ANNUAL REVIEWS

Annual Review of Linguistics

Individual Differences in Language Processing: Phonology

Alan C.L. Yu[1] and Georgia Zellou[2]

[1]Phonology Laboratory, Department of Linguistics, University of Chicago, Chicago, Illinois 60637, USA; email: aclyu@uchicago.edu

[2]Department of Linguistics, University of California, Davis, California 95616, USA; email: gzellou@ucdavis.edu

Annu. Rev. Linguist. 2019. 5:6.1–6.20

The *Annual Review of Linguistics* is online at linguist.annualreviews.org

https://doi.org/10.1146/annurev-linguistics-011516-033815

Keywords

individual differences, phonological processing, speech production, speech perception, cognitive processing style, sound change

Abstract

Individual variation is ubiquitous and empirically observable in most phonological behaviors, yet relatively few studies aim to capture the heterogeneity of language processing among individuals, as opposed to those focusing primarily on group-level patterns. The study of individual differences can shed light on the nature of the cognitive representations and mechanisms involved in phonological processing. To guide our review of individual variation in the processing of phonological information, we consider studies that can illuminate broader issues in the field, such as the nature of linguistic representations and processes. We also consider how the study of individual differences can provide insight into long-standing issues in linguistic variation and change. Since linguistic communities are made up of individuals, the questions raised by examining individual differences in linguistic processing are relevant to those who study all aspects of language.

1. INTRODUCTION

In this review, phonological processing is understood to mean any sort of language processing that involves linguistically relevant sounds, which broadly encompasses not only the parsing of the speech signal into phonological categories and the processing of phonological categories in context, but also the parsing of words into higher-order prosodic units. This review focuses on the processing of phonological information in spoken languages from an individual-differences perspective. Linguistic research has traditionally emphasized identification of patterns that are shared across a group of individuals within a speech community. Theories of grammatical representation and processes overwhelmingly focus on these group-level patterns. Not only is this emphasis on group-level patterning ingrained in linguistic descriptions and grammatical analysis, it is reflected even in the very analytic choices linguists make. For example, in the Analysis of Variance (ANOVA) and various forms of regression analyses, arguably the most widely used statistics in linguistics and speech sciences, individual differences are referred to as the "error term." The trend has been to concentrate on population-typical (normative) phenomena, an approach that tends to treat all members of a speech community as if they were the same except for a few rogue outliers who disrupt normal patterns. In contrast, the individual-differences perspective considers variation to be normal—the very standard deviation. Language disorders and atypicalities are thought to be the quantitative extremes of the normal distribution.

Examination of individual variation is not entirely unfamiliar in linguistic research. Sociolinguistic work, particularly within the variationist tradition, has identified heterogeneity within speech communities, questioning the idealized homogeneous assumption of the speech community often adopted, implicitly or explicitly, in linguistic approaches. However, despite the fact that individuals' speech production patterns and their perceptual behaviors may differ along sociolinguistically relevant dimensions, such as age, gender, socioeconomic background, regional dialect exposure, and language ideology (Byrd 1992; Foulkes & Docherty 2006; Labov 1994, 2001), individuals of the same age, gender, social group, dialect, and socioeconomic status may nonetheless differ in linguistic patterns. For example, individual variability has been reported for vowel articulation (Johnson et al. 1993), vowel formant frequencies (Peterson & Barney 1952), voice onset time (VOT; Allen et al. 2003, Newman 1997), consonant articulation (Mielke et al. 2016), coarticulation (Zellou 2017), frication centroid frequencies and skewness (Newman 1997, Newman et al. 2001), as well as sociolinguistically salient variation (Labov 1979). Such individual variability in speech production may come from differences in vocal tract physiology, particularly in relation to the nature of sexual dimorphism of the vocal tract (Vorperian et al. 2011), vocal tract size and shape (Peterson & Barney 1952), idiosyncratic articulatory habits (Klatt 1986), and/or behavioral/etiological factors (Ohala 1994, Sachs et al. 1973). Yet, many variations cannot be attributed to such phonetic factors. As Labov (1979) points out, individual differences in linguistic capacity may also lead to variations in language and speech that are not attributable to speech and/or language disorder. This review focuses on individual variability in phonological processing.

The population-typical and the individual-differences approaches often arrive at different answers because they ask different questions. The two perspectives also differ methodologically. Most population-typical research is experimental in that subjects are randomly assigned to situations wherein the researchers have manipulated something such as the experimental condition, treatment materials, or tasks. The dependent variable is the average effect of the manipulation on outcome measures, such as the influence of speaking rate on coarticulation or the effect of lexical competition on spoken-word recognition. Such experiments ask whether a given manipulation can have an effect on the aggregate responses within a speech community. Meanwhile, rather than creating differences between experimental and control groups through manipulations, the individual-differences approach often focuses on naturally occurring heterogeneity between individuals. Within individual-differences studies, two types of approaches are taken. The first is to simply describe the variation for a particular behavior across participants who represent individuals in a single speech community. The second is to consider, a priori, the factors that make individuals different. For example, it has been hypothesized that individuals vary in executive function abilities, such as selective attention, working-memory capacity, and inhibition skills. An individual-differences approach would investigate whether naturally occurring variation in executive function abilities is associated with individual differences in phonological processing (Kapnoula 2016; Kong & Edwards 2016; Lev-Ari & Peperkamp 2013, 2014). This approach to individual-differences research is correlational in the sense that it investigates factors that have an effect in the world outside the laboratory. The population-typical and individual-differences perspectives are different, and we contend that a proper understanding of individual differences in phonological processing, and of the origins of phonetic and phonological variation in general, depends on understanding these differences. The perspectives are also complementary in that a full understanding of linguistic behavior requires integration across all levels of analysis.

This review focuses on studies of the behavior of individuals and what it can tell us about the nature of phonological representations and processes as well as language variation and change. In Section 2, we provide an overview of various forms of individual variability. While explanations for the prevalence of individual variation in phonological processing remain a largely unsolved puzzle, this prevalence raises many questions. For example, what can individual variation tell us about the representations and mechanisms active during phonological processing? In addition, is individual variation systematic? If so, what accounts for the systematicity? Section 3 explores potential causes of individual variation in phonological processing. Finally, Section 4 discusses recent proposals concerning the idea that language variation, and sound change actuation in particular, might come about as a result of individual differences in how phonological information is stored and processed. Ultimately, since linguistic communities are made up of individuals, the questions raised by the study of individual variation are relevant to those who work in all aspects of language.

2. HOW DO INDIVIDUALS VARY?

The realization of a phonetic category can vary extensively across languages, contexts, and speakers. Consider the stop voicing contrast in English, which is acoustically multidimensional. Voiced and voiceless stops in English differ not only in VOT but also in neighboring vowel duration, fundamental frequency, and formant trajectories (Lisker 1986). Not every individual uses each of these properties to the same extent, however. Various studies document individual variation in the production of VOT (Allen et al. 2003, Newman 1997). Speakers also differ in how they use these various cues to encode voicing contrasts (Shultz et al. 2012). Differences extend to the perceptual domain as well. For example, while VOT is generally considered the primary cue for English initial stop voicing, listeners vary in how much they use f0 cues to discern this contrast (Kong & Edwards 2016, Shultz et al. 2012), and similar variation in perceptual cue weighting has been observed for stop laryngeal contrasts in Korean (Schertz et al. 2015), the /i/–/ɪ/ contrast in English (Escudero & Boersma 2004), and the singleton–geminate contrast in Japanese (Idemaru et al. 2012). Moreover, individual variability in perceptual cue weights appears to be stable over repeated testing across time (Schertz et al. 2015) and resistant to perturbation through short-term manipulation of speech input (Idemaru et al. 2012). Beyond phonetic categorization, individuals also vary in their perceptual acuity, particularly in discriminating the /s/–/ʃ/ distinction (Perkell et al. 2004b) and vowel contrasts (Perkell et al. 2004a). However, individual variability in production and perceptual cue weighting is not entirely unconstrained; Chodroff & Wilson

(2017) have found that mean VOTs of bilabials and velars are highly correlated across speakers, crosslinguistically. They argued that such constraints on individual variability might exist to allow for listeners to adapt across speakers within a speech community, even if listeners vary in their ability to adapt to speaker-specific speech patterns (Cangemi et al. 2015).

Individuals can also vary in their perceptual orientation to acoustic details during phoneme perception. The classic finding of categorical perception, wherein listeners display nonlinear response patterns to categorizing sounds that vary continuously across an acoustic dimension (e.g., Lisker & Abramson 1964), has had a formative impact on theories of sound category representation. This finding has shaped views of phonological processing as well: If listeners treat gradient variations of a sound category as perceptually equivalent, listeners should map sounds onto invariant category representations during speech perception and discard irrelevant phonetic details (Shankweiler et al. 1977). However, recent studies have found that listeners vary in how categorical their perceptual behaviors can be: Some individuals seem to engage in more gradient phonological processing than others (Kapnoula 2016). For example, Kong & Edwards (2016) found that, for the initial stop voicing distinction in English, most speakers displayed somewhat gradient perception. Others displayed either canonical categorical perception or very gradient categorization responses. Moreover, listeners who had a gradient response pattern in a visual analog scaling task also exhibited more sensitivity to the f0 cue in an anticipatory eye-movement task, suggesting a relationship between categorization gradience and reliance on secondary cues. While earlier studies found that listeners perceive speech sounds with some degree of gradience and that this sensitivity to within-category differences is maintained all the way to the level of lexical activation (Toscano et al. 2010), the discovery of individual variability in categorization gradience raises serious questions about the universality of categorical perception and has implications for understanding individual variability in phonological acquisition.

The production and processing of coarticulated speech, the coproduction or gestural overlap of sounds, are another source of variability within and across speakers. For example, vowels are usually somewhat nasalized when produced adjacent to a nasal consonant due to anticipatory, or perseverative, velum lowering, which influences the spectral properties of the neighboring vowel. Listeners are able to consider the coarticulatory effects in deciding whether the nasality present on a vowel is best attributed to the presence of a nasal consonant (i.e., perceptual compensation for coarticulation) or whether it is intended as an inherent property of the vowel (Ohala 1993). A great deal of individual variability in the perception of nasalization in words with VNC (vowel–nasal–oral obstruent) sequences has been reported, however. Beddor (2009), for example, observed distinct perceptual strategies across listeners for the use of anticipatory nasal coarticulatory cues. For some individuals, the presence of nasalization on a vowel was taken as predictive of a nasal consonant, but the evidence was reconsidered when no nasal consonant was produced. For other listeners, the presence of vowel nasalization alone was taken to indicate that a following nasal consonant was present, even if the consonant never materialized in the subsequent signal. Beddor (2009) suggested that the variability might stem from differences in perceptual grammar across individuals. Repp (1981), in discussing individual variability in perceptual discrimination of English sibilants in different vocalic contexts, hypothesized that there are two different strategies for listening to sibilant–vowel sequences. Some listeners are what he referred to as auditory listeners, who segregate the noise portion from the vocalic portion, whereas others are phonetic listeners, who perceive sibilant noise information as more integrated with the vocalic portion. Yu & Lee (2014) extended Repp's findings and showed that individual variation in perceptual compensation for sibilant–vowel coarticulation is more continuous than the original two-listening-mode model (see also Yu 2010).

Lexical information also influences speech processing: Ganong (1980), for example, demonstrated that listeners shift their segmental identification along a VOT dimension to make the percept a real word rather than a nonword (e.g., *kiss* versus *giss*). This effect has been interpreted to be due to "top-down" influence of upper levels of structure on perceptual processing (Myers & Blumstein 2007). Stewart & Ota (2008) found significant individual variation in how the lexical status of a stimulus influences listeners' phoneme identifications; some individuals were less influenced than others by lexical information, and their responses more closely reflected the actual acoustic difference. McMurray et al. (2014) had 74 adolescents with a range of language abilities (including 35 with language impairment) identify several series of nine-step VOT continua spanning two words that differed only in the voicing of the initial stop. Listeners' eye movements and fixations were recorded while they viewed a screen containing pictures of the two words and two unrelated objects. McMurray et al. found that listeners with poorer language skills fixated more strongly on competitors overall, even though language ability is not associated with different auditory sensitivity or phonetic categorization. This finding suggests that individual variability in language ability may be better characterized by individual differences in the ability to suppress competing words (see also McMurray et al. 2010 and discussion in Section 3.3.1, below, regarding the role of executive functions in phonological processing).

3. WHAT IS SYSTEMATIC ABOUT INDIVIDUAL VARIATION IN PHONOLOGICAL PROCESSING?

The fact that individuals vary at so many levels of phonological processing raises important questions regarding the motivations behind such variation. In this section, we offer an overview of the range of mechanisms that have been proposed to account for variation in phonological processing.

3.1. Speaker Background and Experience

A primary source of individual variability is speakers' prior experience (linguistic or otherwise), as evidenced in how foreign-language learners acquire nonnative sounds and sound sequences and how language borrowers incorporate them into their native language. English speakers, for example, display difficulties with nonnative phoneme contrasts, such as Czech retroflex versus palatal fricatives (Trehub 1976), Korean laryngeal contrasts (Francis & Nusbaum 2002), Thai voiced versus voiceless unaspirated stops (Lisker & Abramson 1970), Hindi dental versus retroflex stops, and Salish velar versus uvular ejectives (Werker & Tees 1994). The production of nonnative sounds presents difficulties as well. For example, in addition to having great difficulty in perceiving the English /r/–/l/ contrast, Japanese speakers have difficulty in producing such a contrast (Bradlow et al. 1997). Individuals who have longer experience and exposure to their L2, though, display more accurate nonnative phoneme perception (Flege et al. 1997).

As in production, experiential factors guide speech perception. Lev-Ari & Peperkamp (2016) observed that individuals who live in communities where there is a lower proportion of native speakers of a foreign language that has a trill phoneme (e.g., Spanish) are less likely to misperceive a foreign tap as a trill. In other words, experience with native speakers of a particular foreign language influences listeners' expectations about which nonnative sounds are present in speech from an unknown language. Furthermore, Lev-Ari (2018) found that people with larger social networks are better at vowel perception in noise, suggesting that exposure to more speakers, each with their own idiosyncratic and variable speech patterns, facilitates phonological processing performance in challenging listening conditions. Crucially, this association was not due to differences in the amount of input or to cognitive differences between people with different social network sizes.

Furthermore, effects of prior experience on speech perception and production are not limited to linguistic experience per se. Recent behavioral and neurophysiological studies have demonstrated superior processing of lexical tones in musicians (Chandrasekaran et al. 2009, Wong et al. 2007, Wong & Perrachione 2007). Speakers of a tone language, such as Mandarin, show larger mismatch negativity (MMN) responses than musicians, suggesting that cortical plasticity to pitch contours varies depending on the types of long-term experience in pitch processing individuals experience. English-speaking musicians, as well as native speakers of tone languages, are nonetheless more sensitive to pitch changes, measured in terms of MMN and discrimination judgments, than English-speaking nonmusicians (Chandrasekaran et al. 2009).

Listeners' perceptual responses are also influenced by their knowledge of what sound sequences are possible and impossible in their native language (Davidson 2011, Pitt 1998). Massaro & Cohen (1983), for example, found that when listeners were asked to classify a synthetic /r/–/l/ continuum embedded in a C_i context, where C = {t, p, v, s}, they were most likely to report the ambiguous liquid as [r] when C = /t/ and least likely when C = /v/ or /s/, presumably because *tl-* and *vr-*/*sr-* sequences are phonotactically ill-formed in English. Likewise, wordlikeness judgment tasks are often used to examine individuals' knowledge of phonotactics. In such a task, participants are asked to rate nonwords on the basis of their wordlikeness; specifically, a low rating indicates "impossible; this word could never be a word of English," and a high rating indicates "possible; this word could easily be a word of English." Speakers may estimate the overall phonetic similarity of nonce words to known ones, calculating the degree of support from existing lexical items (e.g., phonological neighborhood density; Bailey & Hahn 2001). Nonce words with more lexical support are often rated as more wordlike than words with less lexical support. Speakers may also evaluate novel words in terms of substrings in the course of word segmentation and lexical access, calculating the probability of each combination of phonemes and features in the lexicon (e.g., phonotactic probability; Vitevitch & Luce 2016). In this case, nonce words containing sequences with higher overall phonotactic probability are generally rated as more wordlike than those with lower phonotactic probability. Since knowledge of lexical support and phonotactic probability depends on the nature of the individual's lexicon, individual differences in lexicon size may play a role in language tasks that require participants to access and manipulate real words. Subjects who happen to know rarer and more unusual English words can perhaps use that knowledge in evaluating nonword stimuli. Lewellen et al. (1993) studied lexical knowledge, as measured by a word familiarity test, and found that subjects who differ in this measure perform differently on tasks involving real-word stimuli. Large et al. (1998) also examined individual differences in wordlikeness judgments and found that participants with greater lexical knowledge treat nonword stimuli more analytically; that is, they assign relatively higher wordlikeness ratings or accept some of the low-probability items. This finding suggests that participants with greater lexical knowledge are able to discriminate differences between nonword stimuli, while participants with less lexical knowledge are less able to make such fine-grained judgments (see also Frisch et al. 2001).

The fact that individuals' experiences affect speech processing raises questions about the stability of individual variation. In the short term, individuals display great susceptibility to the influence of idiosyncratic phonetic aspects of voices both in their perceptual behaviors (i.e., perceptual learning; Kraljic & Samuel 2006, Norris et al. 2003) and in their production (i.e., phonetic imitation; Babel 2012, Zellou et al. 2016). Meanwhile, over longer timescales, individuals appear to have more stable production repertoires (Sonderegger et al. 2017, Yu et al. 2015). However, systematic social and experiential factors influence speakers' speech patterns over time (e.g., Nycz 2011). The tendency for individuals' speech patterns to vary systematically by age is well established: Adolescents tend to have higher rates of nonstandard variants than adults (Labov et al. 2006). However, recent studies have begun to examine individual differences in the nature of this instability over the life span. For instance, Wagner (2012) followed a group of female Philadelphians during the later years of high school and post graduation. Individuals who displayed stronger social ties to the local community, which was associated with informal, interactional styles, were less likely to exhibit reduction of nonstandard phonological variant usage. Meanwhile, those who enrolled in national colleges exhibited greater age grading, adopting higher rates of standard variant usage. Similar patterns of individual variation due to enrollment in a local, national, or Ivy League university was observed by Prichard & Tamminga (2012), suggesting that patterns of higher-education affiliation influence individuals' speech patterns.

3.2. Perception–Production Link

Differences in phonological processing raise questions about the nature of the link between speech production and perception. Gestural theories view speech perception as guided by the recovery of gestures in the underlying signal. Such gestural knowledge might stem from an "innate vocal tract synthesizer" (i.e., Motor Theory; Liberman & Mattingly 1985) or some presumed universal function of perceiving in the world (i.e., Direct Realism; Fowler 2006). Due to the universal nature of the presumed gestural knowledge, which ostensibly explains why perceptual compensation is not unique to humans (Viswanathana et al. 2010), such theories generally provide few insights into the nature of individual variability in speech processing. To the extent that variation is acknowledged, it is attributed to differences in listening modes (e.g., Fowler & Brown 2000). If the universalist assumption is relaxed and an individual's knowledge of (co)articulation derives from their (co)articulatory habits, gestural theories might predict that an individual's perceptual response to coarticulated speech would mirror their own (co)articulation habits, as the objects referenced in perception and production are one and the same (i.e., phonetic gestures of the vocal tract). Along this line, Pierrehumbert (2002) posits a perception–production loop where stored perceptual experiences are weighted by social and attentional factors and such encoded exemplars are drawn upon to generate production targets. Various studies have found empirical evidence supporting a more direct connection between perception and production. Beddor & Krakow (1999), for example, found that Thai listeners compensated for nasal coarticulation less (i.e., were more accurate in detecting vowel nasality in contexts where perceptual compensation is expected to reduce sensitivity to the presence of vocalic nasalization) than English listeners. They explained this difference by appealing to the fact that nasal coarticulation in Thai is less extensive than in English. Thai listeners who experience smaller degrees of contextual nasalization on a regular basis might come to expect less nasalization (and, conversely, be more sensitive to an unexpectedly high degree of nasalization) in the appropriate contexts. Zellou (2017) examined the relationship between individuals' production of anticipatory nasal coarticulation on vowels and their patterns of perceptual compensation. In support of a more direct perception–production link, she found that speakers who produced less nasal coarticulation were more accurate at discriminating nasalized vowels in nasal consonant contexts and that speakers who produced greater coarticulation were more likely to perceptually compensate.

By contrast, theories of perceptual compensation that advocate for auditory representations (Lotto & Holt 2006) predict no necessary connection between the perception and production of coarticulated speech. This prediction is seemingly borne out in empirical studies that report no direct link between individuals' production and perception of speech. For example, Kataoka (2011) found no significant correlation between Californians' production and perception of /u/-fronting in alveolar contexts. Other studies focusing on long-distance vowel-to-vowel coarticulation found that the magnitude of long-distance vowel-to-vowel coarticulation does not correlate with individuals' ability to discriminate coarticulated vowels in isolated contexts (Grosvald & Corina 2012).

However, since Grosvald & Corvina's (2012) perceptual measures did not specifically test for the listeners' ability to utilize knowledge of coarticulation, their findings remain inconclusive.

Shultz et al. (2012) examined speakers' use of covarying VOT duration and f0 for initial stops in English and also found no correlation between individuals' production and perception. They suggested that the lack of a connection between production and perception could reflect the difference in goals across these modalities. This interpretation can explain some of the conflicting empirical results in the literature, as perceptual tasks can vary in terms of the nature of the decision a listener makes and in terms of how representational memory is being accessed. Tilsen & Cohn (2016), for example, explored individual differences in a syllable-count judgment task and a production task of words that have variable syllable-count intuitions (e.g., *fire*). Speakers who produced longer rime durations were more likely to report multisyllabic judgments for these words. The authors suggested that more "metaphonological" tasks recruit conscious use of representations via overt decisions of judgments. Compensation, similarly, is used when making decisions about the underlying structure of a speaker's utterance. Yet, the nature of linguistic decisions can vary depending on the context and goal. For example, Zellou (2017) found that speakers' responses in a task that required making explicit judgments about nasality in context did not correlate with their production, but she found a significant correlation in a task that requires the discrimination of vocalic nasality in different contexts. This finding suggests that the nature of the perceptual task can influence whether or not listeners recruit their idiosyncratic production repertoires.

The conditions under which a perception–production link emerges remain vague and require further investigation. Under certain circumstances and with certain goals, a production–perception link for individuals has been observed. In other circumstances, perceptual behavior appears to be influenced by community-wide patterns. The search for understanding the conditions and contexts under which a direct production–perception link emerges as an active force in phonological processing remains an important avenue for future studies and can provide more evidence for the nature of the representations and mechanisms active in phonological processing.

3.3. Cognitive Processing Styles

Cognitive processing style refers to psychological dimensions representing preferences and consistencies in an individual's particular manner of cognitive functioning, with respect to acquiring and processing information (Ausburn & Ausburn 1978, Messick 1976, Witkin et al. 1977). Individual differences in cognitive processing styles are evident at all levels of human cognition, including vision (Stoesz & Jakobson 2008), learning (Riding & Rayner 2000), and sentence processing (King & Just 1991). We focus on the link between individual variability in phonological processing and individual differences in various dimensions of cognitive processing style, such as executive functioning skills and autistic-like traits.

3.3.1 Individual differences in executive functions. A commonly invoked area of individual differences in cognitive processing style relates to cross-speaker variability in executive functioning skills. Executive functions are a set of general-purpose control processes that regulate one's thoughts and behaviors (Miyake & Friedman 2012), such as mental set shifting (switching flexibility between tasks or mental sets), information updating and monitoring (constant monitoring and rapid addition/deletion of working-memory contents), and inhibition of prepotent responses (deliberate overriding of dominant or prepotent responses). These components of the executive function system have all been implicated in variation in phonological processing.

Differences in attention-related factors interact with language experience to influence which second-language learners are more or less likely to acquire nonnative contrasts. In particular, domain-general attentional factors (i.e., an ability to direct one's attention in a controlled way) have been implicated in enhancing the acquisition of nonnative phoneme contrasts. For example, Kim & Hazan (2010) found that native English-speaking listeners who displayed better abilities in attentional switching and allocation and frequency acuity tended to show better learning of novel Korean stop contrasts. Attentional factors also influence the processing of native contrasts. Kong & Lee (2017) examined Korean listeners' identifications of the Korean three-way laryngeal stop contrast in conditions, with and without distraction as a way to modulate attention. They found that, while listeners' overall reliance on VOT was reduced under distraction, listeners with heavier perceptual reliance on VOT were more hindered by distraction. Similarly, Gordon et al. (1993) showed that listeners in a high-cognitive-load condition showed a decreased reliance on VOT. However, unlike Gordon et al. (1993), who found a corresponding increase in the relative weight given to the onset f0 cue, Kong & Lee (2017) did not find differences in f0 reliance under distraction. Both studies suggest that the use of VOT as a cue to voicing demands greater attentional commitment than the use of onset f0.

A link between increased working-memory capacity and increased inhibition of competing information has also been observed (Lavie et al. 2004). Variation in these abilities relates to spoken word comprehension: When competing speech was present, individuals with low working-memory capacity were less likely to identify their own names being spoken (Conway et al. 2001). Inhibition is another mechanism that has been argued to play a role in lexical access. In order to produce or understand a word, the word first has to be activated and retrieved. It is well known that the lexicon is highly structured and that activation of lexical items involves coactivation and competition of lexical neighbors (e.g., words that overlap in semantic or phonological content with the target word; Goldinger et al. 1989). An interactive model of lexical access accounts for competition by proposing that when a word is activated, words that have overlapping phonological components are also activated (Dell 1986). Inhibition, the ability to actively inhibit information that might be coactivated with target information presumably prevents coactivated neighbors from being selected during lexical access (Vitevich & Luce 1998). Recent research has examined the effect that inhibitory skills have on lexical competition and access. Lev-Ari & Peperkamp (2013) reported that individual differences in inhibitory skill modulate the effects of second-language learning on speakers' first language: The lower the inhibitory skills of late English–French bilinguals (L1 being English), the more French-like is their production and perception of voiceless stop VOT in English. This inhibition effect extends to language-internal factors as well. Lev-Ari & Peperkamp (2014) reported that differences in inhibitory skill lead to individual variations in phonological representations. In comparing the perception and production of words containing a voiced stop that either had a voicing neighbor (the target) or had no voicing neighbor (control), they found that the lower the speakers' inhibitory skills were, the easier it was for them to recognize words with a voiceless neighbor when these words had a shorter, intermediate, prevoicing. They reasoned that this effect was due to the greater activation of the voiceless neighbor since inhibitory skill did not predict recognition time for control words, which do not have a voiceless neighbor. It is noteworthy that these authors did not find an effect of individual differences in inhibition on production of prevoicing, suggesting that inhibition does not play the same role in production. While Scarborough (2012) did not examine the cognitive characteristics of these speakers, she reported individual variation in neighborhood-conditioned phonetic patterns of produced nonwords (i.e., those with either many or few phonologically similar real-word neighbors) where half of the participants exhibited patterns consistent with phonetic enhancement of nonwords with many lexical competitors, while the other participants consistently showed the reverse pattern. These findings highlight the need for further investigations in order to ascertain the mechanism(s) behind the variable effects of lexical neighborhood and, by extension, individual inhibitory skills on spoken-word recognition and production.

3.3.2. Autistic-like traits. An intriguing line of recent research examines the association between levels of "autistic traits" and speech processing abilities in otherwise non-clinically-disordered adults. While the clinical diagnosis of autism spectrum disorder (ASD) involves difficulties in social development and communication alongside the presence of unusually strong repetitive behavior or "obsessive" interests (APA 2013, WHO 1994), cognitive theories of ASD have long argued that individuals with autism have different cognitive processing styles than neurotypicals. Individuals with ASD might show "detail-focused processing in which features are perceived and retained at the expense of global configuration and contextualized meaning" (Happé 1999, p. 217), while individuals with typical central coherence may parse incoming information for higher-level meaning, often at the expense of memory for detail (Happé & Frith 2006). Individuals with ASD also tend to have superior abilities with respect to the processing of low-level perceptual information but exhibit difficulties with the integration of higher-order information (Bonnel et al. 2003, Mottron et al. 2006). Examination of how these different general processing styles interact with perceptual patterns can shed light on the mechanistic underpinnings of language processing.

Motivated in part by recent studies showing that autistic traits, or the broader autism phenotypes, are not restricted to individuals with clinical diagnoses of autism (Constantino & Todd 2003, Lundström et al. 2012), some scholars have explored autistic-like traits for indexing differences in phonological processing. Such studies have been performed with instruments such as the autism-spectrum quotient (AQ; Baron-Cohen et al. 2001), a short, self-administered scale for identifying the degree to which any individual adult of normal IQ may have traits associated with the autism spectrum condition, of which classic autism and Asperger syndrome are the clearest subgroups. The AQ is not a diagnostic measure, although it has been clinically tested as a screening tool; traits as assessed by the AQ show high heritability and are stable cross-culturally. The test consists of 50 items, made up of 10 questions assessing five subscales: social skills, communication, attention to detail, attention switching, and imagination. Stewart & Ota (2008), for example, found that total AQ taken from within the neurotypical population is negatively correlated with the extent of identification shift associated with the Ganong effect (i.e., the bias in categorization in the direction of a known word). In particular, the identification shift associated with the bias toward a known word correlated significantly with the attention switching and imagination components of the AQ. These findings suggest that individuals with certain autistic-like traits are less likely to be affected by lexical knowledge in their phonetic perception, possibly due to their heightened sensitivity to actual acoustic differences. Stewart & Ota (2008) ruled out higher auditory sensitivity, retardation of lexical access, and verbal intelligence as potential alternative explanations for the observed correlation. Specifically, they found no correlation between AQ and performance in a VOT discrimination task, accuracy and speed in a lexical decision task, or individual verbal IQ. Similar findings of a link between AQ and phonological processing have been reported for native Mandarin Chinese speakers from Taiwan (Huang 2007). Yu (2010) found that the magnitude of perceptual compensation for the vocalic effect on sibilant perception is modulated by the listeners' sex and autistic-like traits: English-speaking females with a low AQ are less likely to perceptually compensate for coarticulation (see also Turnbull 2015). Autistic-like traits have also been associated with the processing of higher-order phonological information. Jun & Bishop (2015) investigated effects of prosodic boundary on relative clause attachment in sentences such as "Someone shot the servant of the actress who was on the balcony," where the relative clause can modify either the first noun phrase (NP1) *the servant* (high attachment) or NP2 *the actress* (low attachment). Specifically, these authors employed a prosodic adaptation of the reading-based structural priming task where listeners were presented with auditory sentence primes, such as "The chef couldn't find the lid of the pan that was clean," that were given one of three prosodic profiles: one with a control condition containing no large prosodic boundary or another with conditions containing either early or late boundaries. They found that individuals with poorer communicative and pragmatic language skills, as measured by the communication subscale of the AQ, were less affected by prosodic differences in parsing the utterances (see also Bishop 2012, 2013; Bishop et al. 2015 for other investigations in individual differences in prosodic processing using the AQ).

3.3.3. Declarative and procedural memories. Individual variability in declarative memory (memory for facts; Eichenbaum 2001) and procedural memory (memory for skills and sequences; Eichenbaum & Cohen 2001) have often been linked to individual variability in the learning of (morpho)phonological patterns. One of the most-studied phenomena from this perspective is the formation of regular and irregular past-tense forms in English. Many studies, most notably those by Ullman and his colleagues, have argued that knowledge about irregular morphological forms, both inflection (*drive–drove*) and derivation (*opaque–opacity*), and to a certain extent, even regular morphology (*work–worked*), are tied to declarative memory, as evidenced by frequency, imageability, and phonological neighborhood effects (Ullman 1999). These effects are reliably observed for irregulars, suggesting their obligatory storage in declarative memory, but inconsistently observed in regular forms. Rule-governed grammatical knowledge is often assumed to be under the purview of procedural memory. Ettlinger et al. (2012), for example, examined the learning of morphophonological patterns of word formation using an artificial grammar learning paradigm. In particular, participants were asked to learn rules of vowel harmony that were morphologically conditioned. Crucially, some rules were opaque (i.e., the conditioning environment of the harmony was not evident in the surface form), while others were transparent (i.e., the context that conditions vowel harmony was readily identifiable in the output). The authors found significant individual variation in learning success, which was correlated with the variability with participants' performance on standardized measures of procedural and declarative memories. Specifically, measures of procedural memory correlated with success at learning simple sensorimotor-based phonological patterns, while measures of declarative memory and, to a lesser extent, procedural memory correlated with the acquisition of the opaque pattern. Recently, Wong et al. (2013) linked procedurally based grammar learning to variation in the dopamine receptor D_2 gene. These authors emphasized the preliminary nature of this finding; however, if this finding is replicable and confirmed, it is likely to offer great insights into the neurogenetic basis of normal variations in linguistic grammar learning and its link to domain-general functions.

3.3.4. Neurophysiological factors. Various neurophysiological studies have found individual differences in sensitivity to phonetic contrasts. Díaz et al. (2008), for example, found that early, proficient Spanish–Catalan bilinguals who differed in their mastery of the Catalan (L2) phonetic contrast /e/–/ɛ/ showed corresponding differences in discrimination accuracy of Spanish vowels (/o/–/e/), reflected electrically as an MMN. That is, good perceivers of the Catalan /e/–/ɛ/ contrast showed larger MMN responses to both native (/o/–/e/) and nonnative (/o/–/ö/) phonetic contrasts than poor perceivers. Of particular interest is the finding by Díaz et al. that the observed individual variability did not stem from variation in the general psychoacoustic abilities of the perceivers but rather was linked to speech-specific abilities. The two groups differed in the way their perception system was able to extract relevant features of speech sounds, as evidenced by the between-group difference in the amplitude of the MMN that was present only at frontal electrodes but absent at supratemporal ones. The front generator is associated with the triggering of involuntary attention, while the temporal generator is associated with sensory processing and the comparison of sensory information with memory representations. Assuming that the capacity to behaviorally discriminate between sounds depends on two stages (i.e., the automatic generation of neural signal indicating stimulus change followed by the process to "read" the neural signal and to create new perceptual categories; Näätänen 2001, Tremblay et al. 1998), Díaz et al. (2008) interpreted this finding to mean that, while both groups were equally able to represent the phonetic auditory sensory information and to integrate this information into memory representations (i.e., processing at Stage 2), they may differ in the strength and sensitivity of Stage 1 processing such that the activation of the neural code necessary for the processing at the temporal areas might be hampered.

Further evidence for individual differences in perceptual encoding comes from studies that target the gradiency in neurophysiological responses to acoustic cues. For instance, Toscano et al. (2010) focused on N1, an early cortical auditory evoked potential elicited around 100 ms post stimulus onset, and observed that listeners encoded acoustic cues linearly prior to categorization. That is, there was a one-to-one correspondence with N1 amplitude and VOT values (from voiced to voiceless) independent of phonological categories. Using stimuli varying in both VOT and f0, Kapnoula (2016) found not only that N1 was linearly related to VOT but also that it was modulated by f0. Moreover, the effects of VOT on N1 was more robust for listeners who exhibited gradient categorization responses, suggesting that the differences in categorization gradiency might be related to preperceptual auditory processing. In particular, Kapnoula hypothesized that precise perceptual encoding of acoustic cues allows some listeners to display more gradient sensitivity when categorizing speech sounds. Neural evidence for the nature of the early perceptual processing, as reflected by N1 has been mixed, however. Bidelman et al. (2013), for example, used a vowel continuum with varying steps of first formant frequencies and found that N1 does not necessarily encode acoustic information linearly, but was modulated by listeners' perceptual responses, suggesting that the categorization process may have already emerged around the time frame of N1. Moreover, Bidelman et al. (2013) collected both cortical N1 and brain stem responses to a vowel continuum, and did not find significant correlations between N1 and brain stem frequency-following responses, a scalp-recorded component of the auditory brain stem response that reflects ensemble brain stem phase-locked activity to the eliciting stimulus with millisecond precision (Chandrasekaran & Kraus 2010, Skoe & Kraus 2010). In particular, unlike cortical responses, the brain stem response displays a high test–retest reliability at the individual level (Song et al. 2011). Moreover, individual differences in brain stem responses have been found to predict speech perception in adverse condition (i.e., speech-in-noise; Hornickel et al. 2009) and L2 tone learning (Chandrasekaran et al. 2009).

Individual variability may also stem from differences in the regulation of neurochemistry across individuals. Motivated by the association of striatal function and phonological processing, as evidenced in the linguistic performance of patients with Parkinson disease (Abdullaev & Melnichuk 1997), Tettamanti et al. (2005) measured modulations of the dopaminergic system using [^{11}C]raclopride and positron emission tomography while Italian-speaking participants judged the legality of pseudowords that were made to either conform with or violate the phonotactics of Italian. Crucially, participants in the study by Tettamanti et al. (2005) were drawn from a healthy nonpathological population (eight healthy, right-handed, male university students, ranging from 22 to 29 years old). Nonetheless, the authors found significant correlations between performance in a pseudoword judgment task and dopaminergic input to the left dorsal basal ganglia. In particular, better individual performances correlated with <u>less</u> dopamine release in the left dorsal caudate nucleus, while faster response times correlated negatively with dopamine release in the left dorsal putamen.

4. INDIVIDUAL DIFFERENCES AND SOUND CHANGE

In this review, we have considered how studies of the individual can hone and refine our understanding of how phonological processing works. A more complete understanding of individual differences can shed light on other issues in linguistics as well. In particular, not only do the cognitive, experiential, and social underpinnings of such individual differences inform the selection and construction of psychologically real grammatical models, they also have the potential to inform our understanding of language variation and change. For example, recent research has drawn on interspeaker variation to tackle the issue of language variation and change (Baker et al. 2011, Beddor 2009, Coetzee et al. 2018, Garrett & Johnson 2013, Yu 2013). Such research hypothesizes that understanding the nature and source(s) of individual differences may help us understand the emergence of new variants in language and speech. This line of investigation may help identify the characteristics of linguistic innovators and early adopters of change (Milroy & Milroy 1985). Certain unresolved issues in the study of individual differences have analogs in the field of sound change. For example, while it is clear that variation across individuals within a speech community is ubiquitous and that language is always changing, we do not yet completely understand how or why language changes (Weinreich et al. 1968), just as we are not sure how or why individuals vary. Because of these parallels, the study of sound change is often illuminated by taking a microview of sound-change origins. A dominant question in the sound-change literature concerns how a sound change starts (i.e., the actuation problem). Ohala (1981) argued that the individual listener is the source of sound change, positing that a listener can reanalyze the underlying structure of speakers' intended utterances due to factors that cause the speech signal to be ambiguous. For example, failure to fully compensate for the effects of nasal coarticulation might lead the listener to hear a vowel in a nasal context as nasalized (Beddor & Krakow 1999). Such an event can be a precursor to an individual arriving at a different underlying interpretation for an utterance than the one the speaker intended, for instance, phonologization of vowel nasality. Individual variation might provide answers to the question of when such a sound change is likely to occur. Some authors have argued specifically that listeners who compensate less for coarticulation could be more likely to initiate sound change (Yu 2010, Yu & Lee 2014). Listeners who consistently fail to compensate for coarticulatory context are more likely to hear a target sound as acoustically irregular. The type of natural variation in perception across speakers observed in the range of studies predicts a greater likelihood of events where innovative interpretations of the speech signal, an ostensible precursor to phonetic reanalysis, can occur. Consistent perceptual differences in reconstructed norms (i.e., so-called perceptual errors) can accumulate and lead to a systematically different mental representation for a sound in a given context for an individual.

Furthermore, phonetic innovation is not necessarily unidirectional. For example, a study of sound change in Philadelphia observed over real time that speakers moved in both directions of change, producing both more nasal coarticulation and less nasal coarticulation at different periods in time (Zellou & Tamminga 2014), highlighting the fluidity of change composed of communities of individuals. That is, although individual variation in perceptual and articulatory patterns for the "same" sound is pervasive, under most circumstances, individual variability does not always lead to permanent, community-wide sound change. In other words, variation may also subserve stability within a community. A random sampling of people from a speech community like that observed in most of the studies reviewed here naturally contains a wide range of cross-speaker heterogeneity, which suggests that the community mean often remains stable (Stevens & Harrington 2014). Thus, individual variations in phonological processing and production are the seeds for, but do not inevitably lead to, future sound changes. Community-level sound change actuation and propagation might come about as a result of interactions between individuals with different perceptual and/or articulatory targets for the "same" sound category (Yu 2013, 2016) or different tendencies to attach social meaning to linguistic differences (Garrett & Johnson 2013). To the extent that individual differences in phonological processing lead to variation in production, such articulatory differences must also be perceptible, as perceptibility is a necessary precursor to representational change: Two people who have greater differences in production and/or perception patterns are more likely to perceive one another's variation and might therefore be more likely to interpret differences as linguistically or socially meaningful. Yet, the ability to perceive such a difference itself is further modulated by individual differences in sociolinguistic monitor, a cognitive mechanism hypothesized to govern frequency-linked perceptual awareness (Labov et al. 2011, Levon & Fox 2014). The people who innovate a new variant, or become its early adopters, must also be situated in a crucial nexus of sociolinguistic influence to effect change in others within the community. Because of the necessity for all the many contingencies to be aligned for sound change to propagate at the community level, population-wide changes are predicted to be rare (Baker et al. 2011). Indeed, variation can result in gradual drift across speakers that might randomly build up in a group of influential speakers, leading to community-wide change (see, e.g., Labov 2001 for the case of Celeste S. and Baker et al. 2011 for coarticulation). Variation in phonetic implementation might also lead to change by becoming arbitrarily associated with some social or linguistic meaning, leading to diffusion within a community (Baker et al. 2011, Eckert 1989). Thus, identifying the underlying sources of individual variability might help explain why sound change happens at all and, conversely, why sound change is so rarely actuated even though the phonetic preconditions are always present in speech.

An open question concerns what kinds of individuals are likely to lead and/or propagate sound change. We have reviewed studies where cognitive processes such as working-memory capacity, selective attention and inhibition, and the manifestation of autistic-like traits in neurotypicals predict how individuals process a given speech pattern. Investigating the factors that make individuals more likely to innovate a sound change or to propagate a sound change in progress can provide much-needed insights into this problem. For example, cognitive factors reviewed above could indicate which individuals are most likely to be initiators or propagators of change (Yu 2013). It has also been proposed that individuals who are highly socially connected or influential and who produce particularly innovative phonological variants are those who can spread change rapidly (Baker et al. 2011, Labov 2001).

5. CONCLUSION

Understanding the nature of and mechanisms underlying individual variation in phonological processing can provide rich information about the fundamental nature of language representations and processes. Individual variation highlights the fact that the shared linguistic system is more complex and adaptable than group-level means can reveal. The cognitive and experiential sources of individual variation also provide a window into the fundamental mechanisms involved, and their interactions, during speech processing. The study of individual differences also allows us to take a microview of variation to understand how sound change is actuated and propagated. We hope that framing the study of individual variation in these terms will catalyze more research to address these issues.

Many open questions remain. For example, how does the size of the community influence the nature of observed individual differences? In other words, how does individual variation differ between small or endangered speech communities and larger populations? Questions about interactions between individuals are understudied as well. For example, how do different individuals differ in their interactions? What role do individual differences in interactional style have in explaining sound change? Taking into account the role of individual differences not only affords us the opportunity to reach a better understanding of the variability observed within typical monolingual populations but also may, in the long run, help us better address the challenges that arise in the case of multilingualism, as well as in various hearing and language-related disorders and in other atypical populations (cf. McMurray et al. 2010).

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

We thank our editor, Anne Cutler, for her valuable comments and suggestions on this review. Any errors are of course our own.

LITERATURE CITED

Abdullaev YG, Melnichuk KV. 1997. Cognitive operations in the human caudate nucleus. *Neurosci. Lett.* 234:151–55

Allen JS, Miller JL, DeSteno D. 2003. Individual talker differences in voice-onset-time. *J. Acoust. Soc. Am.* 113:544–52

APA (Am. Psychiatr. Assoc.). 2013. *Diagnostic and Statistical Manual of Mental Disorders*. Washington, DC: APA. 5th ed.

Ausburn LJ, Ausburn FB. 1978. Cognitive styles: some information and implications for instructional design. *Educ. Commun. Technol.* 26:337–54

Babel M. 2012. Evidence for phonetic and social selectivity in spontaneous phonetic imitation. *J. Phon.* 40:177–89

Bailey TM, Hahn U. 2001. Determinants of wordlikeness: phonotactics or lexical neighborhoods? *J. Mem. Lang.* 44:568–91

Baker A, Archangeli D, Mielke J. 2011. Variability in American English s-retraction suggests a solution to the actuation problem. *Lang. Var. Change* 23:347–74

Baron-Cohen S, Wheelwright S, Skinner R, Martin J, Clubley E. 2001. The autism-spectrum quotient (AQ): evidence from Asperger syndrome/high-functioning autism, males, females, scientists and mathematicians. *J. Autism Dev. Disord.* 31:5–17

Beddor P, Krakow RA. 1999. Perception of coarticulatory nasalization by speakers of English and Thai: evidence for partial compensation. *J. Acoust. Soc. Am.* 106:2868–87

Beddor PS. 2009. A coarticulatory path to sound change. *Language* 85:785–832

Bidelman GM, Moreno S, Alain C. 2013. Tracing the emergence of categorical speech perception in the human auditory system. *NeuroImage* 79:201–12

Bishop J. 2012. Focus, prosody, and individual differences in autistic traits: evidence from cross modal semantic priming. *UCLA Work. Pap. Phon.* 111:1–26

Bishop J. 2013. *Prenuclear accentuation: phonetics, phonology, and information structure*. PhD thesis, Univ. Calif., Los Angel.

Bishop J, Chong A, Jun SA. 2015. Individual differences in prosodic strategies to sentence parsing. In *Proceedings of the 18th International Congress of Phonetic Sciences*. London: Int. Phon. Assoc. 5 pp.

Bonnel A, Mottron L, Peretz I, Trudel M, Gallun E, Bonnel AM. 2003. Enhanced pitch sensitivity in individuals with autism: a signal detection analysis. *J. Cogn. Neurosci.* 15:226–35

Bradlow AR, Pisoni DB, Akahane-Yamada R, Tohkura Y. 1997. Training Japanese listeners to identify English /r/ and /l/. IV. Some effects of perceptual learning on speech production. *J. Acoust. Soc. Am.* 101:2299–310

Byrd D. 1992. Preliminary results on speaker-dependent variation in the TIMIT database. *J. Acoust. Soc. Am.* 92:593–96

Cangemi F, Krüger M, Grice M. 2015. Listener-specific perception of speaker-specific production in intonation. In *Individual Differences in Speech Production and Perception*, ed. S Fuchs, D Pape, C Petrone, P Perrier, pp. 123–45. Bern, Switz.: Peter Lang

Chandrasekaran B, Kraus N. 2010. The scalp-recorded brainstem response to speech: neural origins and plasticity. *Psychophysiology* 47:236–46

Chandrasekaran B, Krishnan A, Gandour JT. 2009. Relative influence of musical and linguistic experience on early cortical processing of pitch contours. *Brain Lang.* 108:1–9
Chodroff E, Wilson C. 2017. Structure in talker-specific phonetic realization: covariation of stop consonant VOT in American English. *J. Phon.* 61:30–47
Coetzee AW, Beddor PS, Shedden K, Styler W, Wissing D. 2018. Plosive voicing in Afrikaans: differential cue weighting and tonogenesis. *J. Phon.* 66:185–216
Constantino JN, Todd RD. 2003. Autistic traits in the general population. *Arch. Gen. Psychiatry* 60:524–30
Conway ARA, Cowan N, Bunting MF. 2001. The cocktail party phenomenon revisited: the importance of working memory capacity. *Psychon. Bull. Rev.* 8:331–35
Davidson L. 2011. Phonetic, phonemic, and phonological factors in cross-language discrimination of phonotactic contrasts. *J. Exp. Psychol. Hum. Percept. Perform.* 37:270–82
Dell GS. 1986. A spreading activation theory of retrieval in sentence production. *Psychol. Rev.* 93:283–321
Díaz B, Baus C, Escera C, Costa A, Sebastián-Gallés N. 2008. Brain potentials to native phoneme discrimination reveal the origin of individual differences in learning the sounds of a second language. *PNAS* 105:16083–88
Eckert P. 1989. The whole woman: sex and gender differences in variation. *Lang. Var. Change* 1:245–67
Eichenbaum H. 2001. The hippocampus and declarative memory: cognitive mechanisms and neural codes. *Behav. Brain Res.* 127:199–207
Eichenbaum H, Cohen NJ. 2001. *From Conditioning to Conscious Recollection: Memory Systems of the Brain*. Oxford, UK: Oxford Univ. Press
Escudero P, Boersma P. 2004. Bridging the gap between L2 speech perception research and phonological theory. *Stud. Second Lang. Acquis.* 26:551–85
Ettlinger M, Bradlow AR, Wong PCM. 2012. Variability in learning of complex morphophonology. *Appl. Psycholinguist.* 35:1–25
Flege JE, Bohn OS, Jang S. 1997. Effects of experience on non-native speakers' production and perception of English vowels. *J. Phon.* 25:437–70
Foulkes P, Docherty G. 2006. The social life of phonetics and phonology. *J. Phon.* 34:409–38
Fowler C. 2006. Compensation for coarticulation reflects gesture perception, not spectral contrast. *Percept. Psychophys.* 68:161–77
Fowler CA, Brown JM. 2000. Perceptual parsing of acoustic consequences of velum lowering from information of vowels. *Percept. Psychophys.* 62:21–32
Francis AL, Nusbaum HC. 2002. Selective attention and the acquisition of new phonetic categories. *J. Exp. Psychol. Hum. Percept. Perform.* 28:349–66
Frisch SA, Large NR, Zawaydeh B, Pisoni DB, et al. 2001. Emergent phonotactic generalizations in English and Arabic. *Typol. Stud. Lang.* 45:159–80
Ganong WF. 1980. Phonetic categorization in auditory word perception. *J. Exp. Psychol. Hum. Percept. Perform.* 6:110–25
Garrett A, Johnson K. 2013. Phonetic biases in sound change. See Yu 2013, pp. 51–97
Goldinger SD, Luce PA, Pisoni DB. 1989. Priming lexical neighbors of spoken words: effects of competition and inhibition. *J. Mem. Lang.* 28:501–18
Gordon PC, Eberhardt JL, Rueckl JG. 1993. Attentional modulation of the phonetic significance of acoustic cues. *Cogn. Psychol.* 25:1–42
Grosvald M, Corina D. 2012. Perception of long-distance coarticulation: an event-related potential and behavioral study. *Appl. Psycholinguist.* 33:55–82
Happé F. 1999. Autism: cognitive deficit or cognitive style? *Trends Cogn. Sci.* 3:216–22
Happé F, Frith U. 2006. The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *J. Autism Dev. Disord.* 36:5–25
Hornickel J, Skoe E, Nicol T, Zecker S, Kraus N. 2009. Subcortical differentiation of stop consonants relates to reading and speech-in-noise perception. *PNAS* 106:13022–27
Huang HC. 2007. *Lexical context effects on speech perception in Chinese people with autistic traits*. MA thesis, Univ. Edinburgh, UK
Idemaru K, Holt LL, Seltman H. 2012. Individual differences in cue weights are stable across time: the case of Japanese stop lengths. *J. Acoust. Soc. Am.* 132:3950–64

Johnson K, Ladefoged P, Lindau M. 1993. Individual differences in vowel production. *J. Acoust. Soc. Am.* 94:701–14

Jun SA, Bishop J. 2015. Prominence in relative clause attachment: evidence from prosodic priming. In *Explicit and Implicit Prosody in Sentence Processing: Studies in Honor of Janet Dean Fodor*, ed. L Frazier, E Gibson, pp. 217–40. Stud. Theor. Psycholinguist. 46. Berlin: Springer

Kapnoula EE. 2016. *Individual differences in speech perception: sources, functions, and consequences of phoneme categorization gradiency*. PhD thesis, Univ. Iowa, Iowa City

Kataoka R. 2011. *Phonetic and cognitive bases of sound change*. PhD thesis, Univ. Calif., Berkeley

Kim YH, Hazan V. 2010. Individual variability in the perceptual learning of L2 speech sounds and its cognitive correlates. In *New Sounds 2010: Proceedings of the 6th International Symposium on the Acquisition of Second Language Speech*, pp. 251–56. Poznan, Pol.: Univ. Adama Mickiewicza Poznaniu

King J, Just MA. 1991. Individual differences in syntactic processing: the role of working memory. *J. Mem. Lang.* 30:580–602

Klatt DH. 1986. The problem of variability in speech recognition and in models of speech perception. In *Invariance and Variability in Speech Processes*, ed. JS Perkell, DH Klatt, pp. 300–19. Hillsdale, NJ: Erlbaum

Kong EJ, Edwards J. 2016. Individual differences in categorical perception of speech: cue weighting and executive function. *J. Phon.* 59:40–57

Kong EJ, Lee H. 2017. Attentional modulation and individual differences in explaining the changing role of fundamental frequency in Korean laryngeal stop perception. *Lang. Speech.* In press. **https://doi.org/10.1177/0023830917729840**

Kraljic T, Samuel AG. 2006. Generalization in perceptual learning for speech. *Psychon. Bull. Rev.* 13:262–68

Labov W. 1979. Locating the frontier between social and pscyhological factors in linguistic variation. In *Individual Differences in Language Ability and Language Behavior*, ed. CJ Fillmore, D Kempler, WSY Wang, pp. 327–40. New York: Academic

Labov W. 1994. *Principles of Linguistic Change*, vol. 1: *Internal Factors*. Oxford, UK: Blackwell

Labov W. 2001. *Principles of Linguistic Change*, vol. 2: *Social Factors*. Oxford, UK: Blackwell

Labov W, Ash S, Boberg C. 2006. *Atlas of North American English: Phonetics, Phonology, and Sound Change*. Berlin: Mouton de Gruyter

Labov W, Ash S, Ravindranath M, Weldon T, Nagy N. 2011. Properties of the sociolinguistic monitor. *J. Socioling.* 15:431–63

Large NR, Frisch S, Pisoni DB. 1998. Perception of wordlikeness: effects of segment probability and length on subjective ratings and processing of nonword sound patterns. *Res. Spoken Lang. Proc.* 22:95–125

Lavie N, Hirst A, de Fockert JW, Viding E. 2004. Load theory of selective attention and cognitive control. *J. Exp. Psychol. Gen.* 133:339–54

Lev-Ari S. 2018. The influence of social network size on speech perception. *Q. J. Exp. Physiol.* In press. **http://doi.org/10.1177/1747021817739865**

Lev-Ari S, Peperkamp S. 2013. Low inhibitory skill leads to non-native perception and production in bilinguals' native language. *J. Phon.* 41:320–31

Lev-Ari S, Peperkamp S. 2014. The influence of inhibitory skill on phonological representations in production and perception. *J. Phon.* 47:36–46

Lev-Ari S, Peperkamp S. 2016. How the demographic makeup of our community influences speech perception. *J. Acoust. Soc. Am.* 139:3076–87

Levon E, Fox S. 2014. Salience and the sociolinguistic monitor: a case study of ING and TH fronting in Britain. *J. Engl. Linguist.* 42:185–217

Lewellen MJ, Goldinger SD, Pisoni DB, Greene BG. 1993. Lexical familiarity and processing efficiency: individual differences in naming, lexical decision, and semantic categorization. *J. Exp. Psychol. Gen.* 122:316–30

Liberman A, Mattingly IG. 1985. The motor theory of speech perception revised. *Cognition* 21:1–36

Lisker L. 1986. "voicing" in English: a catalogue of acoustic features signaling /b/ versus /p/ in trochees. *Lang. Speech* 29:3–11

Lisker L, Abramson A. 1964. A cross-language study of voicing in initial stops: acoustical measurements. *Word* 20:384–422

Lisker L, Abramson A. 1970. The voicing dimension: some experiments in comparative phonetics. In *Proceedings of the 6th International Congress of Phonetic Sciences*, pp. 569–73. Prague: Academia

Lotto AJ, Holt LL. 2006. Putting phonetic context effects into context: commentary on Fowler (2005). *Percept. Psychophys.* 68:178–83

Lundström S, Chang Z, Råstam M, Gillberg C, Larsson H, et al. 2012. Autism spectrum disorders and autistic like traits: similar etiology in the extreme end and the normal variation. *Arch. Gen. Psychiatry* 69:46–52

Massaro DW, Cohen MM. 1983. Evaluation and integration of visual and auditory information in speech perception. *J. Exp. Psychol. Hum. Percept. Perform.* 9:753–71

McMurray B, Munson C, Tomblin JB. 2014. Individual differences in language ability are related to variation in word recognition, not speech perception: evidence from eye movements. *J. Speech Lang. Hear. Res.* 57:1344–62

McMurray B, Samelson VM, Lee SH, Tomblin JB. 2010. Individual differences in online spoken word recognition: implications for SLI. *Cogn. Psychol.* 60:1–39

Messick S. 1976. *Individuality in Learning*. San Francisco: Jossey-Bass

Mielke J, Baker A, Archangeli D. 2016. Individual-level contact limits phonological complexity: evidence from bunched and retroflex /ɹ/. *Language* 92:101–40

Milroy J, Milroy L. 1985. Linguistic change, social network and speaker innovation. *J. Linguist.* 21:339–84

Miyake A, Friedman NP. 2012. The nature and organization of individual differences in executive functions: four general conclusions. *Curr. Dir. Psychol. Sci.* 21:8–14

Mottron L, Dawson M, Soulières I, Hubert B, Burack J. 2006. Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *J. Autism Dev. Disord.* 36:27–43

Myers EB, Blumstein SE. 2007. The neural bases of the lexical effect: an fMRI investigation. *Cereb. Cortex* 18:278–88

Näätänen R. 2001. The perception of speech sounds by the human brain as reflected by the mismatch negativity (MMN) and its magnetic equivalent (MMNm). *Psychophysiology* 38:1–21

Newman RS. 1997. *Individual differences and the link between speech perception and speech production*. PhD thesis, SUNY Buffalo

Newman RS, Clouse SA, Burnham JL. 2001. The perceptual consequences of within-talker variability in fricative production. *J. Acoust. Soc. Am.* 109:1181–96

Norris D, McQueen JM, Cutler A. 2003. Perceptual learning in speech. *Cogn. Psychol.* 47:204–38

Nycz J. 2011. *Second dialect acquisition: implications for theories of phonological representation*. PhD thesis, NYU

Ohala JJ. 1981. The listener as a source of sound change. In *Papers from the Parasession on Language and Behavior*, ed. CS Masek, RA Hendrick, MF Miller, pp. 178–203. Chicago: Chicago Linguist. Society

Ohala JJ. 1993. Coarticulation and phonology. *Lang. Speech* 36:155–70

Ohala JJ. 1994. The frequency codes underlies the sound symbolic use of voice pitch. In *Sound Symbolism*, ed. L Hinton, J Nichols, JJ Ohala, pp. 325–47. Cambridge, UK: Cambridge Univ. Press

Perkell JS, Guenther FH, Lane H, Matthies ML, Stockmann E, et al. 2004a. The distinctness of speakers' productions of vowel contrasts is related to their discrimination of the contrasts. *J. Acoust. Soc. Am.* 116:2338–44

Perkell JS, Matthies ML, Tiede M, Lane H, Zandipour M, et al. 2004b. The distinctness of speakers' /s/–/ʃ/ contrast is related to their auditory discrimination and use of an articulatory saturation effect. *J. Speech Lang. Hear. Res.* 47:1259–69

Peterson GE, Barney HL. 1952. Control methods used in a study of the vowels. *J. Acoust. Soc. Am.* 24:175–84

Pierrehumbert J. 2002. Word specific phonetics. In *Laboratory Phonology VII*, ed. C Gussenhoven, N Warner, pp. 101–39. Berlin: Mouton de Gruyter

Pitt M. 1998. Phonological processes and the perception of phonotactically illegal consonant clusters. *Percept. Psychophys.* 60:941–51

Prichard H, Tamminga M. 2012. The impact of higher education on Philadelphia vowels. *Univ. Pa. Work. Pap. Linguist.* 18:11

Repp BH. 1981. Two strategies in fricative discrimination. *Percept. Psychophys.* 30:217–27

Riding RJ, Rayner S. 2000. *International Perspectives on Individual Differences*, vol. 1: *Cognitive Styles*. New York: Ablex

Sachs J, Lieberman P, Erickson D. 1973. Anatomical and cultural determinants of male and female speech. In *Language Attitudes: Current Trends and Prospects*, ed. RW Shuy, RW Fasold, pp. 74–84. Washington, DC: Georgetown Univ. Press

Scarborough R. 2012. Lexical similarity and speech production: neighborhoods for nonwords. *Lingua* 122:164–76

Schertz J, Cho T, Lotto A, Warner N. 2015. Individual differences in phonetic cue use in production and perception of a non-native sound contrast. *J. Phon.* 52:183–204

Shankweiler D, Strange W, Verbrugge R. 1977. Speech and the problem of perceptual constancy. In *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*, ed. R Shaw, J Bransford, pp. 315–45. New York: Erlbaum

Shultz AA, Francis AL, Llanos F. 2012. Differential cue weighting in perception and production of consonant voicing. *J. Acoust. Soc. Am. Express Lett.* 132:95–101

Skoe E, Kraus N. 2010. Auditory brainstem response to complex sounds: a tutorial. *Ear Hear.* 31:302–24

Sonderegger M, Bane M, Graff P. 2017. The medium-term dynamics of accents on reality television. *Language* 93:598–640

Song JH, Nicol T, Kraus N. 2011. Test-retest reliability of the speech-evoked auditory brainstem response. *Clin. Neurophysiol.* 122:346–55

Stevens M, Harrington J. 2014. The individual and the actuation of sound change. *Loquens* 1:e003

Stewart ME, Ota M. 2008. Lexical effects on speech perception in individuals with "autistic" traits. *Cognition* 109:157–62

Stoesz BM, Jakobson LS. 2008. The influence of processing style on face perception. *J. Vis.* 8:1138

Tettamanti M, Moro A, Messa C, Moresco RM, Rizzo G, et al. 2005. Basal ganglia and language: Phonology modulates dopaminergic release. *NeuroReport* 16:397–401

Tilsen S, Cohn A. 2016. Shared representations underlie metaphonological judgments and speech motor control. *Lab. Phonol.* 7:14

Toscano J, McMurray B, Dennhardt J, Luck SJ. 2010. Continuous perception and graded categorization: electrophysiological evidence for a linear relationship between the acoustic signal and perceptual encoding of speech. *Psychol. Sci.* 21:1532–40

Trehub SE. 1976. The discrimination of foreign speech contrasts by adults and infants. *Child Dev.* 47:466–72

Tremblay K, Kraus N, McGee T. 1998. The time course of auditory perceptual learning: neurophysiological changes during speech-sound training. *NeuroReport* 9:3557–60

Turnbull RJ. 2015. *Assessing the listener-oriented account of predictability-based phonetic reduction*. PhD thesis, Ohio State Univ., Columbus

Ullman MT. 1999. Acceptability rating of regular and irregular past-tense forms: evidence for a dual-system model of language from word frequency and phonological neighborhood effects. *Lang. Cogn. Process.* 14:47–67

Viswanathana N, Magnusona JS, Fowler CA. 2010. Compensation for coarticulation: disentangling auditory and gestural theories of perception of coarticulatory effects in speech. *J. Exp. Psychol. Hum. Percept. Perform.* 36:1005–15

Vitevich M, Luce P. 1998. When words compete: levels of processing in perception of spoken words. *Psychol. Sci.* 9:325–29

Vitevitch MS, Luce PA. 2016. Phonological neighborhood effects in spoken word perception and production. *Annu. Rev. Linguist.* 2:75–94

Vorperian HK, Wang S, Schimek EM, Durtschi RB, Kent RD, et al. 2011. Development sexual dimorphism of the oral and pharyngeal portions of the vocal tract: an imaging study. *J. Speech Lang. Hear. Res.* 54:995–1010

Wagner SE. 2012. Real-time evidence for age grad(ing) in late adolescence. *Lang. Var. Change* 24:179–202

Weinreich U, Labov W, Herzog M. 1968. Empirical foundations for a theory of language change. In *Directions for Historical Linguistics*, ed. W Lehmann, Y Malkiel, pp. 95–188. Austin: Univ. Tex. Press

Werker J, Tees RC. 1994. Cross-language speech perception: evidence for perceptual reorganization during the first year of life. *Infant Behav. Dev.* 7:49–63

WHO (World Health Organ.). 1994. *International Classification of Diseases*. Geneva, Switz.: WHO. 10th ed.

Witkin HA, Moore CA, Goodenough DR, Cox PW. 1977. Field-dependent and field-independent cognitive styles and their educational implications. *Rev. Educ. Res.* 47:1–64

Wong PC, Ettlinger M, Zheng J. 2013. Linguistic grammar learning and *DRD2*-TAQ-IA polymorphism. *PLOS ONE* 8:e64983

Wong PC, Perrachione TK, Parrish TB. 2007. Neural characteristics of successful and less successful speech and word learning in adults. *Hum. Brain Mapp.* 28:995–1006

Wong PCM, Perrachione TK. 2007. Learning pitch patterns in lexical identification by native English–speaking adults. *Appl. Psycholinguist.* 28:565–85

Yu ACL. 2010. Perceptual compensation is correlated with individuals' "autistic" traits: implications for models of sound change. *PLOS ONE* 5:e11950

Yu ACL. 2013. Individual differences in socio-cognitive processing and the actuation of sound change. In *Origins of Sound Change: Approaches to Phonologization*, ed. ACL Yu, pp. 201–27. Oxford, UK: Oxford Univ. Press

Yu ACL. 2016. Vowel-dependent variation in Cantonese /s/ from an individual-difference perspective. *J. Acoust. Soc. Am.* 139:1672–90

Yu ACL, Lee H. 2014. The stability of perceptual compensation for coarticulation within and across individuals: a cross-validation study. *J. Acoust. Soc. Am.* 136:382–88

Yu ACL, Abrego-Collier C, Phillips J, Pillion B. 2015. Investigating variation in English vowel-to-vowel coarticulation in a longitudinal phonetic corpus. In *Proceedings of the 18th International Congress of Phonetic Sciences*. London: Int. Phon. Assoc. 5 pp.

Zellou G. 2017. Individual differences in the production of nasal coarticulation and perceptual compensation. *J. Phon.* 61:13–29

Zellou G, Scarborough R, Nielsen K. 2016. Phonetic imitation of coarticulatory vowel nasalization. *J. Acoust. Soc. Am.* 140:3560–75

Zellou G, Tamminga M. 2014. Nasal coarticulation changes over time in Philadelphia English. *J. Phon.* 47:18–35