aspiration. + means that the factor promotes aspiration (binary model) or increases VOT (VOT model); – means the opposite.

Factor	Binary Model (N=1,364)	VOT Model (N=1,391)
prefix is *mis-* (vs. *dis-*)	+ $p = 0.026$	+ $p < 0.001$
consonant is /p/ (vs. /t/)	*n.s.*	– $p < 0.001$
consonant is /k/ (vs. /t/)	+ $p < 0.001$	+ $p = 0.002$
stem secondary stress (vs. no stress)	*n.s.*	+ $p < 0.001$
stem primary stress (vs. no stress)	– $p < 0.001$	+ $p < 0.001$
stem length	– $p = 0.004$	*n.s.*
whole word frequency	– $p < 0.001$	– $p < 0.001$
whole word's lemma's freq.	– $p < 0.001$	– $p < 0.001$
stem frequency	+ $p = 0.006$	+ $p = 0.022$
stem's lemma's frequency	*n.s.*	– $p < 0.001$
stem exists as freestanding word	+ $p < 0.001$	+ $p < 0.001$
stem > word	*n.s.*	+ $p = 0.034$
preceding stimulus has same prefix	*n.s.*	*n.s.*
number prev. stimuli with same prefix	*n.s.*	*n.s.*

We interpret the frequency effects in the spirit of [7]: Assuming there is a race for activation between direct acess to the whole word and a morphologically decomposed route, factors that speed access to the whole-word representation, such as high word frequency, should suppress aspiration; and those that speed the decomposed route, such as high stem frequency, should promote aspiration.

In our discussion of frequency effects above, we invoked prosodic-word structure or influence of a freestanding stem's pronunciation rather than syllable structure, because aspiration was common in many stems that begin with an unstressed syllable (*discontent, misconception, dispossessed, misconceiving/-ed, disconcerting/-s, disconnect, mispronunciation, discontinued, mispronounce, misconducts/-ed*). Even if the /p/ in *mispronounce* is syllable-initial (*mis.pro.nóunce*), it is still not initial in a stressed syllable, and thus not eligible for aspiration without some additional mechanism, such as prosodic structure or influence of *[p^h]ronounce*.

5. CONCLUSION

Across 16 speakers of American English, 110 prefixed and pseudoprefixed words beginning with *mis-* or *dis-* tended to show consistent aspiration or non-aspiration of the following voiceless stop, but many items varied across speakers. Frequency factors were correlated with an item's aspiration, supporting a competition between whole-word and decomposed representations. Aspiration was possible even when the stem begins with an unstressed syllable, suggesting that stem-initial consonants can be treated as though word-initial.

In future work, we plan to test whether priming the prefix can influence aspiration, using the items from this study that showed variation. If the frequency effects truly reflect online production, it should be possible to influence a variable item's pronunciation by influencing its processing.

6. ACKNOWLEDGMENTS

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7. APPENDIX

Number of tokens coded as unaspirated, unsure, or aspirated (with percent); and mean and standard deviation of VOT, in milliseconds:

word	un-asp	un-sure	asp	VOT mean	VOT s.d.
dispel	16	0	0 (0%)	12	5
dispelled	16	0	0 (0%)	14	5
disposable	16	0	0 (0%)	14	5
disposed	16	0	0 (0%)	16	7
disparities	16	0	0 (0%)	16	9
disco	16	0	0 (0%)	25	8
discuss	16	0	0 (0%)	27	8
distils	16	0	0 (0%)	28	7
dispensed	15	0	0 (0%)	17	11
dispensable	14	0	0 (0%)	14	6
disposal	15	1	0 (0%)	16	5
dispersed	15	1	0 (0%)	18	5
displays	15	1	0 (0%)	19	7
mistakes	15	1	0 (0%)	25	7
discovered	15	1	0 (0%)	25	9
disturbing	15	1	0 (0%)	27	10
distinguished	15	1	0 (0%)	27	9
distilled	15	1	0 (0%)	29	8
Mister	15	1	0 (0%)	31	9
displayed	14	1	0 (0%)	21	10
misted	14	1	0 (0%)	29	9
distinctive	14	2	0 (0%)	24	6
disturb	14	2	0 (0%)	29	12
distance	14	2	0 (0%)	29	7
dispensaries	13	2	0 (0%)	13	5
disputes	13	2	0 (0%)	27	14
discrepancy	13	2	0 (0%)	29	9
distillery	13	3	0 (0%)	32	7
distract	13	3	0 (0%)	35	12
discriminated	13	3	0 (0%)	35	11
distressing	13	3	0 (0%)	35	9
disperses	15	0	1 (6%)	19	12
mistress	15	0	1 (6%)	39	8
distressed	15	0	1 (6%)	47	10
distinguish	14	1	1 (6%)	26	8
discretion	14	1	1 (6%)	31	11
discreetly	12	3	1 (6%)	43	14
distort	13	1	1 (7%)	23	7
dispatches	12	2	1 (7%)	18	10
discriminate	10	4	1 (7%)	36	7
dispatching	12	2	2 (13%)	18	12
mistaken	11	3	2 (13%)	26	9
discrimination	11	3	2 (13%)	35	16
discourage	10	4	2 (13%)	41	15
distant	13	0	3 (19%)	34	13
dispatched	10	3	3 (19%)	22	20
districts	10	3	3 (19%)	39	8
discards	10	2	4 (25%)	39	22
discotheque	4	2	2 (25%)	30	9
displaced	8	3	5 (31%)	42	23
disclosures	6	4	5 (33%)	48	17
distributions	5	5	5 (33%)	47	10
distrustful	8	2	6 (38%)	59	22
displacement	6	4	6 (38%)	35	18
displeasing	6	4	6 (38%)	48	27
discourteously	7	2	6 (40%)	60	33
distrust	8	1	7 (44%)	61	28
disclosing	5	4	7 (44%)	51	18
discourtesy	5	3	7 (47%)	62	28
disposition	4	4	7 (47%)	31	14
displeased	8	0	8 (50%)	51	26
disprove	5	3	8 (50%)	58	34
distributed	2	5	8 (53%)	56	4
discourses	2	4	8 (57%)	54	18
distribution	5	1	10 (63%)	45	7
discolored	5	1	10 (63%)	58	23
disclaimers	5	1	10 (63%)	61	26
disproving	3	3	10 (63%)	57	30
discredits	3	2	10 (67%)	64	27
distastes	4	1	11 (69%)	56	20
mistrusted	3	2	11 (69%)	56	29
dispossessed	1	3	10 (71%)	38	14
discredit	4	0	12 (75%)	60	29
discoloring	3	1	12 (75%)	69	25
miscarried	2	2	12 (75%)	57	21
discolorations	2	2	12 (75%)	60	19
disqualified	2	2	12 (75%)	63	21
disqualifying	2	2	12 (75%)	65	21
misconceiving	1	3	12 (75%)	44	9
misplacing	1	3	12 (75%)	58	19
distemper	2	1	12 (80%)	50	17
discomfort	3	0	13 (81%)	52	19
distaste	2	1	13 (81%)	62	20
disconnect	1	2	13 (81%)	48	13
distasteful	1	2	13 (81%)	60	21
misconceived	0	3	13 (81%)	48	15
miscarry	0	3	13 (81%)	69	21
disconcerts	0	2	11 (85%)	55	16
disconcerting	1	1	12 (86%)	46	16
discounted	2	0	13 (87%)	62	21
mispronunciation	1	1	13 (87%)	48	16
discontent	2	0	14 (88%)	49	19
misconception	2	0	14 (88%)	49	13

mistook	2	0	14 (88%)	65	20
discontinued	1	1	14 (88%)	45	12
dispassionate	1	1	14 (88%)	50	25
misplaced	1	1	14 (88%)	59	21
discontinuity	0	1	13 (93%)	61	21
mistimed	0	1	13 (93%)	76	25
mispronounce	1	0	14 (93%)	49	16
misconducts	0	1	14 (93%)	52	16
miscount	0	1	14 (93%)	68	19
misprint	1	0	15 (94%)	61	18
miscarriages	1	0	15 (94%)	65	18
misquoted	0	1	15 (94%)	78	20
mistranslations	0	1	15 (94%)	81	19
mistrial	0	0	14 (100%)	81	11
misconducted	0	0	16 (100%)	48	11
miscalculations	0	0	16 (100%)	65	38
misquote	0	0	16 (100%)	80	13

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