

Effects of Lexical Competition and Dialect Exposure on Phonological Priming

Language and Speech

1–25

© The Author(s) 2016

Reprints and permissions:

sagepub.co.uk/journalsPermissions.nav

DOI: 10.1177/0023830916643737

las.sagepub.com

**Cynthia G. Clopper**

Ohio State University, USA

Abby Walker

Virginia Polytechnic Institute and State University, USA

Abstract

A cross-modal lexical decision task was used to explore the effects of lexical competition and dialect exposure on phonological form priming. Relative to unrelated auditory primes, matching real word primes facilitated lexical decision for visual real word targets, whereas competing minimal pair primes inhibited lexical decision. These effects were robust across two English vowel pairs (mid-front and low-front) and for two listener groups (mono-dialectal and multi-dialectal). However, both the most robust facilitation and the most robust inhibition were observed for the mid-front vowel words with few phonological competitors for the mono-dialectal listener group. The mid-front vowel targets were acoustically more distinct than the low-front vowel targets, suggesting that acoustic-phonetic similarity leads to stronger lexical competition and less robust facilitation and inhibition. The multi-dialectal listeners had more prior exposure to multiple different dialects than the mono-dialectal group, suggesting that long-term exposure to linguistic variability contributes to a more flexible processing strategy in which lexical competition extends over a longer period of time, leading to less robust facilitation and inhibition.

Keywords

Phonological priming, lexical competition, dialect variation, linguistic experience

Introduction

The lexical decision task has been adopted in a number of recent studies to explore the effects of experience on cross-dialect lexical processing (Flocchia, Girard, Goslin, & Konopczynski, 2006; Impe, Geeraerts, & Speelman, 2008; Sumner & Kataoka, 2013; Sumner & Samuel, 2009). The

Corresponding author:

Cynthia G. Clopper, Department of Linguistics, Ohio State University, 108A Ohio Stadium East, 1961 Tuttle Park Place, Columbus OH 43210, USA.

Email: clopper.l@osu.edu

results reveal that lexical processing is faster for familiar standard and local non-standard varieties than for unfamiliar non-local non-standard varieties (Floccia et al., 2006; Impe et al., 2008). This processing benefit for familiar dialects is consistent with earlier research showing more accurate word and sentence recognition for familiar varieties than for unfamiliar varieties (Labov & Ash, 1997; Mason, 1946). A similar processing benefit is observed for local and prestigious non-local dialect-specific phonological variants in lexical decision tasks involving semantic priming: listeners exhibit both within-dialect and cross-dialect semantic priming for local and prestigious non-local phonological variants, but no priming is observed for non-local, non-prestigious variants (Sumner & Kataoka, 2013; Sumner & Samuel, 2009). These results suggest that the processing benefits observed for local and prestigious dialects may be driven in part by familiarity and positive social stereotypes associated with the specific variants characteristic of those varieties (see also Sumner, Kim, King, & McGowan, 2014).

The lexical decision task has also been used to examine the effects of variation in phonological systems, specifically with respect to vowel category mergers, on cross-dialect lexical processing (Dufour, Nguyen, & Frauenfelder, 2007; Rae & Warren, 2002). For example, listeners from a Southern French dialect that is characterized by a merger of /e, ε/, which are distinct in the standard variety, exhibit form priming across the two vowel categories, consistent with their merged production, whereas listeners who maintain the contrast between the two vowel categories exhibit form priming only for same-vowel primes (Dufour et al., 2007). Further, cross-category form priming is blocked for Southern listeners for the /o, ɔ/ vowel pair, despite their also being merged in the Southern dialect, because the /o, ɔ/ contrast is a socially-marked characteristic of standard French and is therefore familiar even to native speakers of other dialects. Similarly, in a semantic priming task, young listeners in New Zealand who produce a robust merger of the diphthongs /iə, eə/ (as [iə]) in words such as *near* and *square*, respectively, exhibit asymmetries in semantic priming consistent with the direction of the ongoing merger-in-progress (Rae & Warren, 2002). Whereas /iə/ words prime semantic associates of both /iə/ and /eə/ words, consistent with the young listeners' merged production, /eə/ words prime semantic associates of only /eə/ words, consistent with the older contrast. This pattern of priming demonstrates the listeners' knowledge of the earlier structure of the pre-merged system, presumably as a result of their exposure to older talkers who maintain the contrast. Thus, in both studies, the merged participants' familiarity with the contrast among another social group facilitated their perception and processing of the contrast.

These examinations of the effects of phonological contrast on form and semantic priming in lexical decision tasks have parallels in the literature on bilingual lexical processing. Like the Southern French listeners in Dufour et al.'s (2007) study, Spanish-dominant Spanish–Catalan bilinguals exhibit cross-category form priming for the /e, ε/ contrast, which is present in Catalan, but not in Spanish, whereas Catalan-dominant bilinguals exhibit form priming only for same-vowel primes (Pallier, Colomé, & Sebastián-Gallés, 2001). These results are consistent with a weaker representation of the Catalan vowel contrast among the Spanish-dominant bilinguals than among the Catalan-dominant bilinguals. Similarly, whereas both native English listeners and Dutch–English bilinguals exhibit cross-modal form priming for matching targets containing /ε, æ/, which are contrastive in English, but not in Dutch, only native English listeners exhibit inhibition for competing minimal pair primes (Broersma, 2012). The Dutch–English bilinguals exhibit neither facilitation nor inhibition for the competing primes, suggesting neither a robust representation of the contrast, which would lead to inhibition comparable to the native English pattern, nor an especially weak representation of the contrast, which would lead to facilitation comparable to the Spanish–Catalan or Southern French pattern (i.e., cross-category form priming). Broersma (2012) further suggested that the bilingual results may reflect a strategic delay in recognizing the auditory prime. That is, rather than suppressing activation for competitors to the recognized prime as

monolinguals are assumed to do, bilingual participants may maintain activation of multiple potential candidates for the auditory prime (including the minimal pair target), leading to neither facilitation nor inhibition.

Cross-language lexical processing research has also demonstrated that Spanish-dominant Spanish–Catalan bilinguals accept more nonword minimal pairs containing /e, ε/ as real words than Catalan-dominant bilinguals (Sebastián-Gallés, Echevierra, & Bosch, 2005), providing further evidence for their weak representation of the Catalan vowel contrast. Although the perception of nonwords has not been explicitly examined in cross-dialect lexical processing, inhibition has been observed for nonword targets preceded by real word minimal pair primes in studies exploring other sources of phonological variation. In a cross-modal lexical decision task, van Alphen and McQueen (2006) observed inhibition for visual nonword targets that were preceded by a real word auditory prime differing from the target only in the voicing of the initial stop consonant (e.g., visual target *plue* following auditory prime “blue”). Inhibition was robust for a number of different phonetic variants of the voiced onset consonant in the auditory prime, suggesting that competition between the auditory prime and the visual target is not dependent on a canonical auditory prime (see also Sumner, 2013). Primes exhibiting dialect-specific variation are similarly expected to inhibit lexical decision for nonword minimal pair targets.

Taken together, the previous research on cross-dialect and cross-language lexical processing demonstrates that the priming paradigm provides a means of probing the phonological representations of listeners with exposure to different varieties. The current study therefore used a cross-modal lexical decision task with form priming to explore the effects of dialect exposure on the representation of subphonemic dialect variation in American English. Unlike the previous studies on cross-dialect lexical processing, which involved either global dialect variation (Flocchia et al., 2006; Impe et al., 2008) or variation between specific phonological variants, such as vowel mergers (Dufour et al., 2007; Rae & Warren, 2002) or rhoticity (Sumner & Kataoka, 2013; Sumner & Samuel, 2009), the current study examined form priming for two vowel pairs that are phonetically variable, and moderately perceptually confusable, across dialects, but that are not merged (or merging) in any variety of American English. The effect of phonological similarity on lexical priming is well-studied, although the results are mixed, with some studies showing facilitation for phonologically similar prime–target pairs (e.g., Hillinger, 1980; Slowiaczek, Nusbaum, & Pisoni, 1987) and others showing inhibition or interference (e.g., Goldinger, Luce, Pisoni, & Marcario, 1992; Hamburger & Slowiaczek, 1996; Radeau, Morais, & Dewier, 1989). Given this previous work, the goal of the current study was not to determine the overall effect of phonological similarity on lexical priming, but to explore how phonetic dialect variation contributes to the phonological similarity effect. Thus, the target vowel categories are robustly contrastive, but their acoustic–phonetic similarity varies across dialects. This design allows for an examination of the effect of experience with variability, which is operationalized here as residential history distinguishing mono-dialectal from multi-dialectal participants, on phonological representation and lexical competition.

The effect of subphonemic variation on lexical access and competition has been explored in previous work using auditory and cross-modal lexical decision tasks (Andruski, Blumstein, & Burton, 1994; Spinelli, McQueen, & Cutler, 2003; Tuinman, Mitterer, & Cutler, 2012; van Alphen & McQueen, 2006). Across studies, the results reveal robust facilitation for subphonemically variable primes relative to unrelated primes. For example, American English listeners exhibit semantic priming for voiceless stop-initial stimulus words with variable voice-onset times (VOTs) that are within the normal range for voiceless stops, and this priming effect is enhanced when the prime word does not have a minimal pair competitor beginning with the homorganic voiced stop (Andruski et al., 1994). Dutch listeners similarly exhibit form priming for both voiced and

voiceless stop-initial stimulus words with variable VOTs that are within the normal ranges, although the presence of a minimal pair competitor does not affect the magnitude of the priming effect (van Alphen & McQueen, 2006). These results suggest that subphonemic variation that does not affect segmental identification also does not reduce lexical facilitation in form or semantic priming.

However, listeners are sensitive to subphonemic variation that is potentially disambiguating between competing lexical targets (Spinelli et al., 2003; Tuinman et al., 2012). For example, French listeners exhibit differential cross-modal form priming for lexical onset [ʁ] and onset [ʁ̥] resulting from liaison (Spinelli et al., 2003). The liaison [ʁ̥] is shorter in duration than the lexical [ʁ], allowing listeners to use duration information to distinguish the two variants. As a result, form priming is more robust for matching prime–target pairs (both lexical or both liaison) than for mismatching prime–target pairs (one lexical and one liaison). British English listeners exhibit even more robust sensitivity to this kind of subphonemic variation in a comparison of lexical vs. intrusive /ɹ/ (Tuinman et al., 2012). As in the French liaison case, the distinction between lexical and intrusive /ɹ/ in British English is reflected in their relative durations. However, unlike the French liaison case, British English listeners exhibit form priming only for matching prime–target pairs (both lexical or both intrusive) and no priming for mismatching prime–target pairs (one lexical and one intrusive).

In the current experiment, we extended this research and examined subphonemic dialect variation which serves a social, rather than linguistic, function of distinguishing among talkers from different regions. The current experimental design is similar to the methods used by Broersma (2012) in her study of lexical competition in Dutch–English bilinguals: a cross-modal lexical decision task was used with two priming conditions to explore facilitation for matching (identity) primes and inhibition for competing (minimal pair) primes. Inhibition for competing primes was examined for both word and nonword targets, as in van Alphen and McQueen's (2006) study. The mono-dialectal and multi-dialectal participants are comparable to Broersma's (2012) native English monolingual and Dutch–English bilingual participants, respectively, although the multi-dialectal participants in the current study were somewhat more heterogeneous in their linguistic experience than Broersma's (2012) bilinguals who were all first language speakers of Dutch and second language (L2) speakers of English. Further, unlike in Broersma's (2012) study, the auditory primes were produced by talkers from two regional dialects of American English to ensure variation in the acoustic–phonetic vowel similarity and perceptual confusability of the stimulus materials so that the effects of dialect exposure on lexical processing could be meaningfully explored.

Matching primes were expected to facilitate lexical decision performance for both participant groups because none of the prime variants are sufficiently unfamiliar to American English listeners to block identity priming. Thus, the results for the matching primes should be comparable to the previous results obtained with subphonemic VOT variation in English and Dutch (Andruski et al., 1994; van Alphen & McQueen, 2006). The competing minimal pair primes were expected to inhibit lexical decision performance for both participant groups because the target vowel categories are unambiguously contrastive for all American English listeners (i.e., there are no vowel mergers to block inhibition). Thus, the results for the competing primes should be comparable to the previous results obtained with English /e, æ/ minimal pairs (Broersma, 2012).

The previous literature suggests two possible predictions for the effect of dialect exposure on these expected facilitation and inhibition effects of matching and competing primes, respectively. On the one hand, previous research on cross-dialect speech processing suggests that exposure to multiple dialects improves cross-dialect lexical processing through increased familiarity with different varieties and variants (e.g., Floccia et al., 2006; Impe et al., 2008; Sumner & Kataoka, 2013; Sumner & Samuel, 2009). From this perspective, the multi-dialectal participants should exhibit

more facilitation and more inhibition than the mono-dialectal participants as a result of faster processing and greater activation of the auditory prime. Increased activation of the prime will facilitate lexical decisions to the same target word, but inhibit lexical decisions to a competitor minimal pair target word. On the other hand, previous research with bilinguals suggests that exposure to multiple languages results in weaker segmental representations in the L2 which lead to the activation of more possible lexical candidates (e.g., Broersma, 2012). Further, the research on cross-dialect perception of vowel mergers suggests that listeners with exposure to multiple varieties may have broader segmental categories than mono-dialectal listeners, giving them the flexibility to accurately identify target words across dialects (e.g., Rae & Warren, 2002). From this perspective, the multi-dialectal participants may have weaker category boundaries between the target vowels than the mono-dialectal participants, leading them to exhibit less facilitation and less inhibition than the mono-dialectal listeners. Less robust category boundaries will lead to greater perceptual confusion between the prime and its competitors, reducing activation of the lexical representation associated with the prime, and leading to reduced facilitation for matching targets and reduced inhibition for mismatching targets.

2 Methods

2.1 Participants

One hundred and forty-nine undergraduates (113 female and 36 male) participated in the experiment for partial course credit. Prior to analysis, data were excluded from participants whose accuracy on the lexical decision task was below 75% ($N = 5$), who were bilingual ($N = 21$), who were substantially older than the other participants ($N = 2$),¹ who reported a history of a speech or hearing disorder ($N = 7$), who used only one hand to make their responses ($N = 3$), or who did not report their residential history ($N = 4$). The remaining 107 participants (81 female and 26 male) were all monolingual native speakers of American English who ranged in age from 18–31 years old (median age = 20 years old).

The participants were assigned to two listener groups based on their residential history, following the primary dialect regions in the United States identified by Labov (1998; Labov, Ash, & Boberg, 2006). The experiment was conducted in the Midland dialect region, which is one of three subregions (i.e., New England, Midland, and West) comprising the General American dialect (Labov, 1998). The Northern, Southern, and Mid-Atlantic regions are each characterized by their own dialect which distinguishes them from each other and from the General American dialect (Labov, 1998). The 55 lifetime residents of the General American dialect regions (New England, Midland, and West), including 52 lifetime residents of the Midland dialect region, comprised the mono-dialectal group. The remaining 52 participants had lived in at least two dialect regions (General American, Northern, Southern, and/or Mid-Atlantic) and/or abroad² prior to the experiment, including their residence in the Midland dialect region where the experiment was conducted, and comprised the multi-dialectal group.

2.2 Stimulus materials

The stimulus materials consisted of consonant–vowel–consonant (CVC) English words and non-words. The vowels in all of the words and nonwords were drawn from two vowel pairs that are modestly perceptually confusable within and across dialects: the low–front vowels / ϵ , æ / and the mid–front vowels / I , ej /. In most varieties of American English, / æ / is lower than / ϵ / (Clopper, Pisoni, & de Jong, 2005). However, the Northern dialect of American English is characterized by

an acoustic–phonetic reversal of these two vowels, involving the raising of /æ/ and the lowering of /ɛ/ (Labov et al., 2006). Given their spectral similarity, these two vowels are moderately perceptually confusable, especially when they are produced by Northern talkers (Clopper, Pierrehumbert, & Tamati, 2010; Hillenbrand, Getty, Clark, & Wheeler, 1995; Jacewicz & Fox, 2012; Wright & Souza, 2012). Similarly, in most varieties of American English, /ɪ/ is lower and backer than /ej/ (Clopper et al., 2005). However, the Southern and Midland dialects of American English exhibit an acoustic–phonetic reversal of these two vowels, involving the raising of /ɪ/ and the lowering of /ej/ (Clopper et al., 2005; Labov et al., 2006). Given their spectral similarity, these two vowels are also moderately perceptually confusable, especially when they are produced by Midland talkers (Clopper et al., 2010; Jacewicz & Fox, 2012). The confirmed perceptual confusability among the vowels in each pair should enhance the potential for lexical competition between the primes and the targets in the lexical decision task (Luce & Pisoni, 1998).

The auditory primes consisted of 192 CVC English words. Four types of real word primes were selected in a 2 (lexical competitor) x 2 (target vowel pair) design: competitor low–front primes; competitor mid–front primes; no-competitor low–front primes; and no-competitor mid–front primes. The competitor low–front primes comprised 24 minimal pairs (48 words total) containing the target low–front vowels /ɛ/ and /æ/ (e.g., *bed* and *bad*; 24 words per vowel). The competitor mid–front primes comprised 24 minimal pairs (48 words total) containing the target mid–front vowels /ɪ/ and /ej/ (e.g., *ridge* and *rage*; 24 words per vowel). The no-competitor low–front primes comprised 24 words containing each of the target vowels /ɛ, æ/ (48 words total) that did not have a minimal pair competitor with the other low–front vowel (e.g., *fetch*, cf. **fatch* and *calf*, cf. **kef*). The no-competitor mid–front primes were 24 words containing each of the target vowels /ɪ, ej/ (48 words total) that did not have a minimal pair competitor with the other mid–front vowel (e.g., *kid*, cf. **cade* and *paid*, cf. **pid*). The four sets of prime words did not differ significantly in log frequency, as estimated in the Hoosier Mental Lexicon (Nusbaum, Pisoni, & Davis, 1984). However, the competitor words had more phonological neighbors (i.e., words differing by one phoneme insertion, deletion, or substitution) in the Hoosier Mental Lexicon (Nusbaum et al., 1984) than the no-competitor words, $F(1, 188) = 10.87, p = 0.001$, consistent with the manipulation of lexical competition. The mid–front words also had more phonological neighbors than the low–front words overall, $F(1, 188) = 13.16, p < 0.001$, given constraints of the English lexicon. Lexical competitor and target vowel pair did not interact for neighborhood density, confirming a comparable difference in neighborhood density for the competitor and no-competitor primes across vowel pairs. A summary of the neighborhood density for each target vowel pair in each competitor condition is shown in Table 1. Neighborhood density of the target word was included as a covariate in the statistical analyses of the lexical decision data to ensure that any observed effects of competitor condition or vowel pair are not simply the result of these neighborhood density differences in the stimulus materials.

To ensure acoustic–phonetic variability in the realization of the target vowels, each of the 192 auditory primes was produced by three female Midland talkers and three female Northern talkers from the Indiana Speech Project corpus (Clopper et al., 2002). The mean first and second formant

Table 1. Mean number of phonological neighbors for each vowel pair in each competitor condition in the stimulus materials. Standard deviations are shown in parentheses.

Prime type	Mid–front	Low–front
Competitor	28 (6)	24 (7)
No-competitor	24 (6)	21 (8)

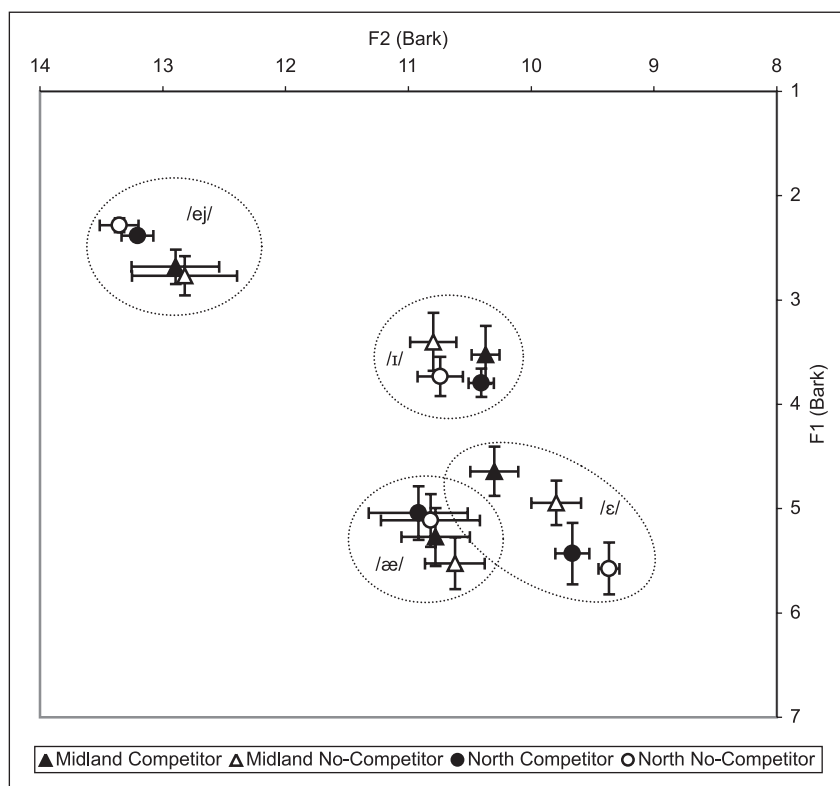


Figure 1. Mean first and second formant frequencies of the vowels /ɪ, ej, ɛ, æ/ in the competitor (filled symbols) and no-competitor (open symbols) primes for the Midland (triangles) and Northern (circles) talkers. Error bars are standard error of talker means. The ellipses were hand-drawn to enclose the four vowel means and standard errors for each vowel class to facilitate interpretation.

frequencies at vowel midpoint for each vowel category for each talker dialect in each competitor condition are shown in Figure 1. As expected, the Northern /æ/ is raised relative to the Midland /æ/ and the Northern /ɛ/ is lowered relative to the Midland /ɛ/. For /ɛ, æ/, the competitor vowels are also more peripheral in the vowel space than the no-competitor vowels, consistent with previous work illustrating the effect of lexical competition on vowel dispersion (Munson & Solomon, 2004; Wright, 2004). The mid-front vowels /ɪ, ej/ also exhibit dialect variation, as expected: the Midland /ej/ is lower than the Northern /ej/ and the Midland /ɪ/ is higher than the Northern /ɪ/. A consistent effect of competitor condition is not observed for the mid-front vowels. For both talker dialects in both lexical competitor conditions, /æ, ej/ are longer in duration and are more diphthongal (i.e., have a longer trajectory length as defined by Fox & Jacewicz, 2009) than /ɛ, ɪ/, respectively, as shown in Table 2. Vowel duration and formant trajectory are therefore robust cues to vowel identity for both vowel pairs, all $t(94) > 6.2, p < 0.001$.

The visual targets in the lexical decision task consisted of 192 real word letter strings corresponding to the auditory primes (e.g., *bed, bad, ridge, rage, fetch, calf, kid, and paid*) and 96 nonword letter strings corresponding to orthographic representations of the non-existent competitors of the no-competitor primes (e.g., *fatch, kef, cade, and pid*). The nonword targets are therefore highly similar to real words and although none appeared in the dictionary that we used to select our

Table 2. Mean vowel duration (ms) and mean trajectory length (Hz) for each vowel category in the stimulus materials. Standard deviations are shown in parentheses.

	/ɪ/	/ej/	/ɛ/	/æ/
Vowel duration	145 (29)	204 (35)	181 (29)	251 (45)
Trajectory length	303 (117)	506 (145)	332 (93)	542 (211)

Table 3. Summary of the lexical decision experiment design with example within-item prime–target pairs.

Target type	Target	Prime		
		Matching	Competing	Unrelated
Competitor	bed	bed	bad	chill
No-competitor	badge	badge	–	fame
Nonword	sape	–	sip	wet

stimulus materials (Nusbaum et al., 1984), some of the nonwords may be real words or almost real words for some participants (e.g., *kip* and *min*). An examination of the distribution of lexical decision errors for the nonwords revealed a skewed distribution with accuracy ranging from 0.60 to 1.00, with a mean of 0.88 and a median of 0.90. An analysis of the data with the six nonwords with accuracy below 75% (i.e., *min*, *ladge*, *mick*, *nake*, *kip*, *rill*, and *fith*) excluded is qualitatively identical to the results observed with the full set of stimulus materials. All items were therefore retained and item was included as a random effect in the analysis. A complete list of the lexical decision targets is presented in the Appendix (Table A1).

Three types of prime–target trials were created from this set of auditory primes and visual targets: matching, competing, and unrelated, as shown in Table 3. For the matching trials, the auditory primes matched the visual target (e.g., visual target *bed* following auditory prime “bed”). Both competitor and no-competitor real word targets occurred in matching trials. Nonword targets did not occur in matching trials because all of the auditory primes were real words. Only real word auditory primes were included because the focus of this study is lexical representation and competition. Nonwords do not have either cognitive lexical representations or conventional orthographic representations. Thus, the process of matching an auditory nonword to an orthographic representation of itself is necessarily different than the processes of lexical activation and competition under investigation in the current study. In particular, unlike real words, auditory nonwords do not have a unique cross-modal orthographic “match” and cross-modal identity priming for nonwords is therefore ill-defined (see also Broersma, 2012; Connine, Blasko, & Titone, 1993; Sumner, 2013). The exclusion of nonword primes also ensured that the lexicality of the auditory prime could not be used to bias responses: all primes were real words and therefore provided no information about whether the following target would be a real word or a nonword.

For the competing trials, the auditory prime was the minimal pair competitor of the visual target (e.g., visual target *bed* following auditory prime “bad”). Both the competitor targets and the nonword targets occurred in competing trials. No-competitor targets did not occur in competing trials because the no-competitor targets did not, by definition, have real word competitors. The competing trials involved highly similar prime–target pairs and previous research has shown that a high proportion of related prime–target pairs in a lexical decision task can lead to facilitation due to response biases (Goldinger et al., 1992; Hamburger & Slowiaczek, 1996). However, strategic

Table 4. Summary of the lexical decision experiment design with example within-participant prime–target pairs.

Trial type	Competitor targets			No-competitor targets			Nonword targets		
	Prime	Target	Trials	Prime	Target	Trials	Prime	Target	Trials
Matching	bed	bed	8	deaf	deaf	6			
	bad	bad	8	badge	badge	6			
	chin	chin	8	chill	chill	6			
	chain	chain	8	date	date	6			
Competing	ham	hem	8				pass	pass	6
	pen	pan	8				web	wab	6
	shape	ship	8				face	fiss	6
	tip	tape	8				dip	dape	6
Unrelated	mate	pen	8	him	peg	6	main	geg	6
	sail	ham	8	base	sap	6	shin	chack	6
	beg	tip	8	half	witch	6	tag	biss	6
	net	shape	8	keg	fame	6	wet	sape	6

responses are reduced when the prime–target pairs are highly similar and when a short inter-stimulus-interval (ISI) is used. In the current study, the ISI was 0 ms and the related prime–target pairs were highly similar minimal pairs, reducing the potential for strategic responses. In addition, the experimental design included related prime–target pairs with both word and nonword targets (see also Broersma, 2012; LoCasto & Connine, 2011; Sumner, 2013; Sumner & Samuel, 2007), which means that the phonological relatedness of the prime and the target could not be used to bias responses. To further ensure that any observed effects could not be attributed to the development of strategic responses over the course of the experiment, trial number was included as a covariate in the statistical analyses.

For the unrelated trials, the auditory prime was phonologically and semantically unrelated to the visual target (e.g., visual target *bed* following auditory prime “chill”). All three target types (competitor, no-competitor, and nonword) occurred in unrelated trials. Thus, the competitor targets occurred in all three prime–target trial types (matching, competing, and unrelated), the no-competitor targets occurred in two of the prime–target trial types (matching and unrelated), and the nonword targets occurred in two of the prime–target trial types (competing and unrelated). No filler trials were included because the design is fully saturated: both word and nonword targets occurred with both phonologically related (i.e., matching or competing) and unrelated primes. Thus, the similarity (or lack thereof) between the prime and the target was not a reliable indicator of the correct response and no fillers were necessary to reduce the potential for response biases.

Six stimulus lists of 192 trials each were created from the 192 auditory primes and 288 visual targets to balance across lists both the talker–word pairings of the auditory primes and the target words within each trial type. Each list included all 192 auditory primes (evenly distributed across the six talkers) 48 of the nonword visual targets, and 144 of the real word visual targets, for a total of 192 trials.³ Within each list, the number of trials of each trial type was balanced for each target type and vowel pair. Thus, as shown in Table 4, the 96 competitor targets were divided evenly among the three prime–target trial types, with eight trials per vowel per trial type. Similarly, a subset of 48 no-competitor targets was divided evenly among the four vowels and the matching and unrelated trial types (with six targets per vowel per trial type) and a subset of 48 nonword

visual targets was divided evenly among the four vowels and the competing and unrelated trial types (with six targets per vowel per trial type). Across lists, all targets appeared in all relevant prime–target trial types (see Table 3), but within each list, each target appeared exactly once (see Table 4). Within each trial type, half of the primes were produced by a Midland talker and half were produced by a Northern talker, with 1–2 primes per talker per trial type. As illustrated in Table 4, although no primes were repeated within-listener and no targets were repeated within-listener, matching primes and targets were presented across trials within-listener. For example, a single listener could experience the visual target *pan* following the auditory prime “pen” in a competing prime–target trial, as well as the visual target *pen* following the auditory prime “mate” in an unrelated prime–target trial.⁴ All participants were randomly assigned to one of the six stimulus lists and 14–23 participants completed each list.⁵

2.3 Procedure

Participants were seated at individual computer stations equipped with a monitor, high-quality circumaural headphones (Sennheiser HD 280 Pro), and a button box (Cedrus RB-730). The experimental procedure was administered using E-Prime version 1.1 which features millisecond timing precision (Psychology Software Tools, Pittsburgh, PA). On each trial, an auditory prime was presented over the headphones at a comfortable listening level. The visual target was presented on the computer screen at the offset of the auditory prime (i.e., with a 0 ms ISI) and remained on the screen until the participant responded. The participants identified the visual target as a real word or a nonword in English by pressing labeled buttons on the button box. They were instructed to respond as quickly as possible without sacrificing accuracy. The order of the trials was randomized separately for each participant.

The accuracy and response time for each trial were recorded. Overall lexical decision accuracy was 94%, standard deviation (SD) = 4%. The analysis of the response time data was limited to these correct responses. To reduce the effects of response time outliers on the analysis, all response times shorter than 200 ms ($N = 27$ or 0.1%; Baayen, 2008, p. 243) and longer than 5000 ms ($N = 23$ or 0.1%) were excluded. The upper response time cutoff was used instead of imposing a time limit for responses in the experiment itself (see e.g., Andruski et al., 1994; Sumner & Samuel, 2009; Tuinman et al., 2012) so that participants were required to respond before the next trial was initiated. This strategy reduced the amount of data lost to temporary participant inattentiveness because typically less than one trial per participant had a response time exceeding the cutoff.⁶ The remaining response times were log-transformed and individual response times that were more than two SDs from the mean of the participant’s log-transformed response times were excluded to increase the normality of the response time distribution ($N = 981$ or 5%). Following this pruning, the vast majority (99.6%) of the response times included in the analysis were shorter than 2000 ms, as expected for a lexical decision task. Thus, this process for handling the response time data led to a more normal distribution, from which long response times likely due to participant inattention were excluded, but in which naturally-occurring long response times likely due to participant or item variability were included. Random effects for participants and items were included in the statistical analysis to further capture this variability.

3 Results

3.1 Response times to real word targets

We expected to observe facilitation for matching trials relative to unrelated trials. A summary of the response times for matching and unrelated trials is shown in Table 5 for each prime type and

Table 5. Response time means (ms) for real word targets preceded by unrelated and matching real word primes. Standard deviations of subject means are shown in parentheses.

Listener group	Vowel pair	Target type	Unrelated primes	Matching primes	Facilitation
Mono-dialectal	Mid-front	Competitor	691 (145)	594 (113)	-97
		No-competitor	694 (165)	569 (116)	-125
	Low-front	Competitor	684 (139)	575 (115)	-109
		No-competitor	688 (145)	582 (130)	-106
Multi-dialectal	Mid-front	Competitor	686 (160)	592 (140)	-94
		No-competitor	667 (184)	580 (135)	-87
	Low-front	Competitor	670 (171)	585 (158)	-85
		No-competitor	681 (141)	582 (146)	-99

vowel pair for each listener group. Facilitation is defined as faster mean response times to the matching trials than to the unrelated trials and was observed across conditions in the lexical decision task.

A linear mixed-effect model predicting response time was constructed to explore the effects of the experimental factors on facilitation. Target vowel pair (mid-front, low-front), target type (competitor, no-competitor), trial type (unrelated, matching), talker dialect (Midland, North), listener group (mono-dialectal, multi-dialectal), and all interactions were included as fixed effects. Given that mean lexical neighborhood density differed across target types, neighborhood density of the target word, the target word neighborhood density $\times$ trial type interaction, and the target word neighborhood density $\times$ trial type $\times$ target type interaction were tested as covariates to distinguish an overall effect of target word neighborhood density from the predicted effect of target type on facilitation. Given that matching trials always required a “word” response, trial number and the trial number $\times$ trial type interaction were also tested as covariates to explore possible learning effects over the course of the experiment. The fixed effects were coded with sum contrasts and the covariates were centered for analysis. Following the recommendations of Barr, Levy, Scheepers, and Tily (2013), maximal design-driven random effects were specified and then removed as necessary to achieve model convergence. The random effects in the facilitation model included random intercepts for participant and target word, as well as random by-participant slopes for trial type and talker dialect and random by-word slopes for trial type and listener group. Log-likelihood comparisons were used to determine statistical significance of individual simple effects and interactions. Given that the interpretation of simple effects and interactions is conditioned on higher-order effects, simple effects and lower-order interactions were not tested for significance if higher-order interactions involving that term were determined to be significant. All of the fixed effects and the significant covariates were included in the final model. The full model output is provided in the Appendix (Table A2).

The mixed-effects model revealed a significant effect of talker dialect, $\chi^2 = 6.69$, $df = 1$, $p = 0.010$, and a significant vowel pair $\times$ target type $\times$ trial type $\times$ listener group interaction, $\chi^2 = 4.05$, $df = 1$, $p = 0.044$. The trial number covariate, $\chi^2 = 371.35$, $df = 1$, $p < 0.001$, and the target word neighborhood density covariate, $\chi^2 = 5.02$, $df = 1$, $p = 0.025$, were also significant. Responses to targets following Northern primes were faster overall ($M = 629$ ms, $SD = 133$ ms) than responses to targets following Midland primes ($M = 636$ ms, $SD = 135$ ms), although the magnitude of this effect was very small (7 ms). An examination of Table 5 reveals the locus of the significant four-way interaction. Whereas the facilitation effect was comparable in magnitude across conditions for the multi-dialectal listeners, the facilitation effect was larger for the no-competitor mid-front targets than for the competitor mid-front targets for the mono-dialectal listeners. Target type did not

affect the magnitude of the facilitation effect for the low-front vowels for the mono-dialectal listeners. A series of identical mixed-effects models with treatment contrasts and different reference levels confirmed significant facilitation effects for all rows in Table 5, all $|t| > 4.59$. Thus, although facilitation was robustly observed across conditions, the mono-dialectal listeners were more sensitive to the lexical competition manipulation of the targets than the multi-dialectal listeners, but only for the mid-front target words.

The significant effects of the experimental factors were crucially independent of the significant covariates. The significant effects of trial number and target word neighborhood density reveal that response times decreased over the course of the experiment, consistent with overall practice effects, and that response times were faster for target words with more neighbors than for target words with fewer neighbors, consistent with previous studies showing facilitation for high density words relative to low density words in visual lexical decision tasks (Andrews, 1992; Yates, Locker, & Simpson, 2004; cf., Luce & Pisoni, 1998; Vitevitch & Luce, 1999 for the opposite effect of neighborhood density in auditory lexical decision tasks). However, none of the interactions involving the covariates were significant, indicating that the overall facilitation effect for matching primes was independent of trial number and that the effect of lexical competition on facilitation was independent of target word neighborhood density. The lack of a trial number $\times$ trial type interaction suggests that participants were not strategically responding "word" to matching trials as a result of learning about the distribution of trial types over the course of the experiment. Further, the overall effect of target word neighborhood density is in the opposite direction of the target type effect: whereas targets with many neighbors were responded to more quickly than targets with fewer neighbors overall, no-competitor targets (with fewer neighbors on average) were responded to more quickly on matching trials than competitor targets (with more neighbors on average) for the mid-front targets for the mono-dialectal listeners. Thus, the lexical competition produced by the auditory prime negated the neighborhood density benefit for the visual target.

We also expected to observe inhibition for competing trials relative to unrelated trials. A summary of the response times for competing and unrelated trials is shown in Table 6 for each talker dialect and vowel pair for each listener group. Only the competitor targets were included in this analysis because the no-competitor targets did not have real word competing primes. Inhibition is defined as slower mean response times to the competing trials than to the unrelated trials and was observed across most of the conditions in the lexical decision task.

A linear mixed-effect model predicting response time was constructed to explore the effects of the experimental factors on inhibition. Target vowel pair (mid-front, low-front), trial type (unrelated, competing), talker dialect (Midland, North), listener group (mono-dialectal, multi-dialectal), and all interactions were included as fixed effects. As in the previous analysis, target word neighborhood density, the target word neighborhood density $\times$ trial type interaction, trial number, and the trial number $\times$ trial type interaction were tested as covariates to ensure that inhibition was not simply the result of overall neighborhood density or strategic responding, respectively. The fixed effects were coded with sum contrasts and the covariates were centered for analysis. Random effects included random intercepts for participants and target words, as well as random by-participant slopes for vowel pair, trial type, and talker dialect and random by-word slopes for trial type and talker dialect. Model-building procedures and assessment of statistical significance were the same as in the previous model examining facilitation. The full model output is provided in the Appendix (Table A3).

The mixed-effects model revealed a significant vowel pair $\times$ trial type $\times$ talker dialect interaction, $\chi^2 = 3.88$, $df = 1$, $p = 0.049$, and a marginal vowel pair $\times$ trial type $\times$ listener group interaction, $\chi^2 = 3.14$, $df = 1$, $p = 0.076$. The trial number covariate, $\chi^2 = 179.07$, $df = 1$, $p < 0.001$, and the target word neighborhood density covariate, $\chi^2 = 3.98$, $df = 1$, $p = 0.046$, were also significant. An

Table 6. Response time means (ms) for real word targets preceded by unrelated and competing real word primes. Standard deviations of subject means are shown in parentheses.

Listener group	Vowel pair	Talker dialect	Unrelated primes	Competing primes	Inhibition
Mono-dialectal	Mid-front	Midland	682 (137)	740 (207)	58
		North	698 (164)	761 (182)	63
	Low-front	Midland	674 (137)	724 (164)	50
		North	694 (164)	695 (167)	1
Multi-dialectal	Mid-front	Midland	692 (189)	713 (177)	21
		North	679 (160)	725 (159)	46
	Low-front	Midland	674 (177)	716 (204)	42
		North	667 (181)	700 (155)	33

examination of Table 6 reveals the loci of the two fixed-effects interactions. First, inhibition was greater for the Northern talkers than the Midland talkers for the mid-front vowel pair, but greater for the Midland talkers than the Northern talkers for the low-front vowel pair. This cross-over effect suggests that inhibition is reduced when acoustic-phonetic distance between competitors is reduced. That is, Northern low-front vowels are less acoustically distinct than Midland low-front vowels, leading to less inhibition. Similarly, Midland mid-front vowels are less acoustically distinct than Northern mid-front vowels, leading to less inhibition. Second, inhibition was similar in magnitude across vowel pairs for the multi-dialectal listeners, but inhibition was greater for the mid-front vowels than the low-front vowels for the mono-dialectal listeners. This interaction suggests that the mono-dialectal listeners were more sensitive to interference from competing lexical items than the multi-dialectal listeners, but only for the mid-front target words. A series of identical mixed-effects models with treatment contrasts and different reference levels confirmed significant inhibition effects, $|t| > 1.96$, for six of the eight rows in Table 6. Inhibition was not significant for the Northern low-front vowels for the mono-dialectal listeners or for the Midland mid-front vowels for the multi-dialectal listeners.

As in the facilitation analysis, the significant effects of the experimental factors were crucially independent of the significant covariates. The significant effects of trial number and target word neighborhood density again reveal that response times decreased over the course of the experiment, consistent with overall practice effects, and that response times were faster for target words with more neighbors than for words with fewer neighbors, consistent with the facilitation analysis and previous visual lexical decision research (Andrews, 1992; Yates et al., 2004). As in the facilitation analysis, none of the interactions involving the covariates were significant, indicating that the overall inhibition effect for mismatching trials was independent of trial number and of target word neighborhood density. In particular, the lack of a trial number $\times$ trial type interaction confirms that the high proportion of related trials in this experiment did not lead to strategic responding to competing trials as a result of learning about the distribution of trial types over the course of the experiment.

3.2 Response times to nonword targets

We also expected to observe inhibition for competing nonword trials relative to unrelated nonword trials. A summary of the response times for competing and unrelated nonword trials is shown in Table 7 for each talker dialect and vowel pair for each listener group. Positive difference scores reflect inhibition and negative difference scores reflect facilitation for the competing nonword

Table 7. Response time means (ms) for nonword targets preceded by unrelated and competing real word primes. Standard deviations of subject means are shown in parentheses.

Listener group	Vowel pair	Talker dialect	Unrelated primes	Competing primes	Difference
Mono-dialectal	Mid-front	Midland	891 (202)	910 (209)	19
		North	876 (202)	889 (217)	13
	Low-front	Midland	819 (183)	823 (189)	4
		North	842 (166)	828 (180)	-14
Multi-dialectal	Mid-front	Midland	842 (214)	885 (259)	43
		North	881 (272)	883 (263)	2
	Low-front	Midland	837 (198)	846 (262)	9
		North	839 (202)	829 (205)	-10

trials relative to the unrelated nonword trials. As shown in Table 7, no overall inhibition or facilitation was observed across the two vowel pairs for either talker dialect for either listener group.

A linear mixed-effect model predicting response time was constructed to explore the effects of the experimental factors on inhibition. Target vowel pair (mid-front, low-front), trial type (unrelated, competing), talker dialect (Midland, North), listener group (mono-dialectal, multi-dialectal), and all interactions were included as fixed effects. As in the previous analyses, trial number and the trial number $\times$ trial type interaction were tested as covariates to ensure that the results do not reflect strategic responding as a result of learning over the course of the experiment. The fixed effects were coded with sum contrasts and the covariates were centered for analysis. Random effects included random intercepts for participants and target words, as well as random by-participant slopes for vowel pair and trial type and random by-word slopes for trial type and talker dialect. Model-building procedures and assessment of statistical significance were the same as in the previous models examining facilitation and inhibition for real words. The full model output is provided in the Appendix (Table A4).

The mixed-effects model revealed a significant vowel pair $\times$ talker dialect $\times$ listener group interaction, $\chi^2 = 3.90$, $df = 1$, $p = 0.048$. The trial number covariate, $\chi^2 = 95.89$, $df = 1$, $p < 0.001$, was also significant. The interaction reflects differences in overall response times to nonword targets as shown in Table 7. Whereas mono-dialectal listeners responded faster to the low-front nonwords than to the mid-front nonwords, especially when preceded by Midland primes, the multi-dialectal listeners responded faster to the low-front nonwords than to the mid-front nonwords, especially when preceded by Northern primes. The effect of trial type was not significant as a simple effect or in interaction with the other factors. Thus, competing real word primes neither inhibited nor facilitated nonword lexical decision responses for either vowel pair for either listener group. As in the previous analyses, the significant interaction among the experimental factors was crucially independent of the significant effect of trial number, which again shows that response times decreased over the course of the experiment, consistent with overall practice effects. As in the previous analyses, the trial number $\times$ trial type interaction was not significant, suggesting that the null result for trial type does not reflect learning about the distribution of trial types over the course of the experiment.

4 Discussion

Matching real word primes facilitated lexical decision response times for both target types, both vowel pairs, and both talker dialects for both listener groups. In a cross-modal lexical decision task,

the auditory prime activates its associated lexical representation. When the matching visual target is presented immediately after the auditory prime, residual activation of the lexical representation from the auditory prime leads to a faster lexical decision response for the matching visual target. Robust identity priming is consistent with early research on phonological form priming (e.g., Slowiaczek & Pisoni, 1986), as well as previous research on cross-dialect and cross-language lexical processing (Broersma, 2012; Dufour et al., 2007; Pallier et al., 2001; Rae & Warren, 2002). Although identity priming can be blocked for unfamiliar variants, as Sumner and Samuel (2009) observed for unfamiliar non-rhotic variants, all of the variants in the current study were sufficiently familiar to both listener groups and priming was consistently observed across both vowel pairs and both talker dialects.

Competing real word primes inhibited lexical decision response times overall for both vowel pairs and both talker dialects for both listener groups. In a cross-modal lexical decision task, the auditory prime activates its lexical representation, as well as the representations of phonologically similar forms, including the minimal pair target. However, the recognition of the auditory prime leads to suppression of phonologically similar forms, including the minimal pair target; thus, when the competing visual target is presented immediately after the auditory prime, residual suppression of its lexical representation from the auditory prime leads to a slower lexical decision response for the competing visual target. Processing of the auditory prime therefore leads to residual activation and facilitation for a matching target, but residual suppression and inhibition for a competing target. Inhibition for phonologically similar primes, including minimal pairs, is consistent with previous research on phonological form priming (e.g., Goldinger et al., 1992; Hamburger & Slowiaczek, 1996; Radeau et al., 1989), as well as Broersma's (2012) findings for the native listeners in her study.

Although some previous auditory form priming studies revealed facilitation for phonologically similar primes (e.g., Hillinger, 1980; Slowiaczek et al., 1987), these studies involved longer ISIs (250 ms for Hillinger, 1980, and 50 ms for Slowiaczek et al., 1987) than our study, in which we presented the visual target at the offset of the auditory prime (i.e., with a 0 ms ISI). Inhibition for phonologically similar prime–target pairs is also more robustly observed in lexical decision tasks than in word naming or shadowing tasks (Radeau et al., 1989), when the proportion of related prime–target pairs is relatively small (e.g., 21% vs. 75%; Hamburger & Slowiaczek, 1996), and when the similarity between the primes and the targets is high (e.g., 3-phoneme overlap vs. 1-phoneme overlap; Hamburger & Slowiaczek, 1996). In the current study, the lexical decision task, short ISI, and moderate proportion of highly related prime–target pairs (58%, including both matching and competing primes; see Table 4) may have enhanced our ability to elicit robust inhibition for competing primes relative to unrelated primes. In particular, the short ISI did not allow the immediate inhibitory effects of the prime to recede before the target was presented (see also Goldinger et al., 1992), the non-verbal response did not allow effects of lexical competition on naming latencies (e.g., Vitevitch, 2002) to interfere with our interpretation of the response times, and the moderate proportion of highly related prime–target pairs prevented participants from adopting a response strategy or bias (see also Hamburger & Slowiaczek, 1996).

No effects of competing word primes on nonword targets were observed for either vowel pair or either listener group, suggesting that activation of a real word target neither facilitated nor inhibited the lexical decision response times to nonword targets. This result differs from the significant inhibition observed for competing word primes and nonword targets in earlier studies of the effects of phonetic variation on lexical processing (Sumner, 2013; van Alphen & McQueen, 2006). An inspection of the distribution of response time difference scores between the unrelated and competing nonword trials across participants confirms that the lack of an effect in the current study was not the result of a mixed pattern of inhibition, as observed in the earlier studies, and facilitation,

resulting from misidentification of the auditory prime as a match to the nonword target. The difference scores were normally distributed around 0, suggesting a consistent lack of both facilitation and inhibition across participants. This difference between the current study and the previous studies may therefore reflect either fundamental differences in the examined sources of variation (phonetic reduction vs. regional dialect) or fundamental differences in the effects of consonant vs. vowel variation on lexical activation and competition. The earlier studies involved consonant variation in VOT (van Alphen & McQueen, 2006) and nasal flapping (Sumner, 2013), whereas the current study involved dialect-specific vowel variation. Vowel perception is less categorical than consonant perception (Pisoni, 1973), which may lead to a different pattern of lexical competition effects across the two segment types. Given that regional phonological variation in American English is predominantly observed in the vowel system, phonetic reduction processes may provide a better source of variation for comparing the effects of consonant vs. vowel variability on lexical competition.

Although robust effects of facilitation and inhibition were observed for matching and competing real word primes, respectively, the magnitude of these effects was significantly affected by the target vowel pair, the prime talker dialect, and the listener group. First, a novel lexical competition effect on facilitation was observed for the mono-dialectal listener group for the mid-front vowel pair. More facilitation was observed for the no-competitor words than for the competitor words, reflecting local lexical competition (Luce & Pisoni, 1998). An auditory prime activates a neighborhood of phonologically similar lexical candidates, including the matching target. Less facilitation is observed when the matching prime activates highly similar phonological neighbors, as in the competitor condition, because there is more competition for lexical access among the set of activated words and the impact of the residual activation from the matching auditory prime is therefore reduced. This effect is crucially independent of an overall effect, in the opposite direction, of the neighborhood density of the visual target word on response times: responses to target words with many neighbors were faster overall than responses to target words with fewer neighbors (see also Andrews, 1992; Yates et al., 2004). Thus, the local competition between the auditory prime and its phonologically similar competitors in the competitor condition overrides the processing benefit for visual targets in dense neighborhoods. This finding also complements Dufour and Peereman's (2003) observation that inhibition for competing auditory prime–target pairs is reduced for targets in larger neighborhoods relative to targets in smaller neighborhoods. Less inhibition is observed when the competing target is in a larger neighborhood because there is more competition for lexical access among the larger set of activated words and the impact of the residual suppression from the auditory prime is therefore reduced.

Second, an interaction between vowel pair and talker dialect was observed on inhibition. We interpret this interaction as reflecting an effect of acoustic–phonetic vowel similarity on inhibition. In particular, the acoustically more similar Midland mid-front vowels and Northern low-front vowels exhibited less inhibition than the acoustically more different Northern mid-front vowels and Midland low-front vowels, respectively. This result suggests that inhibition for competing primes is reduced when the prime itself is more phonetically ambiguous (see Figure 1) and the resulting activation of and competition between the minimal pair lexical representations is more robust. That is, comparable to Dufour and Peereman's (2003) finding that inhibition is reduced for competing primes in large lexical neighborhoods where competition among potential candidates is strong, inhibition is reduced for competing primes that are phonetically ambiguous because competition among potential candidates is strong. This robust competition between potential candidates may lead to delayed recognition of the auditory prime, as suggested by Broersma (2012) for bilingual processing, reducing the suppression of the competitor target and therefore the inhibitory effect of the prime on the target response. Given this account, we predict

that this interaction between talker dialect and vowel pair would not be observed in a design with a longer ISI or in a task in which responses were not speeded (such as word recognition) because the participant would have more time to resolve the identity of the prime before responding to the target.

Third, more inhibition was observed for the mono-dialectal listener group for the mid-front vowel pair than for any of the other listener group $\times$ vowel pair combinations. As suggested above, this increased inhibition is consistent with less lexical competition between the minimal pair prime and target for the mid-front vowel pair for the mono-dialectal listeners relative to the other vowel pair and listener group. Thus, this result, together with the enhanced facilitation for the no-competitor mid-vowel targets for the mono-dialectal listeners described above, suggests that lexical competition is weaker for the mid-front vowel pair than for the low-front vowel pair and for the mono-dialectal listeners than for the multi-dialectal listeners. These results are therefore consistent with the second set of predictions laid out in the introduction. In particular, as expected based on the previous research on bilingual vowel perception (e.g., Broersma, 2012) and cross-dialect perception of vowel mergers (e.g., Rae & Warren, 2002), our results reveal less facilitation and less inhibition for the multi-dialectal listeners than the mono-dialectal listeners, especially for the mid-front vowel pair.

The mid-front vowel pair is both more acoustically different overall (see Figure 1) and less perceptually confusable (Clopper et al., 2010; Jacewicz & Fox, 2012) than the low-front vowel pair, which would lead to a prediction of stronger lexical competition for the low-front pair than for the mid-front pair (Luce & Pisoni, 1998), as observed in the current study. However, the mid-front vowel targets had significantly more competitors ($M = 26$ neighbors) than the low-front vowel targets ($M = 22$ neighbors), which would lead to a prediction of stronger lexical competition for the mid-front pair than for the low-front pair (Dufour & Peereman, 2003), contrary to the observed pattern. Further, the mean response times to the two vowel pairs on the unrelated real word trials were not significantly different in any of the statistical models ($M = 673$ ms for the mid-front vowels; $M = 669$ ms for the low-front vowels), suggesting that the vowel pair effect on facilitation and inhibition was not the result of a difference in baseline performance across stimulus sets that can be attributed to overall lexical competition. Finally, as suggested by Sumner et al. (2014), the social stereotypes associated with the dialect-specific variants of these vowels may contribute to their perception and representation. In particular, positively-evaluated variants are expected to be more robustly represented than negatively-evaluated variants. The social dimension of the variants used in this study is particularly relevant because the distinction between the Midland and Northern dialects is only partially enregistered (Campbell-Kibler, 2012). Thus, although some of the participants may have been able to identify the Northern low-vowel variants as Northern, they are unlikely to hold negative stereotypes about those variants. As a result, all of the low-vowel variants are socially unmarked, which may enhance the effect of acoustic similarity on lexical competition because the variability is not structured around social categories. By contrast, the Southern dialect is strongly enregistered (Campbell-Kibler, 2012) and to the extent that participants identified the Midland variants as Southern-like, they may have also associated negative stereotypes with those variants. As a result, the effect of acoustic similarity on lexical competition may have been reduced because the variability can be tied to social stereotypes. Our findings therefore suggest that a more thorough exploration of these various factors contributing to lexical competition is essential for understanding the nature of lexical representation and processing within and across dialects.

The more robust lexical competition effect for the multi-dialectal listener group than the mono-dialectal listener group suggests that experience with multiple phonological systems affects the activation of word candidates, as suggested by Broersma (2012) for bilinguals. Broersma (2012)

argued that the Dutch–English bilinguals’ experience with two phonological systems leads to a lack of inhibition for the competing real word primes, because the bilinguals have less robust phonological representations for English than native English listeners. These less robust phonological representations lead to uncertainty about the identity of the auditory prime, which allows multiple lexical candidates to remain highly active over a longer time and reduces inhibition for competing primes. Similarly, the effect of dialect experience on lexical competition observed in the current study may reflect greater activation among lexical competitors for multi-dialectal listeners relative to mono-dialectal listeners. Like bilinguals, listeners with exposure to multiple dialects may have more variable phonological representations. Recognition decisions between competing lexical candidates may be delayed so that cross-dialect variability can be accommodated in lexical processing, facilitating performance on a range of tasks relative to less experienced listeners (e.g., Floccia et al., 2006; Labov & Ash, 1997). Unlike for bilinguals, however, suppression of competing words is not sufficiently reduced to eliminate all inhibition effects for multi-dialectal listeners. Rather, as a result of their native language experience the multi-dialectal listeners exhibit reduced inhibition relative to mono-dialectal listeners. Similar to the effect of talker dialect on inhibition discussed above, we predict that this effect of listener dialect would not be observed in a design with a longer ISI or in a task in which responses were not speeded because the participants would have more time to resolve the identity of the prime before responding to the target.

This interpretation of extended lexical activation of competitors among multi-dialectal listeners is also consistent with Goldinger et al.’s (1992) suggestion that phonologically similar primes inhibit lexical processing of targets, but that this inhibition can be over-ridden by strategic biases. That is, the multi-dialectal listeners may adopt a strategy of delaying recognition of the auditory primes, thereby reducing the inhibitory effect of competing primes on target responses. This potential bias for multi-dialectal listeners to maintain flexible mappings between the acoustic signal and phonological or lexical categories is further consistent with evidence for rapid adaptation to dialect variation in laboratory settings, in which listeners quickly learn new signal-to-phoneme mappings to maximize their comprehension of unfamiliar talkers (e.g., Dahan, Drucker, & Scarborough, 2008; Maye, Aslin, & Tanenhaus, 2008; Weatherholtz, 2015). However, our data do not allow us to distinguish between multi-dialectal participants with different kinds of cross-dialect experience (cf., Sumner & Samuel, 2009). Thus, additional research is necessary to determine whether experience with particular variants is critical to the observed patterns or if mere exposure to multiple varieties can lead to strategic delays in lexical activation and suppression, regardless of the familiarity of the variants that are presented. The results of the current study suggest that long-term exposure to multiple dialects as a result of a mobile residential history leads to an overall processing strategy that is more flexible than the strategy adopted by mono-dialectal listeners. This more flexible processing strategy leads to greater short-term uncertainty about the signal-to-phoneme mapping, which results in more competition among potential word candidates in speeded lexical processing.

Acknowledgements

We would like to thank Kenney Hensley, Erin Loxley, Jane Mitsch, and Macy Uchino for assistance with data collection and McKenna Reeher and Rory Turnbull for assistance with the acoustic analysis of the auditory primes.

Funding

This work was supported by the National Science Foundation [BCS-1056409].

Notes

1. Older participants were excluded because they are more likely to exhibit hearing loss than younger participants.
2. Although living abroad almost certainly leads to different linguistic experiences than mobility within the United States, we grouped the two participants who had lived abroad with the multi-dialectal listeners to ensure that the mono-dialectal listener group was as homogeneous as possible. Of the two multi-dialectal participants who had lived abroad, one had lived in three US dialect regions plus Germany and the other had lived in the General American dialect region plus Australia. Thus, both had exposure to multiple varieties of English.
3. Participants responded “word” on a mean of 142 trials (standard deviation = 6.4), confirming that their responses mirrored the actual distribution of real words (N = 144) and nonwords (N = 48) in the stimulus materials, and suggesting that the participants did not have response strategies based on expectations of equal numbers of real words and nonwords in the experiment.
4. Although some cross-trial priming is possible given this design, any facilitation due to cross-trial priming would reduce the magnitude of the effects we report (i.e., would more likely lead to Type II than Type I errors). Specifically, prior auditory exposure to a target in an unrelated trial would shorten the response time to that target, thereby reducing the facilitation effect observed in the comparison between unrelated and matching trials. Similarly, prior auditory exposure to a target in a competing trial would shorten the response time to that target, thereby reducing the inhibition effect observed in the comparison between unrelated and competing trials. The use of six stimulus lists and the randomization of the trials separately by participant further ensured that any cross-trial facilitation is distributed randomly throughout the data.
5. This uneven distribution is due to the fact that five participants were removed prior to analysis for low overall accuracy. We tested list as a factor in all of the reported statistical analyses to ensure that the uneven number of participants across lists did not impact our results. List was not significant in any of these analyses and will not be discussed further.
6. Despite the relatively low number of response times excluded in this first pruning step, this step was necessary to avoid skewing the by-subject response time means and standard deviations calculated in the next step of the pruning process.

References

- Andrews, S. (1992). Frequency and neighborhood effects on lexical access: Lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18(2), 234–254.
- Andruski, J. E., Blumstein, S. E., & Burton, M. (1994). The effect of subphonetic differences on lexical access. *Cognition*, 52(3), 163–187.
- Baayen, H. (2008). *Analyzing Linguistic Data: A Practical Introduction to Statistics using R*. Cambridge, UK: Cambridge University Press.
- Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278.
- Broersma, M. (2012). Increased lexical activation and reduced competition in second-language listening. *Language and Cognitive Processes*, 27(7/8), 1205–1224.
- Campbell-Kibler, K. (2012). Contestation and enregisterment in Ohio’s imagined dialects. *Journal of English Linguistics*, 40(3), 281–305.
- Clopper, C. G., Carter, A. K., Dillon, C. M., Hernandez, L. R., Pisoni, D. B., Clarke, C. M., ... Herman, R. (2002). The Indiana Speech Project: An overview of the development of a multi-talker multi-dialect speech corpus. In D. B. Pisoni (Ed.), *Research on Spoken Language Processing Progress Report No. 25* (pp. 367–380). Bloomington, IN: Speech Research Laboratory, Indiana University.
- Clopper, C. G., Pierrehumbert, J. B., & Tamati, T. N. (2010). Lexical neighborhoods and phonological confusability in cross-dialect word recognition in noise. *Laboratory Phonology*, 1(1), 65–92.
- Clopper, C. G., Pisoni, D. B., & de Jong, K. (2005). Acoustic characteristics of the vowel systems of six regional varieties of American English. *Journal of the Acoustical Society of America*, 118(3/1), 1661–1676.

- Connine, C. M., Blasko, D. G., & Titone, D. (1993). Do the beginnings of spoken words have a special status in auditory word recognition? *Journal of Memory and Language*, 32(2), 193–210.
- Dahan, D., Drucker, S. J., & Scarborough, R. A. (2008). Talker adaptation in speech perception: Adjusting the signal or the representations? *Cognition*, 108(3), 710–718.
- Dufour, S., Nguyen, N., & Frauenfelder, U. H. (2007). The perception of phonemic contrasts in a non-native dialect. *Journal of the Acoustical Society of America: Express Letters*, 121(4), EL131–EL136.
- Dufour, S., & Peereman, R. (2003). Inhibitory priming effects in auditory word recognition: When the target's competitors conflict with the prime word. *Cognition*, 88(3), B33–B44.
- Floccia, C., Girard, F., Goslin, J., & Konopczynski, G. (2006). Does a regional accent perturb speech processing? *Journal of Experimental Psychology: Human Perception and Performance*, 32(5), 1276–1293.
- Fox, R. A., & Jacewicz, E. (2009). Cross-dialectal variation in formant dynamics of American English vowels. *Journal of the Acoustical Society of America*, 126(5), 2603–2618.
- Goldinger, S. D., Luce, P. A., Pisoni, D. B., & Marcario, J. K. (1992). Form-based priming in spoken word recognition: The roles of competition and bias. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18(6), 1211–1238.
- Hamburger, M., & Slowiczek, L. M. (1996). Phonological priming reflects lexical competition. *Psychonomic Bulletin and Review*, 3(4), 520–525.
- Hillenbrand, J., Getty, L. A., Clark, M. J., & Wheeler, K. (1995). Acoustic characteristics of American English vowels. *Journal of the Acoustical Society of America*, 97(5/1), 3099–3111.
- Hillinger, M. L. (1980). Priming effects with phonemically similar words: The encoding bias hypothesis reconsidered. *Memory and Cognition*, 8(2), 115–123.
- Impe, L., Geeraerts, D., & Speelman, D. (2008). Mutual intelligibility of standard and regional Dutch language varieties. *International Journal of Humanities and Arts Computing*, 2(1/2), 101–117.
- Jacewicz, E., & Fox, R. A. (2012). The effects of cross-generational and cross-dialectal variation on vowel identification and classification. *Journal of the Acoustical Society of America*, 131(2), 1413–1433.
- Labov, W. (1998). *The three dialects of English*. In M. D. Linn (Ed.), *Handbook of dialects and language variation* (pp. 39–81). San Diego, CA: Academic Press.
- Labov, W., & Ash, S. (1997). *Understanding Birmingham*. In C. Bernstein, T. Nunnally, & R. Sabino (Eds.), *Language variety in the south revisited* (pp. 508–573). Tuscaloosa, AL: University of Alabama Press.
- Labov, W., Ash, S., & Boberg, C. (2006). *The atlas of North American English: phonetics, phonology and sound change; a multimedia reference tool*. New York, NY: Mouton de Gruyter.
- LoCasto, P. C., & Connine, C. M. (2011). Processing no-release variants in connected speech. *Language and Speech*, 54(2), 181–197.
- Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing*, 19(1), 1–36.
- Mason, H. M. (1946). Understandability of speech in noise as affected by region of origin of speaker and listener. *Speech Monographs*, 13(2), 54–68.
- Maye, J., Aslin, R. N., & Tanenhaus, M. K. (2008). The Weckud Wetch of the Wast: Lexical adaptation to a novel accent. *Cognitive Science*, 32(3), 543–562.
- Munson, B., & Solomon, N. P. (2004). The effect of phonological neighborhood density on vowel articulation. *Journal of Speech, Language, and Hearing Research*, 47(5), 1048–1058.
- Nusbaum, H. C., Pisoni, D. B., & Davis, C. K. (1984). *Sizing up the Hoosier Mental Lexicon: Measuring the familiarity of 20,000 words*. In D. B. Pisoni (Ed.), *Research on Speech Perception Progress Report No. 10* (pp. 357–376). Bloomington, IN: Speech Research Laboratory, Indiana University.
- Pallier, C., Colomé, A., & Sebastián-Gallés, N. (2001). The influence of native-language phonology on lexical access: Exemplar-based versus abstract lexical entries. *Psychological Science*, 12(6), 445–449.
- Pisoni, D. B. (1973). Auditory and phonetic memory codes in the discrimination of consonants and vowels. *Perception & Psychophysics*, 13(2), 253–260.
- Radeau, M., Morais, J., & Dewier, A. (1989). Phonological priming in spoken word recognition: Task effects. *Memory and Cognition*, 17(5), 525–535.

- Radeau, M., Morais, J., & Segui, J. (1995). Phonological priming between monosyllabic spoken words. *Journal of Experimental Psychology: Human Perception and Performance*, 21(6), 1297–1311.
- Rae, M., & Warren, P. (2002). Goldilocks and the three beers: Sound merger and word recognition in NZE. *New Zealand English Journal*, 16, 33–41.
- Sebastián-Gallés, N., Echeverría, S., & Bosch, L. (2005). The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals. *Journal of Memory and Language*, 52(2), 240–255.
- Slowiaczek, L. M., Nusbaum, H. C., & Pisoni, D. B. (1987). Phonological priming in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13(1), 64–75.
- Slowiaczek, L. M., & Pisoni, D. B. (1986). Effects of phonological similarity on priming in auditory lexical decision. *Memory and Cognition*, 14(3), 230–237.
- Spinelli, E., McQueen, J. M., & Cutler, A. (2003). Processing resyllabified words in French. *Journal of Memory and Language*, 48(2), 233–254.
- Sumner, M. (2013). A phonetic explanation of pronunciation variant effects. *Journal of the Acoustical Society of America: Express Letters*, 134(1), EL26–EL32.
- Sumner, M., & Kataoka, R. (2013). Effects of phonetically-cued talker variation on semantic encoding. *Journal of the Acoustical Society of America: Express Letters*, 134(6), EL485–EL491.
- Sumner, M., & Samuel, A. G. (2007). Lexical inhibition and sublexical facilitation are surprisingly long lasting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33(4), 769–790.
- Sumner, M., & Samuel, A. G. (2009). The effect of experience on the perception and representation of dialect variants. *Journal of Memory and Language*, 60(4), 487–501.
- Sumner, M., Kim, S. K., King, E., & McGowan, K. B. (2014). The socially weighted encoding of spoken words: A dual-route approach to speech perception. *Frontiers in Psychology*, 4(1015), 1–13.
- Tuinman, A., Mitterer, H., & Cutler, A. (2012). Resolving ambiguity in familiar and unfamiliar casual speech. *Journal of Memory and Language*, 66(4), 530–544.
- van Alphen, P. M., & McQueen, J. M. (2006). The effect of voice onset time differences in lexical access in Dutch. *Journal of Experimental Psychology: Human Perception and Performance*, 32(1), 178–196.
- Vitevitch, M. S. (2002). The influence of phonological similarity neighborhoods on speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28(4), 735–747.
- Vitevitch, M. S., & Luce, P. A. (1999). Probabilistic phonotactics and neighborhood activation in spoken word recognition. *Journal of Memory and Language*, 40, 374–408.
- Weatherholtz, K. (2015). *Perceptual learning of systematic cross-category vowel variation*. Doctoral dissertation, Ohio State University. Retrieved from <https://etd.ohiolink.edu/>
- Wright, R. (2004). *Factors of lexical competition in vowel articulation*. In J. Local, R. Ogden, & R. Temple (Eds.), *Phonetic interpretation: papers in laboratory phonology VI* (pp. 75–86). Cambridge, UK: Cambridge University Press.
- Wright, R., & Souza, P. (2012). Comparing identification of standardized and regionally valid vowels. *Journal of Speech, Language, and Hearing Research*, 55(1), 182–193.
- Yates, M., Locker, J. L., & Simpson, G. B. (2004). The influence of phonological neighborhood on visual word perception. *Psychonomic Bulletin and Review*, 11(3), 452–457.

Appendix

The lexical decision targets used in the lexical decision task are shown in Table A1. All real word targets were also used as auditory primes. The competitor targets are presented in their competitor pairs (mid–front and low–front) and were preceded by either a matching auditory prime, the competing auditory prime, or a phonologically unrelated auditory prime across stimulus lists. The non-competitor targets were preceded by either a matching auditory prime or a phonologically unrelated auditory prime across stimulus lists. The competing nonword targets are presented to the right of

their real word competitor and were preceded by either this competing auditory prime or a phonologically unrelated auditory prime across stimulus lists.

The model output for the facilitation, inhibition, and nonword analyses are presented in Tables A2, A3, and A4, respectively.

Table A1. The lexical decision targets used in the lexical decision task.

Competitor targets							
Mid-front pairs				Low-front pairs			
bit	bait	bed	bad				
chin	chain	beg	bag				
dim	dame	bet	bat				
fill	fail	dead	dad				
fit	fate	fed	fad				
hill	hail	gem	jam				
hit	hate	guess	gas				
kick	cake	head	had				
lick	lake	hem	ham				
lit	late	leg	lag				
mid	made	men	man				
mitt	mate	mesh	mash				
nip	nape	mess	mass				
pill	pail	met	mat				
rid	raid	neck	knack				
ridge	rage	net	gnat				
ship	shape	peck	pack				
sick	sake	pen	pan				
sill	sail	pet	pat				
tick	take	said	sad				
tip	tape	set	sat				
wick	wake	shell	shall				
will	wail	ten	tan				
wit	wait	wreck	rack				

No-competitor targets and competing nonword targets (*)							
Mid-front targets				Low-front targets			
chill	*chale	bake	*bick	bell	*bal	badge	*bedge
chip	*chape	base	*biss	check	*chack	cab	*keb
did	*dade	cape	*kip	chef	*shaff	cap	*kep
dip	*dape	chase	*chiss	deaf	*daff	cat	*ket
ditch	*daitch	date	*dit	death	*dath	dam	*dem
gym	*jame	face	*fiss	debt	*dat	fan	*fen
him	*hame	faith	*fith	deck	*dack	gag	*geg
hip	*hape	fake	*fick	fell	*fal	half	*heff
hitch	*haitch	fame	*fim	get	*gat	hat	*het
kid	*cade	gate	*git	hedge	*hadge	have	*hev
lip	*lape	lace	*liss	jet	*jat	jazz	*jezz
nick	*nake	maim	*mim	keg	*kag	lamb	*lem

Table A1. (Continued)

No-competitor targets and competing nonword targets (*)

Mid-front targets				Low-front targets			
pick	*pake	main	*min	ledge	*ladge	lap	*lep
pit	*pate	make	*mick	let	*lat	lash	*lesh
pitch	*paitch	paid	*pid	peg	*pag	pad	*ped
rib	*raib	race	*riss	sell	*sal	pal	*pel
rich	*raitch	rail	*rill	shed	*shad	pass	*pess
rig	*rague	rain	*rin	tell	*tal	ram	*rem
rim	*rame	same	*sim	them	*tham	rat	*ret
shin	*shain	shake	*shick	web	*wab	sack	*seck
sip	*sape	vase	*viss	wedge	*wadge	sap	*sep
thin	*thane	veil	*vill	well	*wal	tag	*teg
tin	*tane	wade	*wid	wet	*wat	tap	*tep
witch	*waitch	wave	*wiv	yes	*yass	van	*ven

Table A2. Model output for the facilitation analysis. The dependent variable was the log-transformed response times.

Fixed effects	Estimate	t-value
Intercept	6.390	346.20
Vowel pair	0.007	1.20
Trial type	0.083	18.90
Target type	-0.007	-1.20
Talker dialect	0.008	2.80
Listener group	0.006	0.30
Trial number	-0.001	-19.50
Target word density	-0.002	-2.30
Vowel pair x trial type	-0.003	-0.90
Vowel pair x target type	-0.007	-1.20
Trial type x target type	0.002	0.70
Vowel pair x talker dialect	<0.001	0.10
Trial type x talker dialect	-0.003	-1.20
Target type x talker dialect	0.004	1.50
Vowel pair x listener group	<0.001	0.00
Trial type x listener group	0.006	1.50
Target type x listener group	<0.001	0.00
Talker dialect x listener group	-0.001	-0.50
Vowel pair x trial type x target type	-0.001	-0.20
Vowel pair x trial type x talker dialect	-0.004	-1.60
Vowel pair x target type x talker dialect	-0.001	-0.30
Trial type x target type x talker dialect	0.002	0.70
Vowel pair x trial type x listener group	0.002	0.80
Vowel pair x target type x listener group	0.001	0.40
Trial type x target type x listener group	0.001	0.20
Vowel pair x talker dialect x listener group	<0.001	-0.10
Trial type x talker dialect x listener group	<0.001	-0.20

(Continued)

Table A2. (Continued)

Fixed effects	Estimate	t-value
Target type x talker dialect x listener group	-0.001	-0.30
Vowel pair x trial type x target type x talker dialect	-0.003	-1.30
Vowel pair x trial type x target type x listener group	0.005	2.00
Vowel pair x trial type x talker dialect x listener group	-0.001	-0.60
Vowel pair x target type x talker dialect x listener group	-0.002	-0.80
Trial type x target type x talker dialect x listener group	0.004	1.60
Vowel pair x trial type x target type x talker dialect x listener group	0.001	0.40

Table A3. Model output for the inhibition analysis. The dependent variable was the log-transformed response times.

Fixed effects	Estimate	t-value
Intercept	6.502	325.10
Vowel pair	0.020	2.10
Trial type	-0.025	-5.30
Talker dialect	-0.001	-0.30
Listener group	0.010	0.50
Trial number	-0.001	-13.50
Target word density	-0.003	-2.00
Vowel pair x trial type	-0.006	-1.60
Vowel pair x talker dialect	-0.006	-1.70
Trial type x talker dialect	<0.001	-0.10
Vowel pair x listener group	0.002	0.60
Trial type x listener group	<0.001	0.10
Talker dialect x listener group	-0.003	-0.70
Vowel pair x trial type x talker dialect	0.007	2.00
Vowel pair x trial type x listener group	-0.006	-1.80
Vowel pair x talker dialect x listener group	-0.002	-0.50
Trial type x talker dialect x listener group	-0.002	-0.70
Vowel pair x trial type x talker dialect x listener group	0.001	0.20

Table A4. Model output for the nonword analysis. The dependent variable was the log-transformed response times.

Fixed effects	Estimate	t-value
Intercept	6.710	340.30
Vowel pair	0.028	3.90
Trial type	0.004	0.90
Talker dialect	0.000	0.10
Listener group	0.006	0.30
Trial number	-0.001	-9.90
Vowel pair x trial type	-0.005	-1.40
Vowel pair x talker dialect	0.002	0.40
Trial type x talker dialect	-0.003	-0.90

Table A4. (Continued)

Fixed effects	Estimate	t-value
Vowel pair x listener group	0.008	1.90
Trial type x listener group	0.002	0.50
Talker dialect x listener group	0.001	0.40
Vowel pair x trial type x talker dialect	-0.002	-0.50
Vowel pair x trial type x listener group	-0.001	-0.20
Vowel pair x talker dialect x listener group	0.007	2.00
Trial type x talker dialect x listener group	0.001	0.20
Vowel pair x trial type x talker dialect x listener group	0.001	0.40