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Research Article

语音弱化和地域方言对元音产出的影响

Effects of phonetic reduction and regional dialect on vowel production

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ABSTRACT

Many linguistic factors contribute to variation in vowel dispersion, including lexical properties, such as word frequency, and discourse properties, such as previous mention. Indexical factors, such as regional dialect, similarly contribute to spectral vowel variation in production. A handful of previous studies have further suggested that linguistic and indexical factors interact such that talkers produce more extreme sociolinguistic variants in linguistic contexts that promote phonetic reduction, such as high frequency and high predictability words. The goal of the current study was to extend the empirical base of this research through an exploration of the interactions between regional dialect and lexical phonological similarity, discourse mention, and speaking style, respectively, on vowel production in Northern and Midland American English. The results revealed more extreme regional dialect variants in reduction-promoting contexts, consistent with previous research. However, substantial variability in phonetic reduction and its interaction with dialect variation was also observed across linguistic contexts, vowel categories, and acoustic domains (temporal vs. spectral), suggesting that a more complex account of the cognitive, linguistic, and indexical factors contributing to phonetic reduction processes is necessary.

1. Introduction

Phonetic reduction processes are realized on vowels in both the temporal domain, as shorter duration, and in the spectral domain, as centralization in the vowel space. Although phonetic vowel reduction is considered a distinct process from phonological vowel reduction (i.e., alternations with /ə/; Fourakis, 1991; Padgett & Tabain, 2005), phonetic vowel reduction is typically described as involving centralization towards a "neutral" vowel (i.e., /ə/; Fourakis, 1991; van Bergem, 1993). This centralization is captured quantitatively as the distance in the vowel space from a particular vowel to the acoustic center of the space, defined as the grand mean of F1 and F2 values across vowels (Bradlow, Torretta, & Pisoni, 1996; Fourakis, 1991; Munson & Solomon, 2004; Scarborough, 2010; Scarborough & Zellou, 2013; Wright, 2004; Zellou & Scarborough, 2015). This dispersion approach to assessing spectral vowel reduction reflects the theoretical understanding of this process as involving articulatory undershoot or gestural economy in reduced forms relative to unreduced forms (Lindblom, 1990; Recasens, 1999).

Numerous linguistic contexts have been shown to contribute to phonetic vowel reduction in the temporal and/or spectral domains, including lexical frequency, lexical phonological similarity, semantic predictability, discourse mention, and speaking style (for a review, see Clopper and Turnbull (in press)). Specifically, high frequency words, words with few phonological neighbors, predictable words, repeated mentions of words, and words in a casual speaking style are phonetically reduced relative to low frequency words, words with many phonological neighbors, less predictable words, first mentions of words, and words in a careful speaking style. The theoretical interpretation of these effects is that phonetic reduction arises when the lexical target is easy for the talker and/or the listener to access. For example, Lindblom's (1990) hyper- and hypospeech (H&H) theory describes phonetic reduction as a trade-off between gestural economy, which benefits the talker, and the maintenance of perceptual distinctiveness, which benefits the listener (see also Aylett and Turk (2004, 2006)). That is, according to the listener-oriented account (e.g., Aylett & Turk, 2004, 2006; Lindblom, 1990), phonetic reduction is a result of the competing needs of the talker to maintain comprehensibility of the message while expending as little energy as possible. Thus, when the listener is expected to easily understand the message, the talker can reduce

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or hypoarticulate, but when the listener is expected to have more difficulty understanding the message, the talker must speak more clearly and avoid reduction. This listener-oriented approach makes strong assumptions about the talker's ability to track the listener's needs. However, the evidence for this type of real-time listener modeling is somewhat mixed (Arnold, 2008; Bard et al., 2000; Kahn & Arnold, 2015; Snedeker & Trueswell, 2003), leading to alternative proposals that phonetic reduction reflects primarily speech production processes, such as retrieval and planning (e.g., Arnold, Kahn, & Pancani, 2012; Baese-Berk & Goldrick, 2009; Bard et al., 2000; Jurafsky, Bell, Gregory, & Raymond, 2001). That is, according to the talker-oriented account (e.g., Baese-Berk & Goldrick, 2009; Jurafsky et al., 2001), phonetic reduction is a result of the cognitive processes underlying speech production. Specifically, word forms that are easy to access in production are reduced relative to word forms that are more difficult to access, due to differences in lexical access speed and/or activation.

In both the listener-oriented and talker-oriented approaches to phonetic reduction, the typical assumption is that the observed effects across all of the various linguistic contexts derive from a single underlying process. For example, Lindblom (1990) drew explicit connections between lexical sources of reduction, such as lexical frequency and phonological similarity, and stylistic sources of reduction. Similarly, Aylett and Turk (2004) drew explicit connections between lexical sources of reduction, including lexical frequency, and discourse-level sources of reduction, including discourse mention. The talker-oriented proposals similarly range across linguistic contexts, including phonological similarity (Baese-Berk & Goldrick, 2009), discourse mention (Bard et al., 2000), and semantic predictability (Arnold et al., 2012; Jurafsky et al., 2001), consistent with the suggestion that the findings across contexts reflect a single underlying process. However, the results of several recent studies provide preliminary evidence that phonetic reduction may arise from different processes (Turnbull, 2015; Watson, 2010). For example, Lam and Watson (2010) found that discourse mention led primarily to temporal reduction, whereas semantic predictability led primarily to reduction in intensity. Watson (2010) interpreted these results as suggesting that intensity and f0 reflect listener-oriented processes, such as semantic predictability, whereas duration reflects talker-oriented processes, such as priming across discourse mentions. This proposed alignment between acoustic-phonetic domains (duration vs. intensity and f0), cognitive reduction processes (speech production constraints vs. listener modeling), and linguistic contexts (discourse mention vs. contextual predictability) provides an interesting avenue of inquiry for vowel reduction, especially given that temporal and spectral vowel reduction are not necessarily correlated (Fourakis, 1991; cf. Moon & Lindblom, 1994). In the current study, we consider variability within and across linguistic contexts in temporal and spectral vowel reduction, and their interaction with social indexing of regional dialect information.

1.1. *Phonetic vowel reduction and social indexing*

The results of a small set of studies from different laboratories have provided preliminary evidence that the same contexts that lead to phonetic reduction also lead to more frequent and/or more extreme sociolinguistic variants that index group identity information about the talker, such as greater /æ/-raising in the Northern dialect of American English or greater /ɑj/ monophthongization in African American English (Clopper & Pierrehumbert, 2008; Hay, Jannedy, & Mendoza-Denton, 1999; Munson, 2007a). The linguistic contexts examined in these studies range from lexical properties to discourse properties and the relevant social categories include regional background, racial identity, and sex typicality. In the first of these studies, Hay et al. (1999) examined the production of /ɑj/ in the speech of Oprah Winfrey, an African American talk show host. They observed more monophthongal /ɑj/ tokens, consistent with Ms. Winfrey's African American identity, in high frequency words relative to low frequency words. Similarly, Munson (2007a) observed a larger sex difference in vowel space dispersion for high frequency and low neighborhood density words than for low frequency and high neighborhood density words, respectively. Finally, Clopper and Pierrehumbert (2008) observed more extreme regional dialect variants for Northern American English talkers in words that were predictable given their preceding sentence context relative to words that were less predictable. Thus, across all three of these reduction-promoting contexts (high frequency, low density, and high predictability targets), more extreme sociolinguistic variants and/or larger sociolinguistic differences between groups were produced relative to contexts that do not promote phonetic reduction.

The theoretical account of these findings follows Lindblom's (1990) listener-oriented approach. In particular, all three sets of authors argued that talkers produce more extreme sociolinguistic variants in contexts in which they are likely to be understood by the listener (Clopper & Pierrehumbert, 2008; Hay et al., 1999; Munson, 2007a). That is, just as easy contexts for the listener allow for gestural economy leading to reduction, easy contexts for the listener allow for more extreme social indexing without sacrificing communication. Critically, this listener-oriented interpretation of the interaction between phonetic reduction and social indexing does not assume that social indexing is a conscious process. Hay et al. (1999) made this point explicitly in their discussion of Ms. Winfrey's speech, but Munson's (2007a) data also provide evidence for the implicit nature of this interaction. In particular, Munson's (2007a) results show a larger sex-based difference in vowel space dispersion for low density words than for high density words. This interaction is unlikely to be the result of an explicit or conscious strategy on the part of the talkers in his study to exaggerate sex differences in low density words, given that vowel space dispersion is not stereotypically associated with sex differences and that native speakers do not have strong intuitions about lexical neighborhood density. Further, although the listener-oriented perspective is directly invoked in all three of these previous studies, talker-oriented factors related to processing time and the nature of socially-indexed representations may also contribute to the observed findings. For example, more extreme sociolinguistic variants may be easier to access for the talker, leading to the production of those variants in easy processing contexts (Clopper & Pierrehumbert, 2008; Munson, 2007a). Thus, in parallel to the phonetic reduction literature, both listener-oriented and talker-oriented accounts of the interaction between phonetic reduction and social indexing have been proposed.

1.2. Reduction-promoting linguistic contexts

We selected three linguistic contexts that promote phonetic vowel reduction for examination in the current study, including one lexical property (i.e., lexical competition), one discourse property (i.e., discourse mention), and one property of the interlocutor (i.e., lab-based speaking style). Following Lindblom (1990), we assume that phonetic reduction is realized along a continuum from more reduced to less reduced. From this perspective, reduction in a given context is always relative to another context, and no state along the continuum is the unmarked default state. In the current study, we interpret our analyses from the perspective of relative reduction because we are expecting to observe greater social indexing in reduction-promoting contexts, but the results could just as easily be interpreted as variation in social indexing as a function of degree of hyperarticulation.

The three linguistic contexts that we selected allowed us to engage with theoretical questions about the process or processes underlying phonetic reduction and its interaction with social indexing. First, although Munson (2007a) previously examined lexical neighborhood effects in the context of indexical variation related to sex, we included lexical competition in our study because this context presents an especially thorny issue in the phonetic reduction literature. In particular, whereas spectral vowel reduction is robustly reported in the literature for words with few neighbors relative to words with many neighbors, temporal vowel reduction as a function of lexical competition is often not observed, especially when the target words are produced in isolation (Munson, 2007b; Munson & Solomon, 2004; Zellou & Scarborough, 2015; cf. Gahl, Yao, & Johnson, 2012; Scarborough, 2010; Scarborough & Zellou, 2013). Thus, the existing literature provides evidence for independent effects of lexical competition on temporal and spectral vowel reduction. Further, the magnitude of the effect of lexical competition on spectral vowel reduction is variable across vowel categories (Scarborough, 2010; Watson & Munson, 2007; Wright, 2004) and the necessary comparisons across words leads to uncontrolled (and given lexical gaps, potentially uncontrollable) segmental effects (Gahl, 2015; Gahl et al., 2012). For example, the effect of lexical competition on vowel dispersion was significant for only five of 10 vowels (/i, æ, ɑ, ɔ, u/, but not /ɪ, ej, ɛ, ʌ, ow/) in Wright's (2004) study, only four of six vowels (/ej, æ, ʌ, ow/, but not /ɛ, ɑ/) in Scarborough's (2010) study, and only four of seven vowels (/ej, æ, ow, u/, but not /i, ɛ, ɑ/) in Watson and Munson's (2007) study. Our analysis provides additional data on the vowel-specificity of the effect of lexical competition on reduction.

Although most of the previous research on lexical competition and phonetic reduction has focused on measures of dispersion in the F1 × F2 vowel space (Munson, 2007a, 2007b; Munson & Solomon, 2004; Scarborough, 2010; Scarborough & Zellou, 2013; Watson & Munson, 2007; Wright, 2004), variability has also been found in the specific dimensions of the vowel space (i.e., F1 and F2) in which reduction is observed. In particular, Scarborough and Fougeron (2016) found that reduction of words with few neighbors in French was limited to lowering of non-low vowels. Similar variability has been observed when comparing across speaking styles. For example, Scarborough and Fougeron (2016) also found reduction in plain speech relative to careful speech only in the F1 dimension in French. Ferguson and Kewley-Port (2007) similarly observed reduction in F1 in plain speech relative to careful speech in English, as well as reduction in plain speech in F2 for front vowels only. This variability across vowel categories and acoustic dimensions echoes similar effects in the literature on phonetic reduction of unstressed vowels relative to stressed vowels. For example, Fourakis (1991) found greater reduction in the F2 dimension for back vowels than for front vowels and greater reduction in the F1 dimension for high vowels than for low vowels in English (cf. Padgett & Tabain, 2005, on Russian). We explored the potential specificity of the effects of lexical competition, discourse mention, and speaking style on reduction through separate analyses of F1 and F2.

Finally, the proposed relationship between ease of processing and lexical competition leads to different predictions for the talker and the listener. Whereas English-speaking listeners exhibit faster and more accurate processing for words with few phonological neighbors (Luce & Pisoni, 1998; Vitevitch & Luce, 1999), talkers exhibit faster and more accurate processing for words with many phonological neighbors (Vitevitch, 2002), especially when the neighbors are low in frequency (Vitevitch & Sommers, 2003).[1] Thus, two competing interpretations of the lexical competition effect on phonetic reduction are presented in the literature and the current study contributes to this discussion by exploring the effect of lexical competition on phonetic reduction in the context of regional dialect variation.

Second, discourse mention has been studied primarily from the perspective of temporal word or vowel reduction and has been observed for both native (Baker & Bradlow, 2009; Bard et al., 2000; Fowler & Housum, 1987) and non-native (Baker et al., 2011) talkers. However, the effects of discourse mention on vowel quality are unknown. The current study explores both temporal and spectral vowel reduction in all three linguistic contexts and therefore contributes new insight into the acoustic domains of second mention reduction. Further, as in the case of lexical competition, two competing interpretations of the effect of discourse mention on phonetic reduction have been proposed in the literature. In particular, Fowler (1988) found that second mention reduction did not occur in word list reading, leading to a listener-oriented interpretation of second mention reduction as conveying information to the listener about new vs. given words in meaningful prose (see also Baker & Bradlow, 2009; Fowler & Housum, 1987). By contrast, Bard et al. (2000) found that talkers reduced second mentions of words even with new interlocutors, leading to a talker-oriented interpretation of second mention reduction as reflecting facilitation in lexical access for words that the talker has already produced and/or perceived (see also Kahn & Arnold, 2012, 2015; Lam & Watson, 2010). The current study further contributes to this discussion by exploring the effect of discourse mention on both temporal and spectral vowel reduction in the context of regional dialect variation.

Third, the inclusion of speaking style in our study allows us to consider phonetic reduction processes in a more conscious or explicit linguistic context. Whereas the lexical and discourse effects may reflect automatic, unconscious processes related to ease of

[1] Note that Spanish-speaking talkers exhibit the the opposite pattern: words are produced more quickly and more accurately when they have few neighbors (Vitevitch & Stamer, 2006).

processing, the manipulation of speaking style is a controlled and explicit response to specific instructions about the imagined interlocutor's needs (Uchanski, 2005). Further, social indexing may interact differently with speaking style than with lexical competition and discourse mention. According to Labov (1972), talkers produce fewer socially-marked variants as the formality of the interaction increases. In the current study, an imagined hearing-impaired or non-native interlocutor in the careful speech condition may lead to more formal speech than an imagined friend in the plain lab speech condition. This additional stylistic effect may contribute to a larger interaction between phonetic reduction and social indexing in the speaking style analysis than in the lexical competition and discourse mention analyses.

Finally, in our analyses in the current study, we consider the three linguistic contexts (lexical competition, discourse mention, and speaking style) and their interactions with social indexing separately (cf. Burdin, Turnbull, & Clopper, 2015). These separate analyses allow us to consider the similarities and differences between implicit processing-driven phonetic reduction due to lexical competition and discourse mention, on the one hand, and explicit interlocutor-driven phonetic reduction due to speaking style, on the other, in the context of regional dialect variation. In addition to the novel focus on regional dialect variation, this comparison across linguistic contexts contributes to the growing literature examining the independent and combined effects of these factors on phonetic reduction. For example, Munson and Solomon (2004) found independent effects of lexical frequency and neighborhood density on spectral vowel reduction and Scarborough and Zellou (2013) found independent effects of neighborhood density and speaking style on both temporal and spectral vowel reduction. However, Zellou and Scarborough (2015) observed an interaction between lexical frequency and neighborhood density on spectral vowel reduction, leading to the least reduction for low frequency, high density words. Similarly, Baker and Bradlow (2009) observed an interaction among lexical frequency, discourse mention, and speaking style on temporal word reduction, leading to the greatest reduction for high frequency second mention words in plain speech. Finally, Hay and Foulkes (2016) observed an interaction between lexical frequency and discourse mention on medial /t/ lenition, in which the least lenition was observed for low frequency first mention words. Given these previous findings demonstrating both independent and interactive effects of these factors on phonetic reduction, we expected to observe variability across linguistic contexts in overall phonetic reduction, as well as in reduction in the context of regional dialect variation.

1.3. The current study

The primary goal of the current study was to further explore the relationship between phonetic reduction and sociolinguistic variation in three reduction-promoting contexts (lexical competition, discourse mention, and speaking style) with a particular focus on regional dialect variation in American English. The regional dialects we examined were Northern and Midland American English, which exhibit different vowel systems. The Northern dialect is spoken in the upper midwestern United States and is characterized by the Northern Cities Shift, an ongoing sound change which involves the raising and fronting of /æ/, the backing and lowering of /ɛ, ʌ/, and the fronting and lowering of /ɑ, ɔ/ (Labov, Ash, & Boberg, 2006). The Midland dialect is spoken in the lower midwestern United States and is characterized by the lowering of /ɔ/ towards /ɑ/. Although this lowering can result in the merger of /ɔ, ɑ/, the vowels remain distinct for many talkers in the Midland region (Clopper, Pisoni, & de Jong, 2005; Labov et al., 2006). Both dialects are characterized by the fronting of /u/ (Clopper et al., 2005). More extreme social indexing was therefore predicted to be realized through these dialect-specific vowel shifts, including more /æ/-raising and/or -fronting among Northern talkers, more /ɑ/-lowering and/or -fronting among Northern talkers, and more /u/-fronting among both groups of talkers.

The talkers in the current study were young adults recorded at large, public midwestern universities where both dialects are well-represented among the student population. Although the vowel systems of the two dialects exhibit considerable acoustic-phonetic differences, both varieties are perceptually non-stigmatized and as many as half of all midwesterners may not recognize the two varieties as distinct (Campbell-Kibler, 2012). Despite this lack of explicit social awareness of this regional variation, Clopper and Pierrehumbert (2008) observed more /æ/-fronting among Northern talkers in high-predictability contexts than low-predictability contexts, suggesting more extreme social indexing in reduction-promoting contexts. As discussed above, this variability in social indexing across linguistic contexts need not involve a conscious strategy, and Clopper and Pierrehumbert's (2008) results suggest that this variability can be observed when comparing Midland and Northern talkers, despite the relatively low level of social awareness of the two dialects. We therefore expected to observe similar variation in social indexing as a function of phonetic reduction across the three linguistic contexts that we examined in the current study.

To explore the relationship between phonetic reduction processes and regional dialect variation, we followed previous research in the phonetic reduction literature and assessed temporal reduction based on vowel duration (Section 3) and spectral reduction based on vowel dispersion from the acoustic center of the vowel space (Section 4). Given previous research demonstrating variation across vowel categories in spectral reduction due to lexical stress (Fourakis, 1991; Padgett & Tabain, 2005) and lexical competition (Scarborough, 2010; Watson & Munson, 2007; Wright, 2004), separate planned comparisons were conducted for dispersion for each vowel category and the interpretation of the spectral analyses was further confirmed by separate analyses of F1 and F2 variation for each vowel as a function of linguistic context and talker dialect.

We expected to observe phonetic vowel reduction in words with few lexical competitors relative to words with more lexical competitors (Munson & Solomon, 2004; Scarborough, 2010; Watson & Munson, 2007; Wright, 2004), in second mention words relative to first mention words (Baker & Bradlow, 2009; Bard et al., 2000; Fowler & Housum, 1987), and in plain lab speech relative to careful lab speech (Ferguson & Kewley-Port, 2007; Picheny, Durlach, & Braida, 1986; Smiljanic & Bradlow, 2005). Across these linguistic contexts, we further predicted that regional dialect-specific variants would be more extreme for words with few lexical competitors relative to words with more lexical competitors, in second mention words relative to first mention words, and in plain lab speech relative to careful lab speech. Finally, we expected to observe some interactions between the linguistic contexts and regional dialect because phonetic reduction processes and dialect-specific variation are sometimes in conflict (Clopper & Pierrehumbert, 2008). In particular, whereas backing of /æ/ is expected as a result of phonetic reduction, fronting of /æ/ is expected as a regional variant in the Northern dialect. Thus, consistent with Clopper and Pierrehumbert's (2008) findings, in reduction-promoting contexts, we expected to observe a more front dialect-specific Northern /æ/, but a backer, reduced Midland /æ/. Similarly, whereas raising of /ɑ/ is expected as a result of phonetic reduction, lowering of /ɑ/ is expected as a regional variant in the Northern dialect. Thus, parallel to our prediction for /æ/, we expected to observe a lower dialect-specific Northern /ɑ/, but a raised, reduced Midland /ɑ/ in reduction-promoting contexts. Finally, given that /u/ is fronted in both dialects, reduction of /u/ is expected to involve primarily lowering, whereas greater fronting is expected when social indexing is enhanced. Thus, in parallel with our predictions for /æ, ɑ/, we expected to observe more fronting than lowering of /u/ for both talker dialects in reduction-promoting contexts.

2. Methods

2.1. Lexical competition materials

Twenty female talkers from the Indiana Speech Project Corpus (Clopper et al., 2002) were selected for the lexical competition materials. The talkers were all monolingual native speakers of American English with no history of speech or hearing disorders reported at the time of recording. They ranged in age from 18–22 years old ($M=19.5$ years). 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. Each talker was recorded reading isolated words, nonwords, sentences, passages, and in conversation with the experimenter over the course of two recording sessions in a sound-attenuated booth. The talkers wore a high-quality head-mounted microphone (Shure SM10A) and their speech was recorded directly to hard disk in 16-bit digital sound files with a sampling rate of 44.1 kHz.

Sixty-four CVC English words were selected for the lexical competition analysis from the list of nearly 1000 isolated CVC words in the corpus. Sixteen target words were selected for each of the four point vowels in American English: /i, æ, ɑ, u/. The point vowels are more likely to exhibit spectral reduction than less peripheral vowels (Wright, 2004; cf. Scarborough, 2010; Watson & Munson, 2007). This set of vowels also includes two vowels that are shifting in the Northern dialect but not in the Midland dialect (/æ, ɑ/), one vowel that is shifting in both dialects (/u/), and one vowel that is not shifting in either dialect (/i/). The point vowels therefore allow for an exploration of the interaction between ongoing dialect-specific vowel shifts and spectral reduction due to lexical competition. For each vowel, eight of the target words were lexically “easy” and eight of the target words were lexically “hard”. The lexical difficulty of the target words was defined following Wright (2004) and was based on the lexical characteristics provided in the Hoosier Mental Lexicon (Nusbaum, Pisoni, & Davis, 1984). The lexically easy words had significantly fewer neighbors than the lexically hard words (easy $M=14.78$, hard $M=26.34$, $t(62)=-8.51$, $p<.001$) and the neighbors of the easy words were significantly lower in mean log frequency than the neighbors of the hard words (easy $M=1.68$, hard $M=2.17$, $t(62)=-8.95$, $p<.001$). Thus, lexical competition in this analysis was defined primarily from a listener-oriented perspective: the easy words had fewer and less frequent lexical competitors than the hard words, making them easier for a listener to recognize (e.g., Luce & Pisoni, 1998; Sommers, Kirk, & Pisoni, 1997). The easy and hard words did not differ in mean log frequency (easy $M=2.01$, hard $M=2.20$) or familiarity (easy $M=6.89$, hard $M=6.84$ on a 7-point scale; Nusbaum et al., 1984). To facilitate acoustic analysis and avoid known conditioning environments for dialect variation, the initial consonant in each target word was either an obstruent or a nasal and the final consonant was an obstruent. For /u/, the number of initial alveolar consonants was matched for the easy and hard words, because fronting of /u/ is more extreme following alveolar consonants than other consonants (Labov et al., 2006). In addition, given the effect of following voicing on vowel duration, for each vowel, the number of following voiced consonants was matched for the easy and hard words. The target easy and hard words are shown in Table 1.

2.2. Discourse mention and speaking style materials

Twenty female talkers from the Ohio State University community were recruited for the discourse mention and speaking style materials. They received partial course credit in an introductory linguistics course or payment for participating. The talkers were all monolingual native speakers of American English with no history of speech or hearing disorders reported at the time of recording.

Table 1
Target easy and hard words for each vowel category in the lexical competition analysis. The easy words have fewer neighbors than the hard words and the neighbors of the easy words are lower in mean log frequency than the neighbors of the hard words.

Vowel	Easy words	Hard words
/i/	cheap, cheek, chief, knead, peace, tease, teeth, thief	beak, beat, heat, heed, neat, peep, seed, seek
/æ/	dab, dash, gag, gap, nab, nap, path, tag	bad, bat, hack, has, hat, mad, mat, sad
/ɑ/	chop, dodge, hop, job, josh, mob, mop, posh	cod, cop, cot, hot, mock, pod, pot, sod
/u/	deuce, duke, food, goof, goose, juice, move, soothe	boot, dude, hoot, moose, news, toot, tooth, whose

They ranged in age from 18–22 years old ($M = 19.5$ years). 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. Each talker was recorded reading passages (for the discourse mention analysis) and isolated sentences (for the speaking style analysis) in a single recording session in a sound-attenuated booth. The order of the two tasks (passages and sentences) was counterbalanced across talkers. The talkers wore a high-quality head-mounted microphone (Shure SM10A) and their speech was recorded with a solid state digital recorder (Marantz PMD661) in 16-bit digital sound files with a sampling rate of 22.05 kHz.

Four passages based on Baker and Bradlow's (2009) stimulus materials were constructed for the discourse mention analysis. The passages contained a total of eight target words for each of the four point vowels in American English: /i, æ, ɑ, u/. Each target word was presented twice within a single passage, for a total of 64 target utterances per talker. The distance between the two mentions within a passage ranged from 7–97 words ($M = 32$) and all first and second mention pairs appeared in a similar syntactic phrase and/or syntactic position across mentions to encourage comparable prosodic realizations. Fowler and Housum (1987) found no effect of the distance between mentions on the magnitude of second mention reduction and Baker and Bradlow (2009) found significant effects of second mention reduction that were independent of prosodic structure. Thus, the target words in this analysis were coded simply as first or second mention and any variation due to the distance between mentions or prosodic structure was captured statistically by random effects for items.

In this analysis, unlike in the lexical competition analysis, the reduction phenomenon involves a within-word comparison across mentions in the passage (i.e., the first and second mentions of the same target word). The phonetic and lexical characteristics of the target words were therefore less strictly controlled because cross-word comparisons were not necessary. The target words varied from 1–3 syllables in length and in multisyllabic words, the target vowel bore primary lexical stress. The target words included proper nouns, which are not included in the Hoosier Mental Lexicon (Nusbaum et al., 1984), so frequency and neighborhood density values for these words were obtained from the Irvine Phonotactic Online Dictionary (Vaden, Halpin, & Hickok, 2009). The target words varied in frequency from 0–240 tokens per million ($M = 32$) and in neighborhood density from 0–43 neighbors ($M = 14.5$). Item effects were handled statistically in all models with covariates for lexical frequency and neighborhood density. The within-word design of the stimulus materials was captured statistically using random intercepts for items and, when model convergence permitted, random slopes for discourse mention by items. The target words are shown in Table 2 and the full passages are shown in the Appendix. The order of the passages was randomized separately for each talker.

Thirty-two high predictability sentences from the Speech Perception in Noise (SPIN) test (Kalikow, Stevens, & Elliott, 1977) were selected for the speaking style analysis. The sentences contained a total of eight target words for each of the four point vowels in American English: /i, æ, ɑ, u/. The 32 target words were all monosyllabic and appeared in sentence-final position. They were semantically predictable in their sentence context. The target words are shown in Table 3 and the full set of sentences is provided in the Appendix. The set of 32 sentences was produced once in random order in each of two blocks, for a total of 64 sentences per talker. In the first block, the talkers were instructed to read the sentences as if they were talking to a friend to elicit plain lab speech. In the second block, the talkers were instructed to read the sentences as if they were talking to a hearing-impaired person or non-native speaker of English to elicit careful lab speech. Thus, all of the careful speech tokens were also second mentions in the experimental context. Although second mention reduction is not observed in word list reading and may be limited to meaningful prose (Fowler, 1988), all of the talkers completed the two sentence blocks in this order so that any reduction due to repetition of the materials would not be confounded with the plain speaking style. The effect of speaking style on phonetic reduction and social indexing may therefore be underestimated in this task.

As in the discourse mention analysis, the reduction phenomenon in the speaking style analysis involves a within-word comparison across styles (i.e., the same target word in both plain and careful speech). The phonetic and lexical characteristics of the target words were therefore not strictly controlled because cross-word comparisons were not necessary. According to the Hoosier Mental Lexicon (Nusbaum et al., 1984), the target words varied in log frequency from 1–2.8 ($M = 1.9$) and in neighborhood density from 2–35 neighbors ($M = 16.9$). As in the discourse mention analysis, item effects were handled statistically in all models with covariates for lexical frequency and neighborhood density and the within-word design of the stimulus materials was captured using random intercepts for items and, when model convergence permitted, random slopes for speaking style by items.

2.3. Analysis

Productions of the 64 target words produced by each of the 20 talkers in each of the three sets of materials were analyzed acoustically. Three tokens were unavailable in the lexical competition analysis due to mispronunciations or errors in the original recordings, resulting in a total of 1277 tokens. Twelve tokens were unavailable in the discourse mention analysis due to

Table 2
Target words for each vowel category in the discourse mention analysis.

Vowel	Target words
/i/	beets, cheese, geese, piece, steeple, street, week, zebras
/æ/	African, Avenue, cabbage, capitol, classes, factory, giraffes, lab
/ɑ/	blocks, botany, Copper, Poppy, pot, Robert, squash, stock
/u/	blue, cuckoos, Judy, Lucy, noodles, root, soup, zoo

Table 3
Target words for each vowel category in the speaking style analysis.

Vowel	Target words
/i/	beads, beak, feast, fee, seeds, sheets, tea, thief
/æ/	cap, chat, mast, scab, splash, strap, trap, wax
/ɑ/	clock, cops, cot, crop, flock, lock, ox, plot
/u/	booth, bruise, clue, crew, cruise, glue, juice, loot

mispronunciations or reading errors, resulting in a total of 1268 tokens. Two tokens were unavailable due to mispronunciations or reading errors in the speaking style analysis, resulting in a total of 1278 tokens. For each token, the onset and offset of the vowel were marked by hand and the duration and first and second formant frequencies at the temporal midpoint were extracted automatically and hand-corrected as necessary. The formant frequencies were converted to Bark for analysis (Traunmüller, 1990).

Three sets of analyses were conducted on these acoustic data to explore the interaction between talker dialect and phonetic reduction. First, the duration measure was used to examine the effects of lexical competition, discourse mention, speaking style, and talker dialect on temporal vowel reduction in Section 3.[2] Second, to assess the effects of lexical competition, discourse mention, speaking style, and talker dialect on spectral vowel reduction in Section 4, a measure of dispersion from the center of the vowel space was calculated for each vowel token. Given that /u/-fronting was observed for both dialects, the overall shape of the vowel space defined by the point vowels was a parallelogram rather than the familiar IPA trapezoid (see also Hagiwara, 1997). Thus, defining the center of the vowel space as the grand mean across the four point vowels would result in a fronted estimate for the F2 center. The center of the vowel space was therefore defined as the grand mean of the F1 of /i, ɑ/, representing the highest and lowest point vowels, respectively, and the grand mean of the F2 of /i, ɑ/, representing the most front and most back point vowels, respectively, across all of the target words (see also Scarborough & Zellou, 2013; Zellou & Scarborough, 2015). As shown in Figs. 4–6, this measure of the center of the vowel space visually approximates the center of the parallelogram, but is further forward than a mid-central vowel, such as /ə/, would be in an idealized trapezoidal space. The vowel space center was calculated separately for each talker for each of the three sets of materials (i.e., lexical competition, discourse mention, and speaking style). Vowel dispersion was defined as the Euclidean distance in the F1 $\times$ F2 Bark space from a given token to the talker's vowel space center. Finally, to further understand the competing effects of talker dialect and spectral reduction on vowel variation, the F1 and F2 vowel midpoint measures were analyzed separately. This analysis allowed us to examine the effects of linguistic context and talker dialect in each of the two dimensions of the vowel space and consider how variation in these two dimensions contributes to overall spectral reduction.

Vowel duration, vowel dispersion in Bark, and F1 and F2 at vowel midpoint in Bark were assessed statistically using linear mixed-effect models in R. For vowel duration and vowel dispersion, an omnibus model was constructed for each dependent variable with vowel category, talker dialect, status (easy vs. hard, first vs. second mention, or plain vs. careful style), and their interactions as fixed effects. All of the fixed effects were coded with sum contrasts so that the model outputs can be directly interpreted as main effects. Given the potential positive correlation between vowel duration and dispersion (Moon & Lindblom, 1994), vowel duration was also included as a fixed covariate in the dispersion analysis. As described above, lexical frequency and neighborhood density were also included as fixed covariates in the discourse mention and speaking style analyses. To examine potential interactions between talker dialect and spectral reduction phenomena within each vowel category and across linguistic contexts, planned comparison analyses of the dispersion and formant frequency data were conducted separately for each vowel category with talker dialect, status, and their interaction as fixed effects. As in the omnibus dispersion analysis, duration was a covariate fixed effect in all of these analyses and lexical frequency and neighborhood density were covariate fixed effects in the discourse mention and speaking style analyses. For each model, the maximal design-driven random effect structure for talkers and target words that resulted in model convergence and uncorrelated random effects (all $|r|<0.9$) was retained (Barr, Levy, Scheepers, & Tily, 2013). Given that only female talker data were analyzed and that random effects for talkers were included in the statistical analysis, normalization of the acoustic measures was unnecessary. Log-likelihood comparisons were used to determine the statistical significance of the fixed effects and interactions in each model.

3. Temporal reduction: Vowel duration

3.1. Lexical competition

The mean vowel durations of the easy and hard words in each vowel category are shown in Fig. 1 for the Midland (left) and Northern (right) talkers. The omnibus linear mixed-effect model on vowel duration revealed a significant main effect of vowel category ($\chi^2=19.54$, $df=3$, $p<0.001$), reflecting intrinsic duration differences across vowel categories, and a significant vowel category x talker dialect interaction ($\chi^2=9.34$, $df=3$, $p=0.025$). As shown in Fig. 1, all of the vowels were longer for the Northern talkers than the Midland talkers, but this dialect difference was largest for /æ/ and smallest for /i/. None of the other main effects or interactions were

[2] Although previous studies of second mention reduction have reported word duration measures (e.g., Baker & Bradlow, 2009; Fowler & Housum, 1987), we report vowel duration measures in our discourse mention analysis for consistency with our analyses of lexical competition and speaking style.

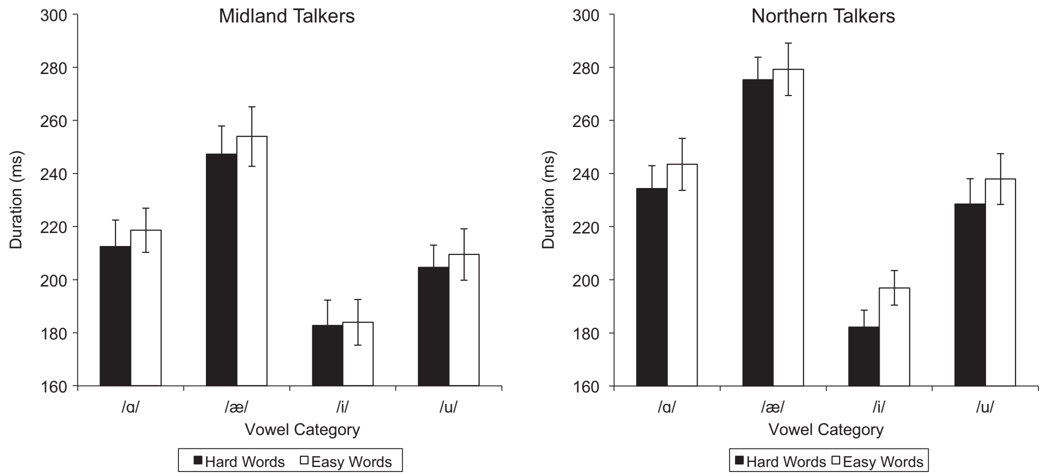

Fig. 1. Mean vowel duration in the lexical competition analysis for the easy and hard words in each vowel category for the Midland (left) and Northern (right) talkers. Error bars are standard error of talker means.

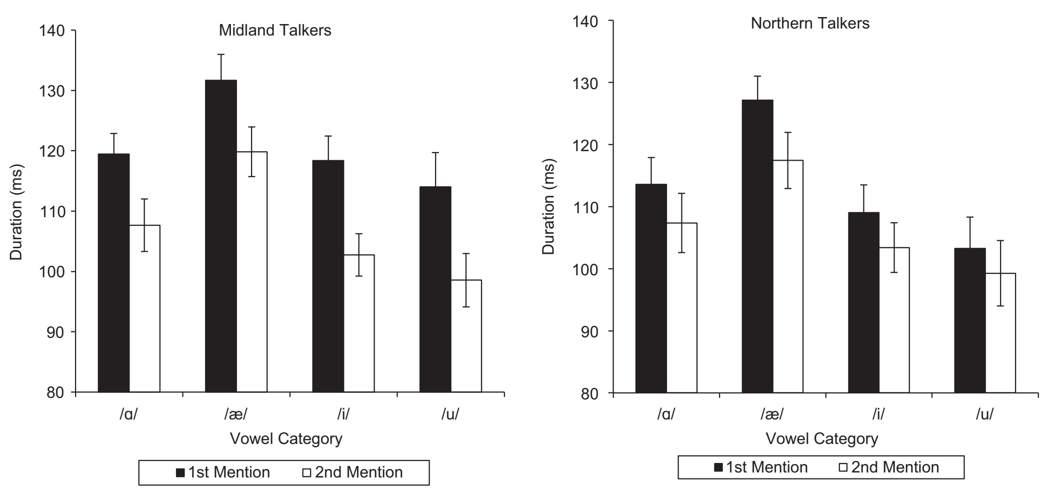

Fig. 2. Mean vowel duration in the discourse mention analysis for the first and second mention targets in each vowel category for the Midland (left) and Northern (right) talkers. Error bars are standard error of talker means.

significant. Critically, although the easy words have numerically longer durations than the hard words in Fig. 1, neither the main effect of lexical competition nor any of the interactions involving lexical competition were significant.

3.2. Discourse mention

The mean vowel durations of the first and second mentions of the words in each vowel category are shown in Fig. 2 for the Midland (left) and Northern (right) talkers. The omnibus linear mixed-effect model on vowel duration revealed a significant talker dialect x mention interaction ($\chi^2=5.95$, $df=1$, $p=0.015$), a significant main effect of mention ($\chi^2=8.79$, $df=1$, $p=0.003$), a marginal main effect of vowel ($\chi^2=7.17$, $df=3$, $p=0.067$), and a significant effect of the lexical frequency covariate ($\chi^2=8.76$, $df=1$, $p=0.003$). None of the other main effects or interactions were significant. As expected, vowels varied in their intrinsic durations and were shorter in high frequency words than low frequency words and in second mentions than first mentions across vowel categories. As shown in Fig. 2, the talker dialect x mention interaction reflects a larger effect of mention for the Midland talkers than the Northern talkers.

3.3. Speaking style

The mean vowel durations of the careful and plain productions of the words in each vowel category are shown in Fig. 3 for the Midland (left) and Northern (right) talkers. The omnibus linear mixed-effect model on vowel duration revealed a significant vowel category x speaking style interaction ($\chi^2=11.30$, $df=3$, $p=0.010$) and a significant main effect of speaking style ($\chi^2=20.56$, $df=1$, $p<0.001$). None of the other main effects or interactions were significant. As shown in Fig. 3, longer durations were observed for all vowel categories in careful speech than plain speech, but the style effect was largest for /i/.

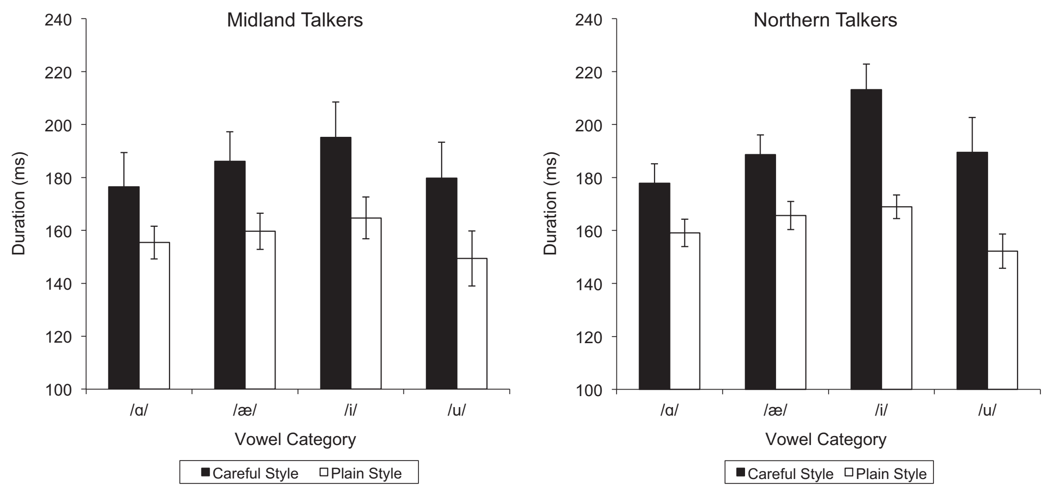

Fig. 3. Mean vowel duration in the speaking style analysis for careful and plain speech in each vowel category for the Midland (left) and Northern (right) talkers. Error bars are standard error of talker means.

3.4. Discussion

Significant temporal vowel reduction was observed for second mentions relative to first mentions and in plain speech relative to careful speech, but temporal vowel reduction was not observed for easy words relative to hard words. These results are consistent with previous research, in which duration differences between first and second mentions (Baker & Bradlow, 2009; Fowler & Housum, 1987) and between careful and plain speech (Smiljanic & Bradlow, 2005, 2009) are robustly observed, but duration differences between easy and hard words are not typically observed, especially when the words are produced in isolation (Munson, 2007b; Munson & Solomon, 2004; cf. Gahl et al., 2012; Scarborough, 2010; Scarborough & Zellou, 2013). The lack of an effect of lexical competition on temporal reduction in the current study can most likely not be attributed entirely to the production context (i.e., words vs. sentences), however, because the neighborhood density covariate was not significant in either the discourse mention analysis or the speaking style analysis, which both involved longer utterances. Thus, our results provide evidence for differences in temporal reduction across linguistic contexts. Whereas both discourse mention and speaking style exhibit robust temporal reduction effects, lexical competition does not.

In addition to the overall effects of discourse mention and speaking style on vowel duration, significant interactions revealed that temporal reduction in these contexts was not uniform across vowel categories and talker dialects. The observed temporal reduction in plain speech was mediated by vowel category and the observed temporal reduction in second mentions was mediated by talker dialect. Plain speech temporal reduction was most robust for /i/, consistent with /i/ exhibiting the longest duration overall and therefore having the greatest opportunity to reduce without deletion (see Fig. 3). Second mention temporal reduction was more robust for Midland talkers than Northern talkers, consistent with Clopper and Smiljanic's (2015) finding that Midland talkers exhibit more syllable-to-syllable variation in vowel duration than Northern talkers. In particular, the interaction with talker dialect in the discourse mention analysis revealed shorter Northern vowels than Midland vowels in first mentions, but not in second mentions. Thus, the Midland talkers in the current study exhibited greater vowel duration differences across first and second mentions than the Northern talkers, consistent with greater vowel duration variability across syllables in the Midland dialect relative to the Northern dialect. This dialect difference contrasts with the results of the lexical competition analysis, in which the Northern vowels were longer than the Midland vowels overall, and may reflect variability across talkers within each dialect or the effects of prosodic structure (Baker & Bradlow, 2009) or speaking rate (Kendall, 2013) on the realization of isolated words vs. words in read passages across dialects.

A comparison of the results across all three linguistic contexts reveals additional differences in the realization of the vowels related to the nature of the speech materials. The vowels in the sentences in the speaking style analysis were longer than the vowels in the passages in the discourse mention analysis, but shorter than the vowels in the isolated words in the lexical competition analysis. The differences between the words in the sentences in the speaking style analysis and the words in the passages in the discourse mention analysis may reflect both prosodic differences in reading isolated sentences vs. passages and the consistent phrase-final position of the target words in the sentences vs. the more variable phrase positions of the target words in the passages (see Appendix). The differences between the words in sentences in the speaking style analysis and the isolated words in the lexical competition analysis are expected given a comparison of running speech vs. citation-form words.

Taken together, the results of the vowel duration analysis reveal variability in temporal reduction across linguistic contexts that generally corresponds to previous findings in the field. Temporal reduction is robust for discourse mention and speaking style, but not for lexical competition, suggesting similarities in phonetic reduction due to discourse mention and speaking style, but qualitative differences in phonetic reduction due to lexical competition, which may be limited to the spectral domain. The analysis in Section 4 explores the similarities and differences in phonetic reduction in the spectral domain across these three linguistic contexts. Given that regional dialects of American English are characterized primarily in terms of variation in vowel quality, a second goal of the analysis in Section 4 was to determine the combined effects of phonetic reduction and talker dialect on vowel production in the spectral domain.

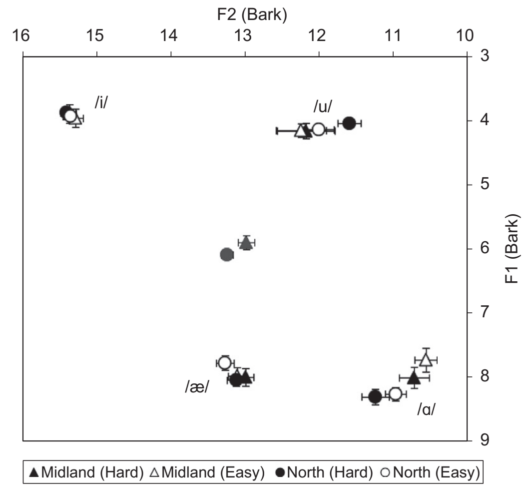

Fig. 4. Mean F1 x F2 vowel space in the lexical competition analysis for the easy and hard words for each talker dialect. Mean vowel space centers are shown with gray symbols. Error bars are standard error of talker means.

Table 4
Summary of the planned comparison mixed-effect models for vowel dispersion in the lexical competition analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold and marginal effects ($0.05<p<0.07$) are in italics.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=3.014, t=33.29	β=2.182, t=12.63	β=3.479, t=24.36	β=2.258, t=9.79
Dialect (Midland)	β=0.005, t=0.10	β=0.125, t=1.85	β<0.001, t<0.01	*β=−0.211, t=−2.03*
Easy/Hard (Easy)	*β=−0.050, t=−2.01*	β=−0.072, t=−1.87	β=0.041, t=0.86	β=−0.092, t=−1.17
Duration	β<0.001, t=0.99	β=−0.001, t=−0.95	**β=−0.002, t=−2.78**	β=0.001, t=0.95
Dialect x Easy/Hard	β=−0.004, t=−0.23	**β=0.075, t=2.86**	β=−0.042, t=−1.31	**β=0.071, t=2.33**
Log-likelihood	−48	−221	−171	−294
Random effects	Talker: intercept	Talker: intercept	Talker: intercept	Talker: intercept
	Talker: easy/hard	Word: intercept	Talker: easy/hard	Word: intercept
	Word: intercept	Word: dialect	Word: intercept	

Vowel duration was included as a covariate in all of the spectral analyses to control for the variability observed in the temporal reduction analyses.

4. Spectral reduction: Vowel space dispersion

4.1. Lexical competition

The mean vowel formant frequencies of the easy and hard words produced by the Midland and Northern talkers are shown in Fig. 4. As expected based on previous descriptions of these two dialects, /æ/ was higher and /ɑ/ was lower and more front for the Northern talkers than the Midland talkers. Both dialects exhibited fronted /u/ (relative to /ɑ/), and /u/ was more front for the Midland talkers than the Northern talkers. The acoustic center of the vowel space is shown for each talker dialect with gray symbols in Fig. 4. As expected, given how the acoustic center was calculated, the acoustic center falls on the line connecting /i, ɑ/ and phonetic reduction towards this center for these two vowels is expected to involve a change in both F1 and F2. The center falls below and slightly to the left of /u/ and almost directly above /æ/. Thus, phonetic reduction for these two vowels is expected to involve primarily a change in F1.

The omnibus linear mixed-effect model on vowel dispersion revealed a significant vowel category x talker dialect interaction ($\chi^2=9.81$, $df=3$, $p=0.020$), consistent with the patterns of dialect-specific vowel variation shown in Fig. 4, as well as a significant main effect of vowel ($\chi^2=53.35$, $df=3$, $p<0.001$), reflecting inherent differences in distance from the center of the vowel space across vowel categories. The analysis also revealed a significant three-way interaction ($\chi^2=10.34$, $df=3$, $p=0.016$), suggesting variation across vowel categories in the combined effects of talker dialect and lexical competition on vowel dispersion. None of the other main effects or interactions were significant.

The planned comparison linear mixed-effect models for each vowel category revealed significant talker dialect x easy/hard status interactions for /æ/ ($\chi^2=6.52$, $df=1$, $p=0.011$) and /u/ ($\chi^2=5.36$, $df=1$, $p=0.021$), a marginal effect of easy/hard status for /i/ ($\chi^2=3.62$, $df=1$, $p=0.057$), a marginal effect of talker dialect for /u/ ($\chi^2=3.75$, $df=1$, $p=0.053$), and a significant effect of the duration covariate for /ɑ/ ($\chi^2=7.24$, $df=1$, $p=0.007$). Both talker dialects produced less dispersed /i/ for easy words than hard words, consistent with reduction in easy words relative to hard words. The Midland talkers produced marginally less dispersed /u/ than the

Table 5
Summary of the planned comparison mixed-effect models for F1 in the lexical competition analysis. Significant effects (p<0.05 by log likelihood comparisons) are in bold.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=3.929, t=29.60	β=8.077, t=41.65	β=8.524, t=59.72	β=4.173, t=43.65
Dialect (Midland)	β=0.012, t=0.17	β=0.034, t=0.43	**β=−0.229, t=−2.58**	β=0.030, t=0.47
Easy/Hard (Easy)	β=0.031, t=0.71	β=−0.070, t=−1.75	β=−0.073, t=−2.03	β=0.022, t=1.07
Duration	β<−0.001, t=−0.06	β<−0.001, t=−0.69	**β=−0.002, t=−3.95**	β<−0.001, t=−0.58
Dialect x Easy/Hard	β=0.004, t=0.18	**β=0.062, t=2.12**	β=−0.060, t=−1.66	β=−0.025, t=−1.80
Log-likelihood	−124	−272	−240	−47
Random effects	Talker: intercept Talker: easy/hard Word: intercept	Talker: intercept Word: intercept	Talker: intercept Talker: easy/hard Word: intercept	Talker: intercept Word: intercept

Table 6
Summary of the planned comparison mixed-effect models for F2 in the lexical competition analysis. Significant effects (p<0.05 by log likelihood comparisons) are in bold and marginal effects (0.05<p<0.07) are in italics.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=15.261, t=178.39	β=13.083, t=80.81	β=11.012, t=55.45	β=12.199, t=31.61
Dialect (Midland)	β=−0.025, t=−0.43	β=−0.069, t=−0.88	*β=−0.239, t=−2.17*	β=0.200, t=1.04
Easy/Hard (Easy)	β=−0.036, t=−1.43	β=0.066, t=1.38	*β=−0.106, t=−1.90*	β=0.129, t=0.67
Duration	β=0.001, t=1.61	β<0.001, t=0.31	β=−0.001, t=−0.84	β=−0.001, t=−0.70
Dialect × Easy/Hard	β=−0.005, t=−0.47	β=−0.009, t=−0.53	β=0.029, t=0.82	**β=−0.094, t=−2.32**
Log-likelihood	73	−123	−233	−384
Random effects	Talker: intercept Talker: easy/hard Word: intercept	Talker: intercept Word: intercept	Talker: intercept Talker: easy/hard Word: intercept	Talker: intercept Talker: easy/hard Word: intercept

Northern talkers, especially for the hard words. Given the fronting of /u/ in both talker dialects, this result also reflects greater fronting of /u/ in easy words than hard words, especially for the Northern talkers (see Fig. 4). The Northern talkers' productions of /æ/ were closer to the acoustic center of the vowel space than the Midland talkers' /æ/ productions for the easy words only. An inspection of Fig. 4 reveals that whereas /æ/ in easy and hard words was similar for the Midland talkers, the Northern /æ/ in easy words was higher and more front than the /æ/ in hard words. Thus, in easy words, the Northern /æ/ was more consistent with the ongoing shift in the Northern dialect, whereas in hard words, the Northern /æ/ was more similar to the unshifted Midland /æ/. No significant effects of talker dialect or easy/hard status were observed for the dispersion of /ɑ/. The significant effect of the duration covariate for /ɑ/ dispersion is in the unexpected direction: longer vowels were less dispersed than shorter vowels, suggesting that longer vowels are not always more peripheral than shorter vowels in a given category (cf. Moon & Lindblom, 1994). A summary of the planned comparison models for dispersion in the lexical competition analysis is provided in Table 4.

Our interpretation of these results critically requires understanding the individual contributions of variation in F1 and F2 to the observed patterns of dispersion. We therefore examined the effects of lexical competition and talker dialect on F1 and F2 separately. We expected to observe lexical competition effects on F1 and/or F2 for /i/, as well as talker dialect x lexical competition interactions on F2 for /u/ and on F1, and possibly F2, for /æ/. The linear mixed-effect models for each vowel category for F1 revealed a significant talker dialect x lexical competition interaction for /æ/ (χ^2=4.47, df=1, p=0.034), which parallels the same interaction observed in the dispersion analysis, a significant main effect of talker dialect for /ɑ/ (χ^2=4.79, df=1, p=0.029), consistent with /ɑ/-lowering among Northern talkers, and a significant effect of the duration covariate for /ɑ/ (χ^2=13.89, df=1, p<0.001), as found in the dispersion analysis. A summary of the planned comparison models for F1 in the lexical competition analysis is provided in Table 5.

The linear mixed-effect models for each vowel category for F2 revealed a significant talker dialect x lexical competition interaction for /u/ (χ^2=4.69, df=1, p=0.030), consistent with our interpretation of the dispersion analysis results, a marginal main effect of talker dialect for /ɑ/ (χ^2=3.63, df=1, p=0.057), consistent with /ɑ/-fronting among Northern talkers, and a marginal effect of lexical competition for /ɑ/ (χ^2=3.29, df=1, p=0.070). As shown in Fig. 4, the effect of lexical competition on F2 for /ɑ/ is in the unexpected direction: easy words have more peripheral (i.e., backed) /ɑ/ productions than hard words. A summary of the planned comparison models for F2 in the lexical competition analysis is provided in Table 6.

4.2. Discourse mention

The mean vowel formant frequencies of the first and second mentions of the words produced by the Midland and Northern talkers are shown in Fig. 5. The vowel space for the Northern talkers is expanded overall relative to the vowel space for the Midland talkers, which makes direct visual comparisons of the vowel spaces somewhat challenging. However, both talker dialects exhibited fronted /u/ (relative to /æ, ɑ/). The acoustic center of the vowel space is shown for each talker dialect with gray symbols in Fig. 5. As expected, given how the acoustic center was calculated, the acoustic center falls on the line connecting /i, ɑ/ and phonetic reduction towards this center for these two vowels is expected to involve a change in both F1 and F2. The center falls almost directly below /u/ and above and slightly to the left of /æ/. Thus, phonetic reduction for these two vowels is expected to involve primarily a change in F1.

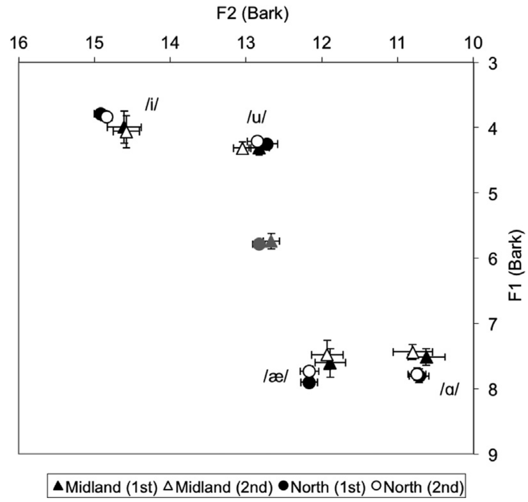

Fig. 5. Mean F1 x F2 vowel space in the discourse mention analysis for the first and second mention targets for each talker dialect. Mean vowel space centers are shown with gray symbols. Error bars are standard error of talker means.

Table 7
Summary of the planned comparison mixed-effect models for vowel dispersion in the discourse mention analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold and marginal effects ($0.05<p<0.07$) are in italics.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=2.567, t=23.59	β=2.110, t=17.65	β=2.713, t=25.96	β=2.027, t=15.03
Dialect (Midland)	β=−0.055, t=−1.01	β=0.072, t=1.02	β=−0.068, t=−1.11	β=0.050, t=0.75
Mention (1st)	β=0.036, t=1.78	*β=0.055, t=2.04*	β=0.037, t=1.32	β=−0.020, t=−0.81
Duration	β=0.001, t=1.63	β=0.001. t=1.58	**β=0.002, t=3.23**	**β=−0.003, t=−3.28**
Frequency	**β=−0.002, t=−4.16**	β=−0.005, t=−1.13	**β=−0.006, t=−4.51**	β<−0.001, t=−0.23
Density	**β=0.014, t=4.33**	β=0.006, t=1.04	β=0.004, t=2.10	β=0.001, t=0.18
Dialect x Mention	β=−0.002, t=−0.15	β=−0.012, t=−0.56	*β=0.029, t=1.61*	β=−0.024, t=−1.01
Log-likelihood	−110	−159	−116	−201
Random effects	Talker: intercept Word: intercept Word: dialect Word: mention	Talker: intercept Word: intercept Word: dialect x mention	Talker: intercept Word: intercept Word: dialect Word: mention	Talker: intercept Word: intercept Word: dialect Word: mention

Table 8
Summary of the planned comparison mixed-effect models for F1 in the discourse mention analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=3.916, t=24.12	β=7.832, t=45.42	β=7.340, t=42.97	β=4.409, t=27.61
Dialect (Midland)	β=0.104, t=0.88	β=−0.137, t=−1.25	**β=−0.164, t=−2.20**	β=0.042, t=0.83
Mention (1st)	β=−0.034, t=−1.26	**β=0.078, t=2.47**	β=0.007, t=0.21	β=0.007, t=0.23
Duration	β=0.001, t=0.92	β=−0.001, t=−0.82	β=0.004, t=3.08	β<0.001, t=0.26
Frequency	**β=0.002, t=3.97**	β=−0.004, t=−0.69	β=−0.003, t=−1.29	β=−0.003, t=−1.71
Density	**β=−0.012, t=−3.49**	β=0.002, t=0.33	β=−0.003, t=−0.79	β=−0.004, t=−0.89
Dialect x Mention	β=−0.006, t=−0.23	β=−0.011, t=−0.37	β=0.010, t=0.29	β=−0.012, t=−0.37
Log-likelihood	−250	−290	−300	−275
Random effects	Talker: intercept Word: intercept	Talker: intercept Word: intercept	Talker: intercept Word: intercept	Talker: intercept Word: intercept

The omnibus linear mixed-effect model on vowel dispersion revealed a significant vowel category x mention interaction ($\chi^2=9.06$, $df=3$, $p=0.029$), significant main effects of mention ($\chi^2=4.46$, $df=1$, $p=0.035$) and vowel category ($\chi^2=37.91$, $df=3$, $p<0.001$), as well as significant effects of the lexical frequency ($\chi^2=7.21$, $df=1$, $p=0.007$) and neighborhood density ($\chi^2=5.99$, $df=1$, $p=0.014$) covariates. Modest second mention reduction was observed for /i, æ, ɑ/, but /u/ productions were further from the acoustic center (i.e., fronted) in second mentions relative to first mentions. As expected, high frequency words exhibited less dispersion than low frequency words and words with few neighbors exhibited less dispersion than words with many neighbors.

The planned comparison linear mixed-effect models for each vowel category revealed a marginal talker dialect x mention interaction for /ɑ/ ($\chi^2=3.32$, $df=1$, $p=0.068$), a marginal effect of mention for /æ/ ($\chi^2=3.28$, $df=1$, $p=0.070$), a significant effect of the duration covariate for /ɑ, u/ ($\chi^2=8.59$, $df=1$, $p=0.003$ for /ɑ/; $\chi^2=10.93$, $df=1$, $p<0.001$ for /u/), a significant effect of the frequency covariate for /i, ɑ/ ($\chi^2=8.30$, $df=1$, $p=0.004$ for /i/; $\chi^2=10.03$, $df=1$, $p=0.002$ for /ɑ/), and a significant effect of the density

Table 9
Summary of the planned comparison mixed-effect models for F2 in the discourse mention analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=14.493, t=105.66	β=11.653, t=62.56	β=10.64, t=64.90	β=12.942, t=35.31
Dialect (Midland)	β=−0.147, t=−1.44	β=−0.138, t=−1.23	β=−0.013, t=−0.10	β=0.073, t=−0.74
Mention (1st)	β=0.020, t=0.96	β=−0.025, t=−0.87	**β=−0.055, t=−2.00**	**β=−0.079, t=−2.23**
Duration	β=0.001, t=1.64	**β=0.004, t=3.39**	β<0.001, t=0.27	β=−0.002, t=−1.64
Frequency	**β=−0.001, t=−2.96**	β=−0.003, t=−0.26	β=0.001, t=1.04	β=−0.001, t=−0.27
Density	**β=0.011, t=3.66**	β=−0.005, t=−0.35	β=0.002, t=1.05	β=0.009, t=0.67
Dialect x Mention	β=−0.017, t=−0.84	β=−0.010, t=−0.35	β=−0.036, t=−1.32	β=−0.015, t=−0.44
Log-likelihood	−163	−264	−246	−334
Random effects	Talker: intercept Word: intercept	Talker: intercept Word: intercept Word: dialect	Talker: intercept Word: intercept	Talker: intercept Word: intercept Word: dialect

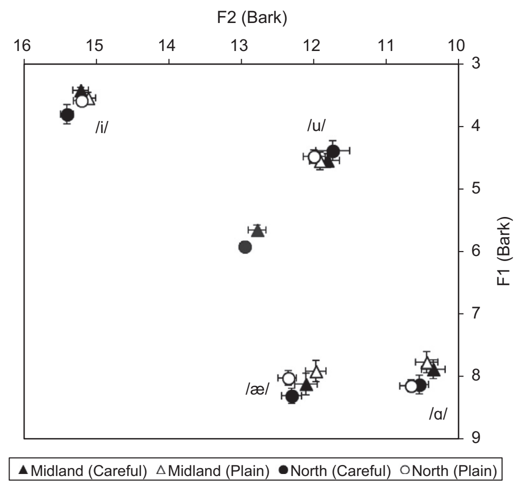

Fig. 6. Mean F1 x F2 vowel space in the speaking style analysis for the careful and plain targets for each talker dialect. Mean vowel space centers are shown with gray symbols. Error bars are standard error of talker means.

covariate for /i/ ($\chi^2=5.64$, $df=1$, $p=0.018$). The effect of mention for /æ/ reflects less peripheral productions (i.e., raising) in second mentions relative to first mentions, consistent with second mention reduction. As shown in Fig. 5, second mentions for /ɑ/ targets were also less dispersed than first mentions, but this second mention reduction was larger for Midland talkers than for Northern talkers. The Northern talkers maintained their shifted (lowered and fronted) /ɑ/ variant in the easy words. The effects of talker dialect and mention were not significant for /i, u/. The effect of the duration covariate for /ɑ/ dispersion is in the expected direction: longer vowels were further from the acoustic center than shorter vowels. However, the duration effect for /u/ is in the unexpected direction: longer vowels were closer to the acoustic center than shorter vowels. Thus, as in the lexical competition analysis, the duration effects suggest that longer vowels are not always more peripheral than shorter vowels in a given category. As in the omnibus analysis, the significant effects of the frequency and density covariates were in the expected directions: high frequency words exhibited less dispersion than low frequency words and words with few neighbors exhibited less dispersion than words with many neighbors. A summary of the planned comparison models for dispersion in the discourse mention analysis is provided in Table 7.

As in the lexical competition analysis, we also examined the effects of discourse mention and talker dialect on F1 and F2 separately for each vowel to confirm our interpretation of the dispersion results. We expected to observe a discourse mention effect on F1 for /æ/ and talker dialect x discourse mention interactions on F1 and F2 for /ɑ/. The linear mixed-effect models for each vowel category for F1 revealed a significant main effect of mention for /æ/ ($\chi^2=6.05$, $df=1$, $p = 0.014$), consistent with our interpretation of the dispersion analysis, a significant main effect of talker dialect for /ɑ/ ($\chi^2=4.32$, $df=1$, $p=0.038$), consistent with /ɑ/-lowering among Northern talkers, and significant effects of the lexical frequency ($\chi^2=8.83$, $df=1$, $p=0.003$) and neighborhood density ($\chi^2=7.31$, $df = 1$, $p=0.007$) covariates for /i/, as found in the dispersion analysis. A summary of the planned comparison models for F1 in the discourse mention analysis is provided in Table 8.

The linear mixed-effect models for each vowel category for F2 revealed significant effects of mention for /ɑ, u/ ($\chi^2=3.94$, $df=1$, $p=0.047$ for /ɑ/; $\chi^2=4.88$, $df=1$, $p=0.027$ for /u/), consistent with fronting of both vowels in second mentions relative to first mentions, significant effects of the lexical frequency ($\chi^2=5.82$, $df=1$, $p=0.016$) and neighborhood density ($\chi^2=7.58$, $df=1$, $p=0.006$) covariates for /i/, as found in the dispersion analysis, and a significant effect of the duration covariate for /æ/ ($\chi^2=11.16$, $df=1$, $p<0.001$). The duration covariate for /æ/ is positive: longer vowels have higher F2 (i.e., more front productions) than shorter vowels. A summary of the planned comparison models for F2 in the discourse mention analysis is provided in Table 9.

Table 10
Summary of the planned comparison mixed-effect models for vowel dispersion in the speaking style analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=3.487, t=31.57	β=2.008, t=10.34	β=3.357, t=12.59	β=0.269, t=0.95
Dialect (Midland)	β=−0.080, t=−1.32	β=0.065, t=0.88	β=−0.009, t=−0.23	β=−0.142, t=−1.78
Style (Careful)	**β=0.114, t=3.96**	**β=0.106, t=3.59**	**β=0.050, t=2.17**	β=0.026, t=0.70
Duration	β=0.203, t=0.45	β=0.701, t=1.46	β=0.451, t=0.94	**β=4.949, t=6.16**
Frequency	β=−0.102, t=−2.85	**β=0.188, t=2.16**	β=−0.040, t=−0.41	**β=0.330, t=2.60**
Density	β<0.001, t=0.12	β=−0.001, t=−0.21	β=−0.004, t=−0.92	**β=0.023, t=2.57**
Dialect x Style	β=−0.049, t=−1.77	β=−0.042, t=−1.46	β=0.008, t=0.37	**β=−0.080, t=−2.36**
Log-likelihood	−197	−141	−98	−310
Random effects	Talker: intercept Talker: style Word: intercept Word: dialect Word: style	Talker: intercept Talker: style Word: intercept	Talker: intercept Talker: style Word: intercept	Talker: intercept Word: intercept

Table 11
Summary of the planned comparison mixed-effect models for F1 in the speaking style analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=3.559, t=17.39	β=7.524, t=41.04	β=8.149, t=43.51	β=3.567, t=6.08
Dialect (Midland)	**β=−0.104, t=−2.01**	β=−0.072, t=−0.76	β=−0.155, t=−1.70	β=0.051, t=0.65
Style (Careful)	β=0.014, t=0.26	**β=0.111, t=3.55**	β=0.022, t=0.67	β=0.002, t=0.05
Duration	β=0.455, t=0.51	β=0.996, t=2.13	β=0.095, t=0.17	**β=−1.717, t=−2.18**
Frequency	β=−0.046, t=−0.59	**β=0.214, t=3.05**	β=−0.081, t=−1.56	**β=0.891, t=2.97**
Density	β=0.002, t=0.23	β=0.001, t=0.16	β=−0.001, t=−0.57	β=−0.032, t=−1.55
Dialect x Style	β=−0.083, t=−1.61	β=−0.020, t=−0.60	β=0.033, t=1.01	β=0.019, t=0.45
Log-likelihood	−428	−158	−197	−294
Random effects	Talker: intercept Word: intercept	Talker: intercept Talker: style Word: intercept Word: dialect x style	Talker: intercept Talker: style Word: intercept	Talker: intercept Talker: style Word: intercept

4.3. Speaking style

The mean vowel formant frequencies of the careful and plain productions of the words produced by the Midland and Northern talkers are shown in Fig. 6. As expected based on previous descriptions of these two dialects, /æ/ was more front and /ɑ/ was lower and more front for the Northern talkers than the Midland talkers. Both dialects exhibited fronted /u/ (relative to /ɑ/). The acoustic center of the vowel space is shown for each talker dialect with gray symbols in Fig. 6. As expected, given how the acoustic center was calculated, the acoustic center falls on the line connecting /i, ɑ/ and phonetic reduction towards this center for these two vowels is expected to involve a change in both F1 and F2. The center falls below and slightly to the left of /u/ and above and slightly to the left of /æ/. Thus, phonetic reduction for these two vowels is expected to involve primarily a change in F1.

The omnibus linear mixed-effect model on vowel dispersion revealed significant main effects of style ($\chi^2=8.01$, $df=1$, $p=0.005$) and vowel category ($\chi^2=43.75$, $df=3$, $p<0.001$), as well as a significant effect of the duration covariate ($\chi^2=23.03$, $df=1$, $p<0.001$). As expected, plain speech vowels were less dispersed overall than careful speech vowels. The effect of the duration covariate was in the expected direction: longer vowels were further from the acoustic center than shorter vowels.

The planned comparison linear mixed-effect models for each vowel category revealed a significant talker dialect x style interaction for /u/ ($\chi^2=5.53$, $df=1$, $p=0.019$), a significant main effect of style for /i, æ, ɑ/ ($\chi^2=9.33$, $df=1$, $p=0.002$ for /i/; $\chi^2=9.34$, $df=1$, $p=0.002$ for /æ/; $\chi^2=4.18$, $df=1$, $p=0.041$ for /ɑ/), a significant effect of the duration covariate for /u/ ($\chi^2=35.01$, $df=1$, $p<0.001$), significant effects of the frequency covariate for /æ, u/ ($\chi^2=3.85$, $df=1$, $p=0.050$ for /æ/; $\chi^2=4.85$, $df=1$, $p=0.028$ for /u/), and a significant effect of the density covariate for /u/ ($\chi^2=4.87$, $df=1$, $p=0.027$). The style effect for /i, æ, ɑ/ confirms less peripheral productions in plain speech relative to careful speech for these three vowels. As shown in Fig. 6, the talker dialect x speaking style interaction for /u/ reflects greater reduction in plain speech relative to careful speech for the Northern talkers than for the Midland talkers. Further, for the Northern talkers, the reduction of /æ, u/ in plain speech corresponds to raising (but not backing) of /æ/ and fronting of /u/, consistent with ongoing shifts in the dialect. As shown in Fig. 6, the reduction of /æ/ for the Midland talkers reflects both raising and backing relative to the careful production. This Midland backing of /æ/ is not towards the acoustic center of the parallelogram-shaped vowel space as defined in the current study, but instead reflects movement towards the idealized location of a mid-central vowel in a trapezoidal vowel space. The effect of the duration and density covariates for /u/ dispersion are in the expected direction: longer vowels are further from the acoustic center than shorter vowels and words with more neighbors are further from the acoustic center than words with fewer neighbors. However, the effect of the frequency covariate for /æ, u/ are in the unexpected direction: high frequency words are further from the acoustic center than low frequency words. A summary of the planned comparison models for dispersion in the speaking style analysis is provided in Table 10.

Table 12
Summary of the planned comparison mixed-effect models for F2 in the speaking style analysis. Significant effects ($p<0.05$ by log likelihood comparisons) are in bold.

	/i/	/æ/	/ɑ/	/u/
Intercept	β=15.222, t=179.66	β=12.190, t=50.26	β=10.463, t=25.81	β=14.271, t=13.89
Dialect (Midland)	β=−0.067, t=−1.09	β=−0.144, t=−1.61	β=−0.102, t=−1.10	β=−0.019, t=−0.19
Style (Careful)	**β=0.065, t=3.75**	β=0.012, t=0.57	β=−0.050, t=−1.89	β=0.014, t=0.33
Duration	β=0.464, t=1.63	β=0.770, t=1.31	β=−0.175, t=−0.25	**β=−6.052, t=−6.24**
Frequency	β=−0.057, t=−2.55	β=−0.133, t=−1.14	β=0.002, t=0.02	β=−0.539, t=−1.02
Density	β=0.002, t=0.86	β=0.008, t=1.44	β=0.003, t=0.51	β=−0.028, t=−0.76
Dialect x Style	β=−0.023, t=−1.37	**β=0.046, t=2.21**	β=0.006, t=0.23	β=0.027, t=0.69
Log-likelihood	−59	−170	−217	−373
Random effects	Talker: intercept Talker: style Word: intercept	Talker: intercept Word: intercept	Talker: intercept Talker: style Word: intercept Word: dialect	Talker: intercept Word: intercept Word: dialect

As in the lexical competition and discourse mention analyses, we also examined the effects of speaking style and talker dialect on F1 and F2 separately for each vowel to confirm our interpretation of the dispersion results. We expected to observe speaking style effects on F1 and F2 for /i, ɑ/ and talker dialect x speaking style interactions on F2 for /u/ and on F1, and possibly F2, for /æ/. The linear mixed-effect models for each vowel category for F1 revealed a significant main effect of speaking style for /æ/ ($\chi^2=9.44$, $df=1$, $p=0.002$), as observed in the dispersion analysis, a significant main effect of talker dialect for /i/ ($\chi^2=3.93$, $df=1$, $p=0.047$), reflecting higher /i/ productions for Midland talkers than Northern talkers (see Fig. 6), significant effects of the frequency covariate for /æ, u/ ($\chi^2=4.27$, $df=1$, $p=0.039$ for /æ/; $\chi^2=5.93$, $df=1$, $p=0.015$ for /u/), as found in the dispersion analysis, and a significant effect of the duration covariate for /u/ ($\chi^2=4.70$, $df=1$, $p=0.030$), as found in the dispersion analysis. A summary of the planned comparison models for F1 in the speaking style analysis is provided in Table 11.

The linear mixed-effect models for each vowel category for F2 revealed a significant talker dialect x speaking style interaction for /æ/ ($\chi^2=4.83$, $df=1$, $p=0.028$), consistent with our interpretation of the dispersion analysis results, a significant main effect of style for /i/ ($\chi^2=10.20$, $df=1$, $p=0.001$), as observed in the dispersion analysis, and a significant effect of the duration covariate for /u/ ($\chi^2=35.63$, $df=1$, $p<0.001$), as found in the dispersion analysis. A summary of the planned comparison models for F2 in the speaking style analysis is provided in Table 12.

4.4. Discussion

The overall findings from the spectral reduction analysis are consistent with previous research demonstrating spectral reduction of some vowels in words with few lexical competitors relative to words with more lexical competitors (Munson & Solomon, 2004; Scarborough, 2010; Wright, 2004, cf. Gahl et al., 2012) and spectral reduction of plain speech relative to careful speech (Smiljanic & Bradlow, 2005, 2009). The results also provide novel evidence for second mention reduction in the spectral domain, which has not been examined in previous work.

In addition to these overall patterns, we also observed substantial variability in spectral reduction within and across the linguistic contexts. Specifically, significant overall spectral vowel reduction was observed for second mentions relative to first mentions and for plain speech relative to careful speech, but spectral vowel reduction for easy words relative to hard words was mediated by a three-way easy/hard status x vowel category x talker dialect interaction. Further, in all three analyses, planned comparisons revealed variability in the realization of spectral vowel reduction across vowel categories and talker dialects. In the lexical competition analysis, spectral reduction of easy words relative to hard words was marginal for /i/ and interacted with talker dialect for /æ, u/. In the discourse mention analysis, spectral reduction for second mentions relative to first mentions was marginal for /æ/ and exhibited a marginal interaction with talker dialect for /ɑ/. In the speaking style analysis, spectral reduction for plain speech relative to careful speech was significant for /i, æ, ɑ/ and interacted with talker dialect for /u/. However, the analyses of F1 and F2 revealed that second mention reduction is observed in the spectral domain to a greater extent than the dispersion analysis suggests. In particular, although the effect of discourse mention was only marginal in the dispersion analysis for /æ, ɑ/, the effect of mention was significant for the F1 of /æ/ and for the F2 of /ɑ, u/. Thus, second mention reduction is observed in the spectral domain, but the pattern of reduction differs qualitatively from the patterns observed for easy vs. hard words and for plain vs. careful speech.

The results of the spectral reduction analysis are also consistent with previous research demonstrating an interaction between phonetic reduction and talker dialect. First, in the analysis of /u/ dispersion, a significant interaction with talker dialect was observed for both lexical competition and speaking style. In both cases, the effect of linguistic context was larger for the Northern talkers than for the Midland talkers, leading to more similar /u/ targets across dialects in easy words than in hard words (see Fig. 4) and in plain speech than in careful speech (see Fig. 6). An inspection of Figs. 4 and 6 further reveals that the effects of talker dialect and linguistic context on /u/ dispersion involve larger changes in F2 than in F1, although larger changes in F1 than F2 would be expected for reduction towards the acoustic center of the vowel space. Thus, this pattern of results suggests more /u/-fronting in easy words relative to hard words and in plain speech relative to careful speech, especially for the Northern talkers, consistent with previous research demonstrating enhancement of sociolinguistic variants in reduction-promoting contexts (Clopper & Pierrehumbert, 2008; Hay et al., 1999; Munson, 2007a). The separate analyses of F1 and F2 variation across linguistic contexts and talker dialects confirm robust effects of talker dialect and lexical competition on /u/-fronting, consistent with this interpretation, although the talker dialect x speaking style interaction for /u/ was not supported by the separate analyses of F1 and F2. The effect size for the duration covariate was especially large for F2 in this analysis, which may have masked any effects of talker dialect or speaking style on /u/-fronting.

Second, in the analysis of /æ/ dispersion, a significant interaction with talker dialect was observed for lexical competition and a significant main effect was observed for speaking style. In the lexical competition analysis, the Northern /æ/ was more similar to the unshifted Midland /æ/ in the hard words than the easy words, whereas the variant produced in the easy words was more shifted in the direction of the Northern Cities Shift (see Fig. 4). Crucially, as in the case of /u/-fronting, the Northern variants observed in the easy words were more consistent with dialect-specific variants than with reduced variants. Whereas reduction of /æ/ would lead to raised and possibly backed productions, the Northern Cities Shift involves raising and fronting of /æ/. The Northern /æ/ in easy words was more front than the /æ/ in hard words, which is unexpected in a simple reduction account, but consistent with the hypothesis that more extreme dialect-specific variants are observed in easy words than hard words. In the speaking style analysis, the spectral effect for /æ/ similarly reflects greater /æ/-raising and -fronting, consistent with the Northern Cities Shift, in the Northern dialect in plain speech than careful speech, whereas the Midland talkers exhibited more traditional reduction towards an idealized center of the vowel space, rather than reduction towards the acoustic center of the space (see Fig. 6). The separate analyses of F1 and F2 variation across linguistic contexts and talker dialects confirm robust effects of talker dialect and lexical competition on /æ/-raising and robust effects of talker dialect and speaking style on /æ/-fronting, consistent with this interpretation of the dispersion results.

Unlike in the lexical competition and speaking style analyses, an interaction with talker dialect was not observed for /u, æ/ in the discourse mention analysis, although the interaction with talker dialect was marginal for /ɑ/. In particular, whereas the Midland talkers show reduction towards the center of the vowel space in second mentions relative to first mentions, the Northern talkers maintain the lowered and fronted production of /ɑ/ consistent with the Northern Cities Shift in second mentions, leading to a smaller difference between first and second mentions for the Northern talkers than for the Midland talkers (see Fig. 5). This pattern also leads to a greater difference between the Midland and Northern talkers' /ɑ/ in second mentions than in first mentions, consistent with enhancement of dialect-specific differences in reduction-promoting contexts. The separate analyses of F1 and F2 variation across linguistic contexts and talker dialects confirm robust effects of talker dialect on F1 and discourse mention on F2 for /ɑ/, but the talker dialect x discourse mention interaction emerges only when both dimensions are considered together in the dispersion analysis.

As in the temporal reduction analysis in Section 3, a comparison of the results across all three linguistic contexts reveals additional differences in the realization of the vowels related to the nature of the speech materials. The vowels in the sentences in the speaking style analysis were more peripheral overall than the vowels in the passages in the discourse mention analysis, but less peripheral overall than the vowels in the isolated words in the lexical competition analysis. These differences reflect overall effects on vowel dispersion of reading isolated words vs. sentences vs. passages, as discussed for duration in Section 3.4. The results of the speaking style analysis are also consistent with variationist interpretations of stylistic effects, including Labov's (1972) proposal that increased formality leads to fewer dialect-specific variants and more standard variants. The instructions in the careful speech block may have encouraged the talkers to produce more formal speech, leading to less extreme regional variants in their careful speech than their plain speech. The degree of /u/-fronting in the speaking style analysis is also intermediate between the /u/-fronting observed in the lexical competition and discourse mention analyses, providing further support for Labov's (1972) claims regarding the role of speech materials in eliciting dialect-specific variation.

Taken together, the results of the vowel dispersion analysis reveal variability in spectral reduction across linguistic contexts and talker dialects that suggest enhancement of dialect-specific variants in reduction-promoting contexts. Significant overall spectral reduction was observed for discourse mention and speaking style, but not for lexical competition, as in the temporal reduction analysis in Section 3. However, the patterns of interactions with talker dialect revealed similarities between the lexical competition and speaking style analyses. In particular, interactions with talker dialect were observed for /æ, u/ in the lexical competition and speaking style analyses, but not in the discourse mention analysis, suggesting qualitative similarities in spectral reduction for lexical competition and speaking style, but qualitative differences in spectral reduction for discourse mention.

5. General discussion

5.1. Phonetic reduction and social indexing

The results of the three analyses provide additional empirical evidence for the relationship between sociolinguistic variation and phonetic reduction processes. First, the lexical competition and speaking style analyses revealed greater /æ/-raising and/or -fronting in the Northern dialect in the reduced context (i.e., low lexical competition and plain speech) relative to the less reduced context (i.e., high lexical competition and careful speech). In both analyses, Northern talkers exhibited higher, but not backer, /æ/ in the reduction-promoting context, whereas Midland talkers exhibited either very little variation across contexts (in the lexical competition analysis) or higher and backer /æ/ in the reduction-promoting context (in the speaking style analysis). Thus, whereas the Midland variation was consistent with phonetic reduction towards the idealized center of the vowel space (i.e., /ə/) in the reduction-promoting contexts, the Northern variation was more consistent with the ongoing Northern Cities Shift in the reduction-promoting contexts. Second, the lexical competition and speaking style analyses revealed greater /u/-fronting in the Northern dialect in the reduced context (i.e., low lexical competition and plain speech) relative to the less reduced context (i.e., high lexical competition and careful speech), although the effect was more robust in the lexical competition analysis than in the speaking style analysis. In both analyses, both dialect groups exhibited more fronted /u/ in the reduction-promoting context, but the effect of linguistic context was larger for the Northern talkers than the Midland talkers. Thus, the Northern variation in particular was more consistent with ongoing /u/-fronting in the reduction-promoting contexts than in the non-reduction-promoting contexts. Finally, the discourse mention analysis revealed some evidence for maintenance of /ɑ/-fronting and -lowering by the Northern talkers in the reduced context (i.e., second mentions). Whereas the Midland talkers exhibited reduction towards the center of the vowel space in the reduction-promoting context, the Northern talkers maintained the lowered and fronted /ɑ/ that is consistent with the ongoing Northern Cities Shift in the reduction-promoting context.

Thus, in all of the analyses in which a linguistic context x talker dialect interaction was observed, the interaction reflected enhancement (for /æ, u/) or maintenance (for /ɑ/) of dialect-specific variants instead of spectral reduction for the Northern talkers. This enhancement and/or maintenance of dialect variation led to larger differences between the Midland and Northern talkers in reduction-promoting contexts for /æ, ɑ/, which are only shifting in the Northern dialect, and to smaller differences between the Midland and Northern talkers in reduction-promoting contexts for /u/, which is fronting in both dialects, but is somewhat more advanced for Midland talkers than for Northern talkers (see Figs. 4–6). This observation that enhancement of dialect variation can lead to both greater differences and greater similarities across dialects reflects the continuum of social indexing that is always available to individual talkers. That is, marking oneself as a member of a regional dialect group by adopting a more extreme variant of a regional change-in-progress can result in either greater similarity with talkers from other regions for whom the change is more advanced or greater distance from talkers from other regions who are not participating in the change.

We predict that the effects that we have observed in the current analysis for dialect variation would also be observed for other dimensions of indexicality. Specifically, reduction-promoting contexts should also correlate with enhancement of indexical marking of age, sex/gender, and a whole host of other locally-relevant social identities. We did not include data from older talkers or from male talkers in the current study and therefore did not explore enhancement of young or female identity markers. However, to the extent that the regional dialects we examined are characterized by ongoing changes that are led by young women, our results may simultaneously reflect social indexing of region, age, and sex. We further expect that these data contain variation reflecting other relevant social identities. In the context of university students, these identities may include categories such as student-athlete, sorority member, etc., and we expect the linguistic markers of these identities to be enhanced in reduction-promoting contexts as well. Some evidence for this broad interpretation of our results is provided by Hay and Foulkes's (2016) recent finding that the effect of topic on lenition of medial /t/ in New Zealand English is enhanced in second mentions relative to first mentions. They provide several possible interpretations of their results, including the proposal that the topics they considered are linked to social identity, which is more robustly linguistically marked in second mentions than first mentions, parallel to the findings reported for vowel reduction by Munson (2007a) and Clopper and Pierrehumbert (2008), as well as the results of the current study.

One alternative explanation for our results is that vowel reduction is realized as movement in a single acoustic dimension (F1 or F2) rather than as centralization, as suggested by some previous work (Ferguson & Kewley-Port, 2007; Fourakis, 1991; Padgett & Tabain, 2005; Scarborough & Fougeron, 2016). This possibility is important to consider because if reduction of /u/ is realized as fronting, rather than as centralization, we would not be able to distinguish enhancement of dialect features (i.e., /u/-fronting) from reduction. Similarly, if reduction of /æ/ is realized as raising, rather than as centralization, we would not be able to distinguish enhancement of the Northern Cities Shift (i.e., /æ/-raising) from reduction. However, for both of these vowels, we observed an interaction between talker dialect and phonetic reduction, which means that indexicality is also central to understanding the effects of reduction from this alternative perspective. In particular, the interactions would be interpreted as reflecting more reduction in the Northern than the Midland dialect for both vowels. That is, phonetic reduction itself would be the index of regional dialect, rather than reduction-promoting contexts leading to the enhancement of regional dialect features. Previous work has demonstrated variation in the magnitude of phonetic and phonological reduction across dialects (e.g., Byrd, 1994; Clopper & Smiljanic, 2015), lending plausibility to this alternative interpretation. However, the dialect differences in spectral reduction in the current study are limited to vowels that are undergoing substantial shifts (i.e., /æ, u/) in one or both dialects. This latter aspect of our findings is not easily captured by this alternative approach, which should predict consistent variation in reduction across vowel categories, but follows straightfowardly from the proposal that phonetic reduction and enhancement of social-indexical features emerge in the same contexts.

5.2. Empirical contributions to our understanding of phonetic reduction

Beyond our specific research question about the interactions between regional dialect variation and phonetic reduction processes, the results of the three analyses also make a number of novel contributions to our understanding of phonetic reduction itself. First, all of the significant effects of the linguistic contexts were in the predicted direction. Thus, the results of this study provide additional evidence for temporal and spectral reduction of easy words relative to hard words, of second mention words relative to first mention words, and of plain speech relative to careful speech. However, the results also revealed substantial variability across the linguistic contexts in terms of the robustness of the effects across vowels and acoustic domains. The most consistent effects were observed in the speaking style analysis, in which style was a significant overall predictor of duration and dispersion, as well as a significant predictor of dispersion for three of the four vowels (/i, æ, ɑ/). The least consistent effects were observed in the lexical competition analysis, in which easy/hard status was not a significant overall predictor of either duration or dispersion and the effect of easy/hard status on dispersion for individual vowels emerged only in interactions with talker dialect for /æ, u/. Intermediate effects were observed in the mention analysis, in which mention was a significant overall predictor of duration and dispersion, but the effect of discourse mention on dispersion for individual vowels was limited to F1 for /æ/ and F2 for /ɑ, u/.

This variability across linguistic contexts may partially reflect the degree of similarity of the vowel targets across conditions. The lexical competition analysis requires comparison across lexical items, which introduces additional sources of variability such as consonantal context. In previous studies, individual vowel categories were represented by as few as one pair of easy and hard words (Munson & Solomon, 2004; Scarborough, 2010; Wright, 2004), and in both Scarborough's (2010) and Wright's (2004) experiments, two of the vowels that exhibited significant effects of lexical competition on vowel dispersion were represented by a single pair of words, suggesting that the results may reflect item-specific effects rather than overall effects of lexical competition. Item-specific effects due to phonetic context are also consistent with Yao's (2011) and Gahl's (2015) findings that the place and manner of articulation of preceding and following consonants have significant effects on vowel dispersion. A careful inspection of the stimulus words in the lexical competition analysis in the current study (see Table 1) in the context of Gahl's (2015) findings reveals that the segmental effects in our stimulus materials are more likely to lead to centralization of the vowels in the hard words than the easy words, which is the opposite of the observed results. For example, Gahl (2015) found that coda alveolar consonants lead to fronting (higher F2) of back vowels and raising (lower F1) of low vowels relative to coda labial consonants. In our materials (see Table 1), the hard words had more following alveolar consonants than the easy words for all four vowel categories. Thus, if the following consonant place of articulation were the critical factor in our analysis, we would expect to see fronting of /ɑ, u/ and raising of /æ, ɑ/ in hard words relative to easy words. Instead, we observed raising of /æ/ and fronting of /u/ in easy words relative to hard words for Northern talkers. Thus, our results more likely reflect true effects of lexical competition than segmental effects of neighboring consonants.

Potential coarticulatory effects are not limited to the lexical competition analysis, however. An inspection of Tables 2 and 3 reveals that a number of the target words in the discourse mention and speaking style analyses had onset clusters containing /r, l/, which may exhibit long-term coarticulatory effects with the following vowel. In particular, /r/ is characterized by a low F2, whereas /l/ is characterized by a low F1 (Espy-Wilson, 1992). Further, /r/ trajectories are shorter preceding unstressed syllables than stressed syllables (Boyce & Espy-Wilson, 1997) and coarticulation is less extensive for easy words than for hard words (Scarborough, 2013), suggesting less coarticulation in reduced contexts (cf. Scarborough & Zellou, 2013). We therefore might expect coarticulatory effects of /r, l/ to differ across contexts in this study. In particular, stronger coarticulation with /l/ should lead to more raising (lower F1) of low vowels /æ, ɑ/ and stronger coarticulation with /r/ should lead to more backing (lower F2) of front vowels /i, æ/ for first mention words and careful speech than for second mention words and plain speech. That is, stronger coarticulation in non-reduction-promoting contexts is predicted to mimic reduction in reduction-promoting contexts for these vowels. Our results may therefore underestimate the effects of discourse mention and speaking style on phonetic reduction, as a result of variation in the magnitude of coarticulation across contexts.

Second, the results of the individual vowel analyses in the spectral domain provide new insights into the nature of spectral vowel reduction. As described in Section 1, the traditional assumption regarding phonetic vowel reduction is that it involves centralization towards /ə/ (Fourakis, 1991; van Bergem, 1993), but centralization is typically quantified as the distance to the center of the acoustic space (Bradlow et al., 1996; Munson & Solomon, 2004; Scarborough, 2010; Scarborough & Zellou, 2013; Wright, 2004). However, as shown in Figs. 4–6, the acoustic center of the space does not correspond to the idealized location for /ə/, which is between /æ, ɑ/ on the front-back dimension on the IPA chart. The variation observed in the speaking style analysis for /æ/ highlights this mismatch between the acoustic center and the idealized center of the vowel space. In particular, the Midland talkers exhibit apparent reduction towards the idealized center (i.e., raising and backing) rather than reduction towards the acoustic center (i.e., raising and possibly fronting). Thus, these results provide evidence for the intuition that reduction involves centralization towards /ə/ and suggest that other measures of vowel reduction, such as distance from measured tokens of /ə/ (van Bergem, 1993), overall vowel space area (Bradlow et al., 1996; Fourakis, 1991), or mean vowel distance between categories (Padgett & Tabain, 2005; Wright, 2004), may provide additional information about the nature of spectral vowel reduction across linguistic contexts.

Further, phonetic vowel reduction in unstressed syllables has been argued to involve greater changes in some dimensions for some vowels than others (e.g., more raising of low vowels than lowering of high vowels; Padgett & Tabain, 2005). The results of the discourse mention analysis provide some evidence that this dimensionality may also be relevant for second mention spectral reduction. In particular, the results reveal fronting of the back vowels /ɑ, u/ and raising of the low vowel /æ/ in second mentions relative to first mentions. These patterns are similar to those observed in unstressed vowels relative to stressed vowels (Fourakis, 1991; Padgett & Tabain, 2005), suggesting a possible prosodic connection between phonetic reduction of unstressed syllables and phonetic reduction of given words in a discourse (see also Baker & Bradlow, 2009; Burdin & Clopper, 2015).

Third, the results of the three analyses revealed independent effects of the linguistic contexts on temporal and spectral reduction. Although duration was a significant predictor of dispersion in a number of the analyses, the direction of the effect was not always as expected. For example, duration and dispersion of /ɑ/ were negatively related in the lexical competition analysis, which means that more dispersed vowels were shorter in duration than less dispersed vowels (cf. Moon & Lindblom, 1994). Further, in the speaking style analysis, a significant overall effect of style was obtained for dispersion even though the significant duration covariate was in the expected direction, further confirming that dispersion does not directly reflect duration. The independence of the two acoustic domains can also be observed in the relative robustness of the temporal and spectral effects within each analysis. Whereas the temporal effects were more robust in the mention analysis, the spectral effects were more robust in the lexical competition analysis. These results confirm that the effects of the linguistic contexts on phonetic reduction operate independently within and across acoustic domains, consistent with Watson's (2010) proposal for a model of phonetic reduction in which different acoustic domains of reduction reflect different cognitive processes underlying different linguistic contexts.

5.3. Theoretical contributions to our understanding of phonetic reduction

The analyses in the current study were not designed to explicitly distinguish between the theoretical accounts of phonetic reduction, but the results provide several pieces of evidence that different processes lead to phonetic vowel reduction within and across linguistic contexts. First, the speaking style manipulation involves explicit instructions to the participant to modify their speech in response to an imagined interlocutor. This manipulation is therefore consciously listener-oriented in a way that lexical and discourse factors may not be. Further, although some differences are observed in the speech directed towards real and imagined interlocutors and in the speech directed towards interlocutors with different needs (e.g., listening in noise vs. non-native listeners; infant vs. adult listeners), stylistic variation in vowel duration and dispersion is comparable across conditions: talkers produce slower, hyperarticulated speech when real or imagined listeners are presumed or known to have processing difficulties (Hazan & Baker, 2011; Hazan, Uther, & Granlund, 2015; Scarborough, Brenier, Zhao, Hall-Lew, & Dmitrieva, 2007; Scarborough & Zellou, 2013; Zellou & Scarborough, 2015). Thus, to the extent that the speaking style effects mirror other phonetic reduction effects, a listener-oriented perspective may provide the most parsimonious account of variation in vowel duration and dispersion across a range of linguistic contexts. However, as discussed above, the temporal and spectral reduction effects in the current study were variable across linguistic contexts, revealing different patterns of similarity to the speaking style results for lexical competition and discourse mention.

In the spectral domain, the lexical competition results revealed similar patterns of interaction with talker dialect as the speaking style results, suggesting that a shared listener-oriented process may explain both sets of results. In contrast, the discourse mention results in the spectral domain were qualitatively different from those obtained in the lexical competition and speaking style analyses, suggesting a potentially different underlying process. A listener-oriented account of the effect of lexical competition on phonetic reduction is consistent with previous interpretations of this effect (Wright, 2004; Zellou & Scarborough, 2015) and is also independently motivated by our data. As discussed above, previous research on phonetic reduction as a function of phonological similarity is somewhat mixed. Whereas most studies, including the current lexical competition analysis, have shown reduction of words with few neighbors relative to words with many neighbors for words produced in isolation (Munson & Solomon, 2004; Scarborough, 2010; Watson & Munson, 2007; Wright, 2004), Gahl et al. (2012) showed the opposite pattern for words produced in running speech: words with many neighbors were reduced relative to words with few neighbors (cf., Zellou & Scarborough, 2015). Gahl (2015) further demonstrated that the effects reported by Wright (2004) can be attributed to segmental effects of the consonants surrounding the target vowels. As discussed above, these mixed results would be difficult to reconcile with one another, except that they reflect a similar mismatch in the literature on the effects of phonological similarity on lexical processing. In particular, although words with many neighbors are more difficult for listeners to identify than words with few neighbors (Luce & Pisoni, 1998; Vitevitch & Luce, 1999), words with many neighbors are typically easier for talkers to produce than words with few neighbors (Vitevitch, 2002; Vitevitch & Sommers, 2003; cf. Vitevitch & Stamer, 2006). Thus, from a listener-oriented perspective, we expect reduction of words with few neighbors, because they are easier for the listener, but from a talker-oriented perspective, we expect reduction of words with many neighbors, because they are easier for the talker. Our results are therefore more consistent with a listener-oriented account of phonetic reduction, in which words with few neighbors are reduced in the spectral domain relative to words with many neighbors, than with a talker-oriented account, in which the opposite pattern is predicted to emerge.

In the temporal domain, the discourse mention analysis revealed similar overall patterns of reduction as the speaking style analysis, whereas the results of the lexical competition analysis revealed limited evidence for temporal reduction overall. This pattern of results suggests that a shared listener-oriented process may explain the discourse mention and speaking style temporal results, given the explicitly listener-oriented nature of the speaking style manipulation. However, this interpretation differs from Lam and Watson's (2010) and Watson's (2010) interpretation of temporal reduction due to discourse mention reflecting talker-oriented speech production processes. One way to reconcile these two accounts would be to separate the interpretation of the spectral and temporal reduction results for speaking style. Specifically, we could entertain the proposal that spectral reduction reflects a listener-oriented goal of perceptual distinctiveness, but temporal reduction reflects talker-oriented processing effort. That is, the effort required by the talker to produce spectrally-dispersed vowels for the listener in careful speech leads to slower processing and longer vowels. This account maintains the direct link between the acoustic domain (temporal vs. spectral) and the cognitive process (speech processing constraints vs. listener modeling), but breaks the one-to-one mapping between the linguistic context and the cognitive process (i.e., speaking style variation is listener-oriented) that our first interpretation provides.

Our results therefore necessitate a more complex model of phonetic reduction in which the acoustic domain of reduction, the linguistic context, and the cognitive process are not uniquely associated with one another. In particular, we suggest that spectral enhancement of vowel contrasts in careful speech and in words with many competitors is primarily listener-oriented, reflecting communicative goals, whereas temporal enhancement in first mentions and in careful speech is primarily talker-oriented, reflecting processing costs associated with lexical access and explicit hyperarticulation. We further propose that the spectral enhancement observed in first mentions is also primarily talker-oriented, reflecting processes associated with prosodic structure, including lexical stress and phrasal prominence.

6. Conclusions

Taken together, despite variability in the underlying phonetic reduction processes, a consistent pattern of interaction between phonetic reduction and regional dialect variation was observed. In all cases when these two factors interacted, the data revealed more extreme regional dialect variants in the contexts that also led to phonetic reduction. As discussed in Section 1.1, this finding can be interpreted from either a listener-oriented perspective, in which the talker takes the opportunity of likely successful communication to provide more robust indexical information to the listener, or a talker-oriented perspective, in which forms that are easy for the talker to access are also more robustly sociolinguistically-marked. Thus, the interactions between sociolinguistic variation and phonetic reduction processes themselves do not provide strong evidence in favor of one of the predominant approaches to phonetic reduction. However, the similarities observed in the spectral domain between the lexical competition and speaking style analyses, as well as the nature of the lexical competition effects, are consistent with a listener-oriented account. In contrast, the similarities observed in the temporal domain between the discourse mention and speaking style analyses may reflect talker-oriented processes, as proposed by Lam and Watson (2010). These results suggest that the connection between linguistic factors and acoustic domains of reduction is not straightforward: whereas spectral reduction in plain speech may reflect listener-oriented processes, temporal reduction in plain speech may reflect talker-oriented processes. These results further suggest that the connection between acoustic domains of reduction and the cognitive processes involved in reduction is not straightforward: whereas spectral reduction in plain speech may reflect listener-oriented processes, spectral reduction in second mentions may reflect talker-oriented processes related to prosodic prominence, such as stress. Further research on the individual and combined effects of these various linguistic and indexical factors is necessary to determine the nature of the complex cognitive processes involved in phonetic reduction, sociolinguistic variation, and their interaction in speech production.

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Appendix

The passages for the discourse mention analysis are shown in (1)–(4). These passages were based on Baker and Bradlow's (2009) passages. We revised their original passages to include target words with the desired stressed vowel categories /i, æ, ɑ, u/. The first mention of each target word is shown in bold and the second mention is shown in italics in each passage. Bolding and italics were not included in the passages presented to the talkers who were recorded for this study.

(1) In today's show we will learn how to make a **soup** with **beets** and **cabbage**. The first step is to wash and slice the *beets* and *cabbage*. Next you fry the **squash** and toss a **piece** of ginger **root** into the **pot**. Make sure the *piece* of ginger *root* isn't too big, or its strong flavor could overpower the *squash*. Finally, add the beets and cabbage, and pour the **stock** into the *pot*. Nearly any type of *stock* will do, but an old chicken carcass boiled down to stock works best. Let it simmer for an hour, and at the end you will have a fantastic *soup* that your whole family will enjoy!
(2) During his senior year of college, **Robert** was having a really hard time. He was flunking all of his **classes**, and he only had enough money to buy ramen **noodles**. Then one day, he decided to become a **botany** major. Suddenly everything changed. He loved the *botany classes*, and started getting all As. *Robert* started working in a **lab**, where he earned enough money to buy wine and **cheese** every **week**, instead of ramen *noodles*. A girl named **Judy** worked in the *lab* too, and he was instantly attracted to her. He got close to her by inviting her over for wine and *cheese* at his house every *week*. After only a couple of these dates, *Judy* became his girlfriend. Robert's life is great, and he owes it all to botany!
(3) On her birthday, **Poppy** showed up early at the **zoo** for work. She was in charge of the birds and the **African** animals. The **cuckoos** and the **geese** were her favorite birds, and the **zebras** and the **giraffes** were her favorite *African* animals. She went to the bird house first, and was surprised to see that the *cuckoos* and the *geese* were missing and her assistant Lisa wasn't there. *Poppy* hurried over to the African animal area and was upset to find that the *zebras* and the *giraffes* were gone too, and her other assistant **Lucy** was nowhere to be found. She muttered, "I can't run the *zoo* by myself", and ran back to her office to find out what was going on. But when she opened the door, Poppy heard a honk and a bunch of voices yelling "Surprise!" She realized with joy that not only had *Lucy* conspired with Lisa to throw a surprise party for her birthday, but they had even brought along all of her favorite animals!
(4) Here's how to get to the best pizza place in town. Go straight down this **street** and follow the signs for the **capitol**. When you get downtown, continue three **blocks** past the *capitol* and take a left onto First **Avenue**, the main *street* in town. You'll go past an old **factory** and a church with a **blue steeple**. Two *blocks* past the *factory* and the church with the *blue steeple* is Fillmore *Avenue*. Turn right and follow this road until it ends at **Copper** Lane. The pizza place is one block down on the left on the corner of *Copper* Lane and Buchanan Avenue. It's called Gina's Pizzeria and you should definitely order the breadsticks!

The complete list of sentences selected from the SPIN test (Kalikow et al., 1977) for the speaking style analysis is shown in (5). The final word is the target word in each sentence.

(5) Ruth had a necklace of glass beads.
The chicken pecked corn with its beak.

I made the phone call from a booth.
Tom fell down and got a bad bruise.
She wore a feather in her cap.
Peter dropped in for a brief chat.
We heard the ticking of the clock.
The detectives searched for a clue.
Paul was arrested by the cops.
Harry slept on the folding cot.
The ship's captain summoned his crew.
The farmer harvested his crop.
The steamship left on a cruise.
The wedding banquet was a feast.
The doctor charged a low fee.
The shepherds guarded their flock.
It was stuck together with glue.
At breakfast he drank some juice.
This key won't fit in the lock.
The burglar escaped with the loot.
The storm broke the sailboat's mast.
The plow was pulled by an ox.
The story had a clever plot.
The cut on his knee formed a scab.
Watermelons have lots of seeds.
She made the bed with clean sheets.
Paul hit the water with a splash.
The sandal has a broken strap.
Ruth poured herself a cup of tea.
The house was robbed by a thief.
The mouse was caught in the trap.
The candle flame melted the wax.

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