LETTERS TO THE EDITOR

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Effects of local lexical competition and regional dialect on vowel production (L)

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(Received 1 October 2013; revised 27 May 2014; accepted 3 June 2014)

Global measures of lexical competition, such as lexical neighborhood density, assume that all phonological contrasts contribute equally to competition. However, effects of local phonetic similarity have also been observed in speech production processes, suggesting that some contrasts may lead to greater competition than others. In the current study, the effect of local lexical competition on vowel production was examined across two dialects of American English that differ in the phonetic similarity of the low-front and low-back vowel pairs. Results revealed a significant interaction between regional dialect and local lexical competition on the acoustic distance within each vowel pair. Local lexical contrast led to greater acoustic distance between vowels, as expected, but this effect was significantly enhanced for acoustically similar dialect-specific variants. These results were independent of global neighborhood density, suggesting that local lexical competition may contribute to the realization of sociolinguistic variation and phonological change.

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PACS number(s): 43.70.Fq, 43.70.Bk [BRM]

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I. INTRODUCTION

Lexical neighborhood density, defined as the number of words differing from a target word by a single phoneme (Luce and Pisoni, 1998) is a global measure of lexical competition that treats all phonemic contrasts as equally potentially confusable. Despite this coarse-grained definition, lexical neighborhood density can account for vowel reduction phenomena: Vowels in words with few high-frequency phonological neighbors are spectrally reduced relative to vowels in words with many high-frequency neighbors (Munson and Solomon, 2004; Scarborough, 2010; Wright, 2004; cf. Flemming, 2010; Gahl *et al.*, 2012).

However, local effects of lexical competition have also been observed in production. For example, voice onset times of voiceless stops are longer for words with a voiced stop minimal pair neighbor than for words without a voiced stop minimal pair neighbor (Baese-Berk and Goldrick, 2009; Goldrick *et al.*, 2013). This finding suggests that the lack of specific contrasts may drive the effects of phonetic reduction that are observed for words with low neighborhood density. Similarly, Yaniv, Meyer, and Gordon (1990) observed more

competition in production between phonetically similar vowels (e.g., /i, ɪ/) than between phonetically less similar vowels (e.g., /i, ɑ/). Their results suggest that some lexical neighbors may exhibit stronger competition effects on a target word than others based on the phonetic properties of the individual segments (see also Meyer and Gordon, 1985).

Regional dialects of American English are characterized by variability in the vowel system that results in greater acoustic similarity of different vowel categories across dialects. For example, the Northern dialect is characterized by the raising and fronting of /æ/, backing and lowering of /ɪ, e/, backing of /ʌ/, and lowering and fronting of /ɑ, ɔ/ (Labov *et al.*, 2005). This raising and fronting of /æ/ and lowering and backing of /e/ lead to greater similarity between /e, æ/ for Northern talkers than for Midland talkers. The Midland dialect is characterized by the merger-in-progress of the low back vowels /ɑ, ɔ/ and fronting of the back vowels /u, ow/ (Labov *et al.*, 2005). This merger-in-progress of /ɑ, ɔ/ leads to greater similarity between /ɑ, ɔ/ for Midland talkers than for Northern talkers. The goal of this study was to explore the potential interaction between dialect variation and lexical contrast in the production of these phonetically similar vowel pairs (e ~ æ, ɑ ~ ɔ).

We expected to observe greater acoustic distance, and thus less-extreme dialect-specific variants, when the two

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vowel categories resulted in a minimal pair in the given context than when the specific lexical contrast was not present. For example, for the Northern raised and fronted /æ/, we expected to observe a less [ɛ]-like variant in *bat* than in *calf* because *bat* contrasts with *bet*, whereas /kɛf/ is not a real English word. Similarly, for the Midland ongoing merger of /ɔ/ and /ɑ/, we expected to observe a less [ɑ]-like variant in *caught* than in *fought* because *caught* contrasts with *cot*, whereas /fat/ is not a real English word.

II. METHODS

A. Stimulus materials

For each of the four target vowels /ɛ, æ, ɔ, ɑ/, familiar CVC English words were selected from the Hoosier Mental Lexicon (Nusbaum *et al.*, 1984) so that the relevant phonological contrast ($\varepsilon \sim \text{æ}$, $\alpha \sim \text{ɔ}$) would result in another English word. Five words were selected for /ɛ, æ, ɔ/, but lexical gaps in English limited the possible candidates for /ɑ/ to four words, including two with relatively unfamiliar competitors (i.e., *ghat* for *got* and *nautch* for *notch*), for a total of 19 “competitor” target words, shown in Table I. In addition, for each vowel, five target words were selected so that the relevant phonological contrast would not result in a real English word for a total of 20 “no-competitor” target words, shown in Table I. The words in the no-competitor condition had significantly fewer neighbors [competitor $M = 21.47$, no-competitor $M = 13.95$, $t(37) = 3.84$, $p < 0.001$] and were significantly lower in log frequency [competitor $M = 2.74$, no-competitor $M = 1.98$, $t(37) = 3.32$, $p = 0.002$] than the words in the competitor condition. The low familiarity of some of the competitors leads to a conservative estimate of the effect of competitor condition on vowel distance because some of the competitor words may have been effectively no-competitor words for some of the participants.

Each of the 39 target words was produced by 20 female monolingual native speakers of American English in the Indiana Speech Project Corpus (Clopper *et al.*, 2002) as part of a recording session including nearly 1000 CVC words. Thus the phonological similarities among the target words themselves should not be a significant factor in our analysis because they were produced in the context of over 900 other words. Ten of the talkers were lifetime residents of the Northern dialect region and the remaining 10 talkers were lifetime residents of the Midland dialect region. Three tokens were unavailable due to errors in the original recordings, resulting in a total of 777 tokens.

TABLE I. Competitor and no-competitor target words.

Vowel	Competitor targets	No-competitor targets
ɛ	dead, guess, head, pet, set	chess, deaf, fetch, jet, wedge
æ	bad, bag, bat, mass, sad	calf, gap, match, pad, sash
ɑ	cot, got, knot, notch	dock, mob, shop, wad, yacht
ɔ	caught, chalk, hawk, sought, taught	cough, fought, gawk, log, wash

B. Analysis

For each token, first (F1) and second (F2) formant frequencies at the temporal midpoint of the vowel were obtained. The formant frequencies were converted from Hertz to Bark for analysis (Traunmüller, 1990). To assess the effects of local lexical competition and talker dialect on acoustic vowel similarity, median vowel distance was calculated between /æ/ and /ɛ/ and between /ɔ/ and /ɑ/. For /ɛ, æ/, median vowel distance was defined as the median of the Euclidean distances in the F1 × F2 Bark space from each /æ/ token to each /ɛ/ token from the same competitor condition for that talker and vice versa. For example, the vowel distance for *bad* for talker C01 was defined as the median Euclidean distance between her production of *bad* (a competitor word with /æ/) and her productions of *dead*, *guess*, *head*, *pet*, and *set* (the set of competitor words with /ɛ/). Distances between /ɔ, ɑ/ were calculated similarly. Median vowel distance was assessed statistically using separate linear mixed-effects models for each vowel pair with dialect, competitor condition (competitor vs no-competitor), and their interaction as fixed effects. The log frequency and the number of neighbors for each target word were also included as fixed factors so that any observed effects of competitor condition could be attributed to the local contrast rather than global competition. Random intercepts for words and talkers and design-driven maximal random talker slopes for log frequency and number of neighbors were also included. Statistical significance was estimated using Markov Chain Monte Carlo simulations (Baayen *et al.*, 2008).

III. RESULTS

The mean F1 and F2 frequencies of the vowels from the competitor and no-competitor conditions produced by the Midland and Northern talkers are shown in Fig. 1. Dialect differences consistent with the Northern and Midland varieties of American English were observed, including higher /æ/ and lower /ɛ/ for the Northern talkers than the Midland talkers, and more similar /ɑ, ɔ/ for the Midland talkers than the Northern talkers.

FIG. 1. Grand mean F1 × F2 Bark space for vowels from the competitor condition (open symbols) and the no-competitor condition (filled symbols) produced by Midland (triangles) and Northern (circles) talkers. Error bars are sample standard errors.

FIG. 2. Grand means of the median vowel distances for words from the competitor and no-competitor conditions for each vowel pair for each talker dialect. Error bars are sample standard errors.

The mean of the median vowel distances for the competitor and no-competitor words for each vowel pair and each dialect are shown in Fig. 2. As shown in Table II, the linear mixed-effects models revealed a significant main effect of dialect for both vowel pairs, a significant effect of competitor condition for /ɑ~ɔ/, and a significant dialect × competitor condition interaction for both vowel pairs. The main effect of dialect for /ε/ reflects the Northern lowering of /ε/ and raising of /æ/, which results in a shorter distance between /ε, æ/ for the Northern talkers than the Midland talkers. However, this main effect of dialect interacts with competitor condition. As shown in Fig. 2, the distance between /ε, æ/ is shorter for the no-competitor words than the competitor words for the Northern talkers, as predicted, but the distance between /ε, æ/ is similar for the competitor and no-competitor words for the Midland talkers. Thus the Northern /ε~æ/ distance for no-competitor words was more consistent with the Northern dialect, whereas the Northern /ε~æ/ distance for competitor words was more similar to the unshifted Midland /ε~æ/ distance. Similarly, the main effect of dialect for /ɑ~ɔ/ reflects the result of the merger-in-progress in the Midland dialect. The low back vowels are more similar for the Midland talkers than the Northern talkers. In addition, as shown in Fig. 2, the distance is shorter between /ɑ, ɔ/ for the no-competitor words than

the competitor words for the Midland talkers, but the distance between /ɑ, ɔ/ is more similar for the competitor and no-competitor words for the Northern talkers. Thus the Midland /ɑ~ɔ/ distance for no-competitor words was more consistent with the ongoing merger, whereas the Midland /ɑ~ɔ/ distance for competitor words was more similar to the Northern /ɑ~ɔ/ distance.

IV. DISCUSSION

The results reveal an effect of dialect on acoustic distance for both vowel pairs, an effect of competitor condition for /ɑ~ɔ/, and a significant interaction between these two factors for both vowel pairs. For /ε, æ/, which are acoustically more similar in the Northern dialect than the Midland dialect, the Northern talkers produced larger differences between the vowels for words with a minimal pair competitor than for words without a minimal pair competitor. For the Midland talkers, this vowel pair is acoustically more different, and they did not show an effect of competitor condition on vowel distance. This lack of a competitor effect for the Midland /ε, æ/ pair may reflect a ceiling effect on the distance that can be produced between these two vowels without encroaching on other vowels, such as /ɪ, eɪ/ (see also Wright, 2004). For /ɑ~ɔ/, which are acoustically more similar in the Midland dialect than the Northern dialect, the Midland talkers produced larger differences between the vowels for words with a minimal pair competitor than for words without a minimal pair competitor. The competitor effect was smaller for the Northern talkers for whom this vowel pair is acoustically more different.

These observed patterns of interaction between dialect and competitor condition provide preliminary evidence that local lexical contrast affects how social information, such as regional background, is phonetically marked, independently of global neighborhood density effects. The presence of a phonetically similar lexical competitor leads to greater acoustic distance between vowels in F1 × F2 space. This competitor effect is enhanced for vowel pairs that exhibit a smaller overall distance as a result of dialect-specific variation. For vowel contrasts that are well-maintained acoustically within a dialect, smaller effects of competitor condition on vowel distance are observed. These findings suggest that a more

TABLE II. Linear mixed effects models of median vowel distance.

	/ε~æ/ Median distance (Log likelihood: -185.6)				/ɑ~ɔ/ Median distance (Log likelihood: -266.8)			
	Variance	SD			Variance	SD		
Random effects:								
Word (Intercept)	0.024	0.155			0.071	0.267		
Talker (Intercept)	0.078	0.278			0.042	0.206		
Talker (Density)	<0.001	0.008			<0.001	0.010		
Talker (LogFreq)	0.006	0.080			0.003	0.057		
Fixed effects:	Estimate	SE	<i>t</i>	pMCMC	Estimate	SE	<i>t</i>	pMCMC
Dialect	0.429	0.153	2.797	0.001	0.331	0.128	2.574	0.006
Condition	0.101	0.131	0.773	0.378	0.640	0.156	4.107	<0.001
LogFreq	0.029	0.085	0.347	0.695	-0.047	0.078	-0.606	0.493
Density	0.002	0.008	0.296	0.771	-0.009	0.010	-0.847	0.333
Dialect × Condition	-0.233	0.076	-3.046	0.002	-0.299	0.091	-3.270	0.001

nuanced view of lexical competition, which considers phonological and phonetic similarity beyond traditional neighborhood density measures [e.g., Luce and Pisoni's (1998) frequency-weighted neighborhood probability rule], may be informative for accounting for vowel variation within and across dialects. In particular, although global neighborhood density predicts spectral reduction (Munson and Solomon, 2004; Scarborough, 2010; Wright, 2004), local lexical contrasts inhibit the diffusion of merging variants to words with minimal pair competitors. This maintenance of acoustic distance between minimal pairs in ongoing sound changes provides a mechanism to account for the observation that phoneme pairs that distinguish relatively few words in a language are more likely to undergo a merger than phoneme pairs that distinguish many words (Wedel *et al.*, 2013).

ACKNOWLEDGMENTS

This work was partially supported by NSF Grant No. BCS-1056409 to Ohio State University and NIH Training Grant T32 DC00012 to Indiana University. We would like to thank Kenney Hensley for research assistance.

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