Part IV

Social and computational dynamics

10

Individual differences in socio-cognitive processing and the actuation of sound change

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10.1 Introduction

What motivates the introduction of new linguistic variants, such as a new sound or a new sound pattern, and how these variants flourish and propagate throughout the speech community? These questions are at the heart of research in phonologization and the origins of sound change. Many theorists drew inspiration from biological evolution and conceptualize the actuation of sound change in terms of a two-step process of variation and selection (Lindblom et al. 1995; Kiparsky 1995; Mufwene 2001; Blevins 2004; Mufwene 2008). New variants propagate across a speech community as a result of a process of selection and rejection by language users who evaluate all variations with respect to their social, articulatory, perceptual, and lexical-systematic dimensions. The sources of variation are many (Ohala 1993b; Lindblom et al. 1995; Mufwene 2008; Beddor 2009). Setting aside the influence of language contact, new variants are commonly assumed to be introduced as the results of the effects of channel biases that are inherent in the modalities of speech communication (e.g. biases in motor planning, speech aerodynamics, gestural dynamics, perceptual parsing; see Garrett and Johnson's chapter in this volume for more discussion) and analytic biases that come from presumed universal computational mechanisms such as Universal Grammar (Wilson 2006; Moreton 2008a). When members of a speech

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community come to share these new perceptual and production targets, sound change obtains. How a speech community, or a community of practice (Eckert 2000), comes to adopt a new norm is a matter of much debate, however. Proponents of exemplar-based models of sound change, for example, argue that sound change may be modeled in terms of drifts of exemplar 'clouds' (e.g. Pierrehumbert 2001a; Wedel 2006, 2007; see also Garrett and Johnson 2011, this volume). That is, assuming that exemplars in such models retain fine phonetic details of particular instances of speech, new variants introduced by persistent bias factors would accumulate in such a fashion that eventually moves the distributions of exemplars in the direction of the biased variants, presumably as a consequence of convergence via imitation. That is, speakers' production targets are altered along some phonetic dimensions to become more similar to those of their fellow interlocutors (Babel 2009; Goldinger 1998; Nielsen 2007; Pardo 2006; Shockley et al. 2004). While the ability to imitate is assumed to be innate (Dijksterhuis and Bargh 2001), imitation is not likely to be the lone driving force behind the systematic propagation of new variants throughout the speech community, since phonetic imitation is not an entirely automatic or unrestricted process. Social factors have been suggested as important motivators for imitation (Giles and Powesland 1975; Clark and Murphy 1982; Bell 1984; Dijksterhuis and Bargh 2001; Babel 2009). Gender difference is the one that is most commonly observed, although there are conflicting results regarding which gender is more likely to imitate. Pardo (2006), for example, found that men were more likely to converge in a map task than women, yet Namy et al. (2002) found female participants converged more than male participants in a shadowing experiment. Speaker attitude toward the interlocutor (Babel 2010; Abrego-Collier et al. 2011) and perceived sexual orientation (Yu et al. 2011) have also been associated with degree of phonetic convergence and divergence. Rather than propagating aimlessly and blindly as implied by a simplistic conception of an exemplar-based model of sound change, these findings suggest that new variants are spread across the speech community when they come to be associated with social significance (Eckert 2000; Labov 2001). It is often argued that social significance may be associated with new variants via the influence of socially-relevant innovators within the speech community (Labov 2001). That is, the propagation of change happens when the sound patterns of an individual or a group of linguistic innovators (i.e. the 'leader(s)' of change) who occupy sociolinguistically influential positions within the community are adopted by members of the speech community. Given that the question of selection hinges on the role of the innovator, research in the *selection* aspect of sound change actuation has focused on uncovering the social dynamics that facilitate the promotion of an innovator (e.g. the network configuration of the social group, the social profile of the innovator, the stylistic practice of the individual, etc).

The twin questions of where variants come from and how they come to acquire social significance via the role of the linguistic innovator within the speech community have traditionally been investigated separately, however. Yet, a truly explanatory theory of sound change, and of language change in general, not only must explain the origins of variation, it should also take into account the orderly differentiation in a language serving a community (Weinreich et al. 1968), as reflected in the associations between linguistic variation and social structures and meanings. Social meanings may be locally-defined (Eckert 2000) or are reflected in macrosocial memberships, such as socioeconomic class, ethnicity, and gender (Labov 2001). Despite these connections, research on the origins of variation is often pursued without the consideration of the sociolinguistic aspects of change. While past research has identified much covariation of linguistic variables with social variables, it remains unclear what factors, if any, there might be to allow or facilitate the coupling of linguistic and social variables in the first place.

In this chapter, I explore the hypothesis of individual variability in cognitive processing as a conduit for linking the introduction of new variants and their eventual spread throughout a community. The proposal advanced in this work consists of three parts. First, I argue that variability in cognitive processing style is an important contributing factor to variation in perceptual and, by extension, production norms across individuals. Second, such variability in cognitive processing style can be shown to correlate with individual differences in social traits. These social traits may in turn influence how an individual interacts with other members of his/her social network. Taken together, it is argued that individuals who are most likely to introduce new variants in a speech community might also be the same individuals who are most likely to be imitated by the rest of the speech community due to their personality traits and other social characteristics.

This article begins with a brief review of factors that might contribute to individual variability in speech perception and production in section 10.2. Section 10.3 motivates the idea that variability in cognitive processing style is associated with variability in cognitive traits that have social significance. Section 10.4 presents data establishing a significant association between socially-relevant cognitive traits such as empathizing and systemizing drives and how individuals perceive and classify speech sounds in a context-specific manner. A discussion of the implications of these findings appears in section 10.5. Section 10.6 concludes with a discussion of the limits of the theory advocated in this study.

10.2 Background

Individual differences in cognitive processing styles are evident at all levels of human cognition, including vision (Stoesz and Jakobson 2008), learning (Riding and Rayner 2000), and sentence processing (Daneman and Carpenter 1983; King and Just 1991). Note that 'individual differences' here are taken to mean variability in cognitive processing that are systematic (i.e. governed by some fixed factors), rather than the results of chance. Before diving into the effects of cognitive processing style on speech processing, I briefly consider individual-level factors that could contribute to variation in phonetic and phonological processing. Broadly speaking, there are two primary sources: experiential and cognitive-biological.

10.2.1 *Speaker background and past experience*

A primary source of individual variability comes from speaker prior experience (linguistic or otherwise), as evidenced in how foreign language learners learn to produce non-native sounds and sound sequences and how language borrowers incorporate these sounds and sound sequences into their native language. English speakers, for example, have been shown to have difficulties with non-native contrasts such as the Czech retroflex vs. palatal fricatives (Trehub 1976), Korean aspirated, weak, vs. strong laryngeal contrasts (Francis and Nusbaum 2002), Thai voiced vs. voiceless unaspirated stops (Lisker and Abramson 1970), Hindi dental vs. retroflex stops, and Salish velar vs. uvular ejectives (Polka 1991; Werker and Tees 1984, 1994). Difficulties are found in the production of non-native sounds as well. In addition to having great perceptual difficulties in perceiving the English /r/–/l/ contrast (Bradlow et al. 1997, Goroto 1971, MacKain et al. 1981, Miyawaki et al. 1975, Mochizuki 1981, Sheldon and Strange 1982, Yamada and Tohkura 1992), Japanese speakers, for example, have difficulties with producing such a contrast as well (Sheldon and Strange 1982; Bradlow et al. 1997).

Many studies have observed that listeners' perceptual responses are influenced by their knowledge of what are possible and impossible sound sequences in the language (Davidson 2011, Dupoux et al. 1999, Hallé et al. 1998, Massaro and Cohen 1983, Kabak and Idsardi 2007, Pitt 1998). Massaro and 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 the least likely when C = /v/ or /s/, presumably due to the fact that *tl-* and *vr-*/*sr-* sequences are phonotactically ill-formed in English. Phonotactic influence can be found in speech production as well. Davidson, in a series of studies (Davidson 2005, 2006a, b), demonstrated that speakers' knowledge of the phonology and phonetics of their native language strongly affects the way they articulate non-native sequences of sounds. For example, she showed that English speakers often repair unattested word-initial sequences (e.g. /zg/, /vz/) by producing the consonants with a less overlapping coordination (Davidson 2005, 2006a).

Effects of prior experience on speech perception and production is 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 and Perrachione 2007). To be sure, speakers of a tone language, such as Chinese, 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 non-musicians (Chandrasekaran et al. 2009). Individuals with extensive music training are also better at acquiring words cued by tonal contrasts than non-musicians (Wong et al. 2007; Wong and Perrachione 2007).

10.2.2 *Cognitive-biological differences*

Notwithstanding the prevalence of prior experience effects on speech perception and production, such factors are not likely to contribute to sound changes that do not involve language contact if speakers within the same linguistic community, all else being equal, have access to the same range of linguistic experience. All else is not equal, however. Chandrasekaran et al. (2010), for example, observed that variability in the likelihood of success in learning lexical tonal contrasts is influenced by pre-training differences in cue-weighting. That is, individuals who attend more to pitch direction as a cue for tonal contrast are better learners than those who do not. Given that these subjects have no prior knowledge of tonal languages and have little or no musical training, the source of such pre-training differences in prior cue-weighting might originate in non-experientially-driven sources. What are these non-experientially-driven sources of individual variability of speech perception and production?

10.2.2.1 *Neurophysiological factors* Díaz et al. (2008) found neurophysiological evidence for individual differences in sensitivity to phonetic contrast even within the perceiver's native language. Their study 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 a mismatch negativity (MMN). That is, good perceivers of the Catalan /e–ɛ/ contrast showed larger MMN responses to both native (/o/–/e/) and non-native (/o/–/ö/) phonetic contrasts than poor perceivers. Two aspects of this study are particularly noteworthy. First, their findings show that the observed individual variability stems not from variation in the general psychoacoustic abilities of the perceivers, but is linked rather to speech-specific abilities. That is, no difference between the two test groups was observed in the participants' response to acoustic conditions such as frequency, duration, and pattern (i.e. sequences of two alternating pure tones). Second, the two groups appear to differ in the way their perception system is able to extract relevant features of speech sounds, as evidenced by the difference in the amplitude of the MMN between the groups that are 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 a 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 to mean that, while both groups are 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.

Individual variability may also come 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's Disease (Abdullaev and 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 acceptability of pseudowords that were made to either conform to or violate the phonotactics of Italian. Crucially, participants in Tettamanti et al.'s (2005) study were drawn from a healthy non-pathological population (eight healthy right-handed male university students, ranging from 22 to 29 years old). Nonetheless, they found significant correlations between performance in the pseudoword judgement task and dopaminergic input to the left dorsal basal ganglia. In particular, better individual performances correlate with *less* dopamine release in the left dorsal caudate nucleus while faster response time correlates negatively with dopamine release in the left dorsal putamen.

10.2.3 *'Autistic traits' and speech perception*

The type of individual variability of interest here concerns differences in cognitive processing style. 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 and Ausburn 1978; Messick 1976; Witkin et al. 1977). A particularly intriguing type of cognitive processing style effect is the association between levels of 'autistic traits' and speech perception abilities in humans. Stewart and Ota (2008), for example, found that total Autism-Spectrum Quotient (AQ; Baron-Cohen et al. 2001b) taken from within a neurotypical population correlates significantly negatively with the extent of identification shift associated with the 'Ganong effect' (i.e. the bias in categorization in the direction of a known word). The AQ is 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's 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 fifty items, made up of ten questions assessing five subscales: social skills, communication, attention to detail, attention-switching, and imagination. The identification shift associated with the bias toward a known word is shown to relate to the 'Attention Switching' and 'Imagination' components of the AQ in particular. These findings suggest that individuals with certain 'autistic traits' are less likely to be affected by lexical knowledge in their phonetic perception, possibly due to their heightened sensitivity to actual acoustic differences. The authors ruled out higher auditory sensitivity, retardation of lexical access, and verbal intelligence as potential alternative explanations for the observed correlation. They found no correlation of AQ with the performance in a VOT discrimination task, accuracy and speed in a lexical decision task, or individual verbal IQ. Similar findings have been reported for native Mandarin Chinese from Taiwan (Huang 2007).

To further examine the extent of the association between 'autistic traits' and variability in human speech perception abilities, Yu (2010) investigated the association between 'autistic traits' and the perceptual compensation for vocalic context and talker voice. Previous studies show that listeners generally perceive more instances of [s] than [ʃ] in the context of [u] than in the context of [a] (Mann and Repp 1980; Mitterer 2006), presumably because listeners take into account the lowered noise frequencies of /s/ in a rounded vowel context. Similarly, when listeners encounter ambiguous sibilants, they more often report hearing /s/ when the talker is male than when the talker is female (Strand 1999), possibly due to the lower peak frequency of /s/ (i.e. more /ʃ/-like) when produced by male talkers than by female talkers.

In Yu's (2010) study, sixty subjects (32 females; age ranging from 18–47, with a mean of 22 (SD = 4.7)) performed a 2–Alternative Forced–Choice task by listening to a series of CV syllables (C = a synthesized 7-step /s/-/ʃ/continuum; V = /a/ or /u/ in either a female or a male voice) and deciding whether the fricative was /s/ or /ʃ/. After the identification task, participants took the Autism-Spectrum Quotient (AQ; Baron-Cohen et al. 2001b), Empathy Quotient (EQ; Baron-Cohen and Wheelwright 2004) and Systemizing Quotient (SQ; Baron-Cohen et al. 2003). All three quotients are short, self-administered scales for identifying the degree to which any individual adult of normal IQ may have traits associated with Autism-Spectrum Condition. Only the effects of AQ were reported in Yu 2010, given that than article was focused on establishing, for the first time, a significant association between 'autistic traits' and perceptual compensation in speech.

Yu (2010a) found that the magnitude of the compensation (i.e. context-dependent identification shifts akin to that of the 'Ganong effect') is modulated by the listener's sex as well as by the level of 'autistic traits' s/he exhibits. In particular, individuals with low AQ, particularly women with low AQ, show the least amount of identification shift, but this effect of overall AQ score on identification shift is only evidenced in the perceptual compensation for vocalic coarticulation, not in the case of talker voice compensation. That is, individuals' overall AQ scores mediate the processing of linguistic information (i.e. vocalic context), but do not seem to influence the processing of socio-indexical information such as the (perceived) sex of the talker. The author did observe that the magnitude of talker voice compensation is modulated by the perceiver's AQ subscores, including the components of Social Skills, Attention to Details, Attention Switching, and Communication. The magnitude of the subscore effects on talker voice compensation is much weaker than the effects of the total AQ and AQ subscores (Attention Switch and Communication) on perceptual compensation for vocalic coarticulation, however.

10.3 The social relevance of individual variation in cognitive processing style

The association between 'autistic traits' and perceptual compensation for vocalic coarticulation in speech is of particular relevance to understanding the connection between the creation of new linguistic variants and their eventual propagation across the speech community. To begin with, given the systematicity of individual variability in perceptual compensation across cognitive processing style, individuals who consistently do not compensate for coarticulatory effects in speech, i.e. the persistent minimal compensators, would presumably have different perceptual and pronunciation norms from individuals who succeed in perceptual compensation, assuming that perceptual experience informs articulatory production. If such persistent minimal compensators also occupy socially significant stations within the speech community, the perceptual and production norms of these individuals might come to be associated with social significance and spread to the rest of the speech community (Eckert 2000, Labov 2001, Milroy and Milroy 1985).

Research on the social and personal characteristics of leaders in linguistic change has found that leaders are more often women rather than men who are core members of their social network. Such leaders also have intimate contacts throughout their local groups as well as in the wider neighborhood and the wider contacts often include people of different social statuses such that their influence spreads downward and upward from the central group (Labov 2001: 360). In light of these characteristics, it is interesting to note that the association of 'autistic traits' with degree of perceptual compensation not only raises questions about the neurocognitive mechanisms underlying such a linkage, it also points to potential sociolinguistic ramifications. Building on the observation that minimal compensation is gender-differentiated (i.e. females are more likely to under-compensate than males and females with lower AQ under-compensate more than females with higher AQ), Yu (2010a) hypothesizes that one contributing factor to reports of women making use of a wider range of variation than men (Eckert 1988, 1989, 2000; Labov 2001) and females being more often the more active agents of the diffusion of sound change compared to men (see Labov 1990, 2001; cf. Schilling-Estes 2002) might be related to women's superior ability to retain variants in speech (i.e. minimal compensation for coarticulation) than men. That is, given that low AQ women are least likely to compensate for coarticulatory influence in speech perception, it is hypothesized that their perceptual exemplar space would encompass a wider array of marginal exemplars (i.e. variants) than individuals who compensate robustly.

To be sure, it remains to be demonstrated that individuals who are minimal compensators have different perceptual and production norms than those who are robust compensators. Also, the gender effect mentioned should be taken with caution as biological sex is only one of many potential factors that influence a person's gender role in society. Notwithstanding these caveats, a link between variation in perceptual compensation with sociolinguistically-relevant factors, such as gender, points to a possible deeper connection between individual variability in speech processing and socio-cognitive traits. Further evidence corroborating this hypothesis regarding the connection between individual socio-cognitive variability and the emergence of sociolinguistic differentiation in sound change comes from studies that establish statistically significant associations between 'autistic traits' and personality traits. The AQ, for example, has been shown to correlate with differences in personality traits such as neuroticism, extraversion, agreeableness, and conscientiousness (Austin 2005; Wakabayashi et al. 2006).[1] In particular, high AQ individuals are associated with high neuroticism, low extraversion, and low agreeableness (Austin 2005) or conscientiousness (Wakabayashi et al. 2006). In addition, Baron-Cohen (2002, 2003), who advances the empathizing-systemizing (E-S) theory of typical psychological sex differences, including autism, proposes that individuals differ in their drives to empathize (i.e. the ability to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion) and to systemize (i.e. the ability to analyze or construct rule-based systems, whether mechanical, abstract, natural, etc.), which can be measured by the Empathy Quotient (EQ; Baron-Cohen and Wheelwright 2004) and the Systemizing Quotient (SQ; Baron-Cohen et al. 2003; Wheelwright et al. 2006) respectively. Goldenfeld et al. (2005) further proposes to determine an individual's brain type (i.e. Types E, S, E(xtreme)E, and ES) using the measure *D*, which is derived based on a normalized difference between standardized EQ and SQ scores.[2] A positive

[1] The Five Factor Model of personality consists of five broad personality dimensions: openness, conscientiousness, extraversion, agreeableness, and neuroticism (John et al. 2008). Openness refers to a general appreciation for art, emotion, adventure, unusual ideas, imagination, curiosity, variety of experience. People with low scores on openness tend to have more conventional and traditional interests. Conscientiousness is a tendency to show self-discipline and aim for achievement. Individuals who are conscientious tend to show a preference for planned rather than spontaneous behavior. Extraversion is characterized by positive emotions and a tendency to seek out stimulation and the company of others. Individuals who are introverted generally lack the social exuberance and activity levels of extraverts and may seem quiet, low-key, and deliberate. However, their lack of social involvement should not be interpreted as shyness or depression. Agreeableness is a tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others. Finally, neuroticism, sometimes called emotional instability, is the tendency to experience negative emotions, such as anger, anxiety, or depression. Individuals who score low in neuroticism are less easily upset and less emotionally reactive.

[2] Standardized quotient scores were transformed using the formulae $S = (SQ - <SQ>)/max(SQ)$ and $E = (EQ - <EQ>)/max(EQ)$, where $<\ldots>$ denotes the typical population mean (see Table 10.1). That is,

D score indicates a brain type of Type S (i.e. *D* scores between the 65th and 97.5th percentile), or Extreme Type S (ES; the top 2.5 per cent), while a negative score indicates brain type of Type E (scores between the 2.5th and 35th percentiles) or Extreme Type E (EE; the lowest scoring 2.5 per cent). Scores close to zero indicate a balanced brain type (i.e. Type B; D scores between the 35th and 65th percentile).

Females are said to be stronger in empathy than their drive in systemizing (E > S, also referred to as Type E), while males have a stronger drive to systemize than to empathize (S > E, or Type S). According to this typology, individuals with Autism-Spectrum Condition (ASC) have an 'extreme male brain' cognitive profile (S >> E, or Extreme Type S: Baron-Cohen 2002). Of particular interest here are findings suggesting that individual differences in empathizing and systemizing abilities also closely associate with differences in personality traits. Nettle (2007), for example, found that EQ correlates significantly with agreeableness as well as with extraversion. SQ is found to correlate moderately with openness. Such differences in personality traits may have consequences for how an individual might interact with other members of his/her social network. EQ, for example, has been shown to be a significant predictor of social network characteristics (Nettle 2007). Individuals with higher EQ are associated with a large sympathy group (i.e. close friends) and a larger support clique (i.e. individuals to whom one turns in a time of major personal problems), as measured by a self-reported amount of social contacts and social support.

The connection between personality traits and empathy, systemizing drive, and brain type is further strengthened in light of the results of a recent survey study conducted with 116 respondents (70 females, age range = 18–36) at the University of Chicago. As shown in Figure 10.1, the EQ scores of the respondents were found to significantly correlate with four personality traits, in order of decreasing magnitude of correlation: Agreeableness ($r = 0.606, p < 0.0001$), Conscientiousness (r = $0.324, p < 0.001$), Extraversion ($r = 0.248, p < 0.01$), and Openness ($r = 0.198, p < 0.05$). EQ is also weakly correlated with respondent's sympathy group ($r = 0.185, p = 0.053$) and support clique ($r = 0.208, p < 0.05$). Unlike what is observed in Nettle's findings, SQ only significantly correlates with Conscientiousness ($r = 0.238, p < 0.05$). Of particular interest are the significant correlation between Brain Type and personality traits. *D* scores correlate significantly negatively with Agreeableness ($r = -0.484, p < 0.0001$) and Extraversion ($r = -0.252, p < 0.01$), suggesting that individuals who are Type E (i.e. high *D* score) are more likely to be more agreeable and extraverted, while Type S (low *D* score) individuals are likely to be less agreeable and more introverted. Individuals with a balanced brain type, which

the difference between the score and the population mean is divided by the maximum possible score of the quotient (80 for the EQ and 150 for the SQ). The original EQ and SQ axes were then rotated by 45°, essentially factor-analyzing S and E, and were normalized by the factor of 1/2 to produce the new measure, $D\ (= 1/2((SQ - <SQ>)/150 - (EQ - <EQ>)/80))$.

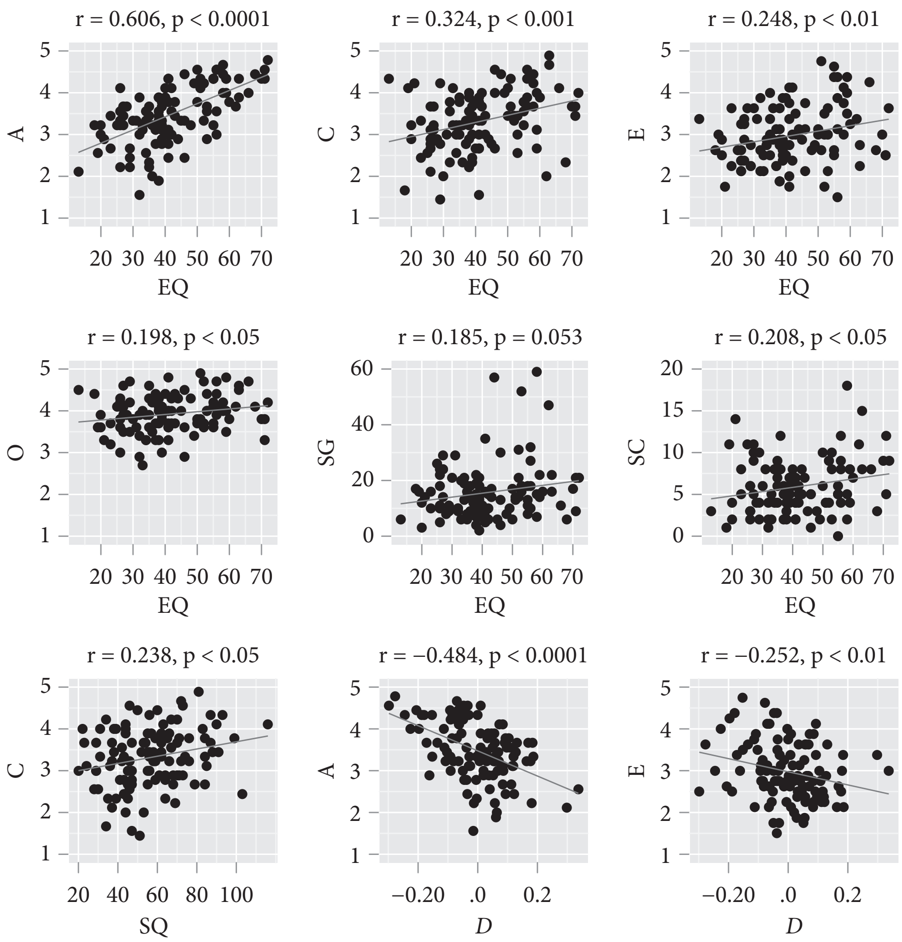

FIGURE 10.1 Significant correlations between individual-difference dimensions (EQ, SQ, and *D*) and personality traits. A = Agreeableness, N = Neuroticism, C = Conscientiousness, E = Extraversion, O = Openness, SG = Sympathy Group, SC = Support Clique.

comprises the bulk of the respondents, tend to exhibit more neutral personality traits, at least with respect to agreeableness and extraversion.

Given the associations between individual-difference dimensions such as EQ, SQ, and brain type, which capture individual differences in cognitive processing styles, personality traits, and other social characteristics, might they also covary with differences in perceptual compensation responses across individuals, as in the case of the AQ? If such an association were established, it would go a long way to establishing a firm link between individual differences in cognitive processing style and the emergence and propagation of sociolinguistically-motivated sound changes.

To this end, in what follows I explore this question through a reanalysis of the data of Yu (2010)'s original study by considering the effects of the three additional individual-difference dimensions mentioned above, Empathy Quotient (EQ: Baron-Cohen and Wheelwright 2004), Systemizing Quotient-Revised (SQ: Baron-Cohen et al. 2003; Wheelwright et al. 2006), and Brain Type (Goldenfeld et al. 2005) on listeners' ability to perceptually compensate for vocalic context in sibilant identification.

10.4 The model

This section lays out the results of a linear mixed-effects model testing for the effects, if any, EQ, SQ, and brain type might have on sibilant perception. As reviewed in section 10.2.3, the data comes from Yu 2010, which tested sixty native speakers of American English (32 females; age range from 18 to 47, with a mean of 22 (SD = 4.7)) on the classification of an /sV–ʃV/ continuum by identifying each initial sibilant as either /s/ or /ʃ/. The experiment was implemented in E-Prime. Subjects heard the test stimuli over headphones in a soundproof booth. Subjects made their selection by pressing one of two labeled keys on a response box. The session consisted of three trial blocks. In each block, all 28 tokens (= 2 vowels × 2 talkers × 7 steps) were presented four times in random order. Each subject categorized 336 tokens (= 2 vowels × 2 talkers × 7 steps × 3 blocks × 4 times). After the identification task, participants took the Autism-Spectrum Quotient questionnaire (AQ: Baron-Cohen et al. (2001b)), the Empathy Quotient (EQ: Baron-Cohen and Wheelwright (2004)), and the Systemizing Quotient (SQ: Baron-Cohen et al. (2003)). A more detailed account of the setup of the experiment and the preparation of the stimuli can be found in the Materials and Methods section in Yu 2010.

10.4.1 *Descriptive statistics*

Descriptive statistics of the quotient scores are summarized in Table 10.1. Recall that the AQ consists of fifty questions. As in Yu (2010), the AQ items were scored on a Likert scale (1–4). The total AQ score was calculated by summing all of the scores for each of the items, with a maximum score of 200 and a minimum score of 50. Scores for the subscales (SS, CM, AD, AS, IM) have a maximum score of 40 and a minimum score of 10. All scales were scored in such a way that a high score is more 'autistic', i.e. lower social skills, difficulty in attention switching/strong focus of attention, high attention to detail and patterns, lower ability to communicate, and low imagination. Like the AQ, the EQ and SQ were self-administered and have a forced-choice format. Participants were asked to indicate whether they 'strongly agree', 'slightly agree', 'slightly disagree', or 'strongly disagree' with a statement. Approximately

TABLE 10.1 Descriptive statistics of measured factors. Scores averaged across the sexes are bolded. The AQ was scored in such a way that a high score is more 'autistic', i.e. lower social skills, difficulty in attention switching, high attention to detail and patterns, lower ability to communicate, low imagination. The EQ and SQ were scored in such a way that individuals with high scores are more empathetic and more systemizing respectively.

Factor	Sex	Mean	Median	Range	SD
Overall AQ		**110.00**	**108**	**78–155**	**17.79**
	f	109.00	105	78–155	18.33
	m	111.20	111	80–151	17.41
Social Skills (SS)		**19.82**	**19**	**12–33**	**5.82**
	f	20.21	19	12–33	5.58
	m	19.38	17	12–31	6.14
Attention Switching (AS)		**24.31**	**24**	**15–36**	**4.79**
	f	24.12	24	17–34	4.70
	m	24.52	25	15–36	4.97
Attention to detail (AD)		**26.74**	**27**	**15–37**	**5.24**
	f	26.42	26	15–37	5.04
	m	27.10	27	18–37	5.51
Communication (CM)		**19.23**	**18**	**10–33**	**4.96**
	f	19.12	18	10–33	5.48
	m	19.34	18	11–27	4.38
Imagination (IM)		**19.65**	**19.50**	**10–30**	**4.44**
	f	18.91	19	10–28	4.56
	m	20.48	21	13–30	4.22
EQ		**45.50**	**45.50**	**10–74**	**13.29**
	f	46.67	47	11–74	12.58
	m	44.17	44	10–71	14.16
SQ		**65.5**	**64.5**	**36–144**	**20.12**
	f	62.40	60	36–103	17.41
	m	69.03	65	36–144	22.60

half the items on each questionnaire are worded so that a high scorer will agree with the item, to avoid response bias. The EQ comprises 40 items and the SQ 75 questions; two points are given for a 'strongly' response and one point for an appropriate 'slightly' response. The maximum scores for EQ and SQ are 80 and 150 respectively, while their minimum is zero.

The distribution of AQ scores was typical of normally developing populations. As a general comparison, the mean total AQ of individuals with ASC (N = 58) in Baron-Cohen et al.'s (2001) study was 35.8 (SD = 6.5), while the mean total AQ of the Cambridge University students they surveyed (N = 840) was 17.6 (SD = 6.4). Applying

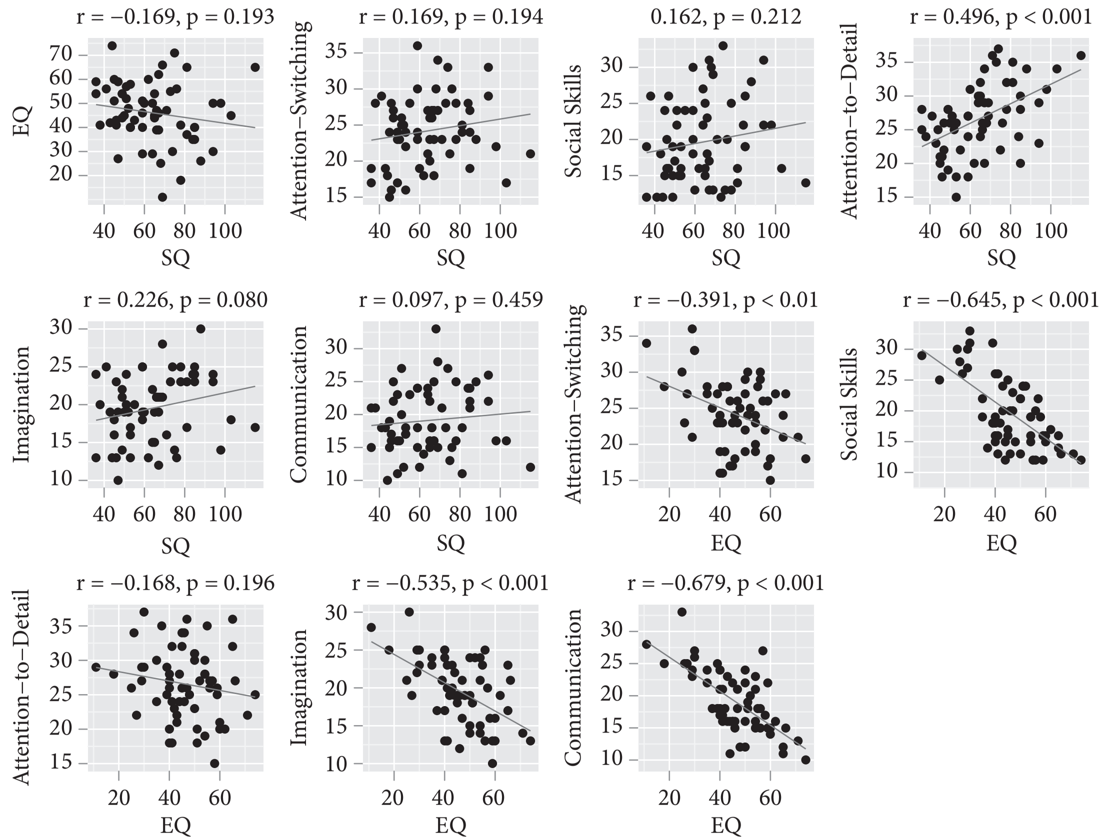

Figure 10.2 Correlations between individual-difference dimensions as measured by the AQ subcomponents, EQ, and SQ for all participants with regression lines superimposed. The Pearson correlation coefficient, given on top of each subplot, corresponds to the overall correlation irrespective of sex.

Baron-Cohen et al.'s scoring method (they did not calculate the AQ on a Likert-scale as in the present study), subjects in the present study have a mean total AQ of 18.45 (SD = 8.25). The distributions of EQ and SQ scores are typical of normal developing populations as well. Wheelwright et al. (2006) reported that the average AQ, EQ, and SQ of the neurotypicals in their study were 16.3(SD=5.9), 44.3(12.2), and 55.6(19.7) respectively. Figure 10.2 summarizes the correlation between individual quotients. SQ correlates significantly only with Attention-to-detail ($r = 0.496, p < 0.001$) and marginally so with Imagination ($r = 0.226, p = 0.08$). EQ correlates significantly with Attention-Switching ($r = -0.391, p < 0.01$), Social Skills ($r = -0.645, p < 0.001$), Imagination ($r = -0.535, p < 0.001$), and Communication ($r = -0.679, p < 0.001$). SQ and EQ do not correlate significantly ($r = -0.169, p = 0.193$).

Subjects' /ʃ/-responses were modeled using a mixed-effects model with a logit link function. The model was fitted in *R* (Team 2010), using the *lmer*() function from the *lm4* package for mixed-effects models. Positive regression weights indicate a positive correlation between a predictor variable and the likelihood of a /ʃ/ response. The current model was selected from a full model containing all individual-difference predictors and their interactions with vocalic context and the subject's biological sex by eliminating predictors that do not significantly improve model likelihood. In addition to EQ, SQ, Brain Type, and the subject's biological sex, the five AQ subscores were entered into the model, in lieu of the overall AQ, to determine whether the effects of EQ, SQ, and Brain Type, whatever they may be, are independent of the effects of the AQ components on perceptual compensation. Given that the number of individuals with extreme brain types (EE and ES) was small in this sample population, only three brain types were considered (i.e. B, E, and S). Exploratory data analysis further revealed that only the contrast between balanced (B) and imbalanced brain types (E and S) was relevant, thus the Brain Type predictor was recoded as a binary predictor (balanced vs. imbalanced). With the changes to the model predictors described above, three AQ subscores (IM, AD, CM) dropped out. The final model contains ten fixed input variables: Trial(1–336), Step (1–7), Subject.Sex (male vs. female), Vowel (/a/ vs. /u/), Talker (male vs. female), AS (1–50), SS (1–50), EQ (0–80), SQ (0–150), Brain Type (balanced vs. imbalanced), as well as a by-subject random slope for Trial.

Categorical variables were sum-coded (i.e. female = 1, male = −1; a = 1, u= −1; balanced = 1, imbalanced = −1). Following Gelman (2008), EQ, SQ, and the AQ subscores were centered and standardized by dividing the difference between the input variable and its mean by two times its standard deviation in order facilitate the comparisons of the magnitude of effects across categorical and continuous factors. Each unit of difference in a standardized quotient score corresponds to a difference of two standard deviations. Overall collinearity of predictors was low. The average partial correlation of fixed effects was 0.014 and the highest variation inflation factor was 2.479.

Table 10.2 Estimates for all predictors in the analysis of listener response in the identification task. '***' = $p < 0.001$; '**' = $p < 0.01$; '*' = $p < 0.05$

Task-specific factors	Coeff	SE(β)
Intercept	−0.576	0.202 **
Trial	−0.059	0.148
Step	3.467	0.054 ***
Vowel	0.466	0.023 ***
Talker	0.644	0.022 ***
Subject.Sex	0.310	0.191
Vowel × Subject.Sex	−0.034	0.021
Vowel × Talker	−0.152	0.021 ***
Vowel × Step	0.199	0.046 ***
Talker × Step	0.222	0.046 ***
Cognitive factors		
AS	−0.040	0.461
SS	0.154	0.596
SQ	0.464	0.404
EQ	0.350	0.528
Brain Type	0.189	0.213
AS × Subject.Sex	0.043	0.385
Vowel × AS	0.206	0.052 ***
Vowel × SS	0.251	0.067 ***
Vowel × SQ	0.217	0.044 ***
Vowel × EQ	0.512	0.059 ***
Vowel × Brain Type	0.096	0.023 ***
Vowel × AS × Subject.Sex	0.162	0.044 ***

Table 10.2 summarizes the parameter estimate β for each of the fixed effects in the model, as well as the estimate of its standard error SE(β), and the significance level. Consistent with previous studies on the perceptual compensation for vocalic coarticulation (Mann and Repp 1980; Mitterer 2006) and the sex of the talker (Strand 1999), the model shows the expected main effects of vocalic context and talker voice on sibilant perception. There is approximately a 20 per cent drop in /ʃ/ response when the following vowel is /u/ ($\beta = 0.466, z = 0.023, p < 0.0001$: Figure 10.3a), rather than /a/, while the drop in /ʃ/ response is about 30 per cent when the talker is male rather than female ($\beta = 0.644, z = 0.022, p < 0.0001$: see Figure 10.3b). There is an interaction effect of vocalic context and talker voice ($\beta = -0.152, z = 0.021, p < 0.0001$); /ʃ/–response is least likely when the talker is male and the following vowel is /u/ (see Figure 10.3c). There are also significant

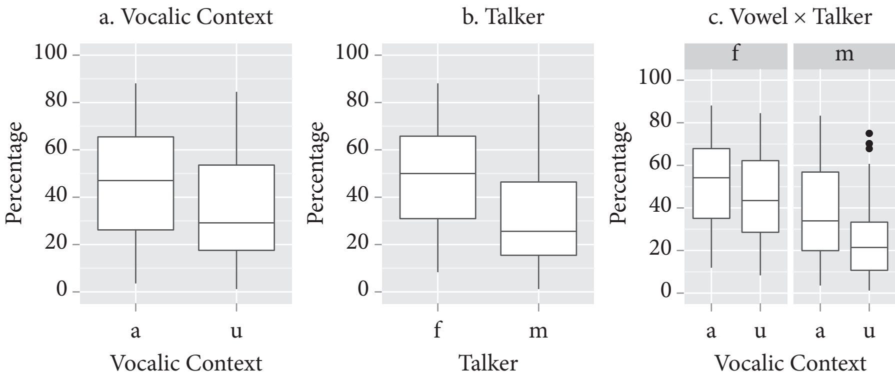

Figure 10.3 Effects of (a) vocalic context, (b) talker, and (c) their interaction, on sibilant identification.

effects of the continuum step on vocalic context and talker voice gender compensation. Beyond these canonical effects, individuals with low AS subscore (i.e. better attention-switching skills: Figure 10.4a) or low SS subscore (better social skills: Figure 10.4b) are less influenced by the effects of vocalic context in sibilant identification. The model likelihood is improved significantly in a model with a Vowel × Attention-Switching interaction ($\chi^2(2) = 16.161, p < 0.001$) or with a Vowel × Social Skills interaction ($\chi^2(2) = 21.473, p < 0.001$) relative to a model without these interactions. The interaction between Vowel and Attention-Switching was mediated by Subject.Sex. Unlike Yu (2010), the three-way interaction between Vowel, Social Skills, and Subject.Sex did not improve data likelihood significantly ($\chi^2(4) = 8.325\ p = 0.080$).

Drive to empathize and to systemize. To test the effects of EQ and SQ on the perceptual compensation for vocalic coarticulation, the significance of data likelihood improvement of models with and without two-way interactions between these cognitive traits and vocalic contexts was examined. The interaction between EQ and Vowel significantly improved the model's likelihood ($\chi^2(2) = 74.472, p < 0.001$: Figure 10.4c); individuals with lower EQ (i.e. poor empathizers) are less affected by the vocalic context in sibilant classification ($\beta = 0.512, z = 0.059, p < 0.001$). The interaction between SQ and Vowel significantly improves data likelihood as well ($\chi^2(2) = 24.128, p < 0.0001$: Figure 10.4d); this interaction indicates that the lower SQ an individual scores (i.e. the less driven an individual is to systemize), the less affected the person is by the vocalic context during sibilant perception ($\beta = 0.217, z = 0.044, p < 0.001$).

Recall in Figure 10.2 that EQ correlates significantly negatively with both the Attention-Switching (AS) and Social Skills (SS) subcomponents of the AQ score. This suggests that poor empathizers (individuals with low EQ) tend to be highly focused (high AS score) and have poor social skills (high SS score). Yet, the results of our statistical analysis thus far suggest that individuals who are less influenced by vocalic contexts in sibilant perception (the minimal compensator) tend to be poor empathizers with good social skills (low SS), and are also easily distractible (i.e. low AS score). These cognitive traits thus appear to be in conflict with each other. That is, a minimal compensator is not likely to be simultaneously a poor empathizer with low social skills and distracted attention (and vice versa). This conflict is resolved once Brain Type is taken into account.

The interaction between Brain Type and Vowel significantly improved the model's likelihood ($\chi^2(2) = 20.983, p < 0.001$: Figure 10.4e), suggesting individuals with imbalanced empathy and systemizing traits (i.e. Types E, EE, S, and ES) are less affected by the vocalic context in sibilant classification than those with a more balanced brain type. This finding helps to explain the puzzle above, since it suggests that not all strong empathizers compensate for vocalic coarticulation equally robustly. Strong empathizers with a weak systemizing drive are less likely to engage in perceptual compensation for vocalic context, as do poor empathizers with a strong systemizing drive. On the other hand, individuals with a balanced drive toward empathy

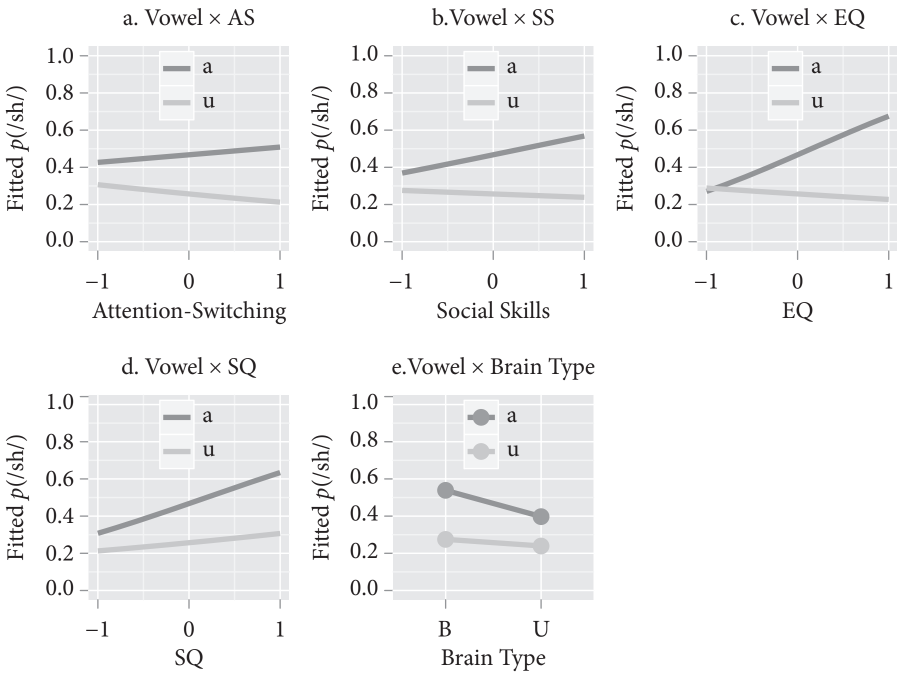

Figure 10.4 Perceptual compensation for vocalic coarticulation as mediated by (a) attention-switching skills, (b) social skills, (c) empathy, (d) systemizing drive, and (e) brain type (balanced (B) vs. unbalanced (U)).

and systemizing (i.e. strong empathizers with a strong drive to systemize or poor empathizers with a weak drive to systemize) are more likely to compensate for vocalic coarticulation.

10.5 General discussion

I have shown evidence that individual differences in cognitive processing style, as measured by the EQ, SQ, and the AS and SS subscores of the AQ, as well as their derivatives such as Baron-Cohen's brain type typology, significantly influence listener's perceptual responses with respect to sibilant perception in context-specific settings. These findings suggest that individuals with different cognitive processing styles might have different perceptual norms. While further research is needed to ascertain whether differences in perceptual norms as modulated by cognitive processing style also correspond to differences in speech production norms, recent studies at least suggest a plausible linkage between individual variability in perceptual norm and individual differences in production targets (Beddor et al. 2002; Harrington et al. 2008; cf. Galantucci et al. 2009; Watkins and Paus 2004). Kataoka (2010, 2011), for example, shows that an individual's context-specific production targets for vowels are correlated with her context-specific perceptual responses. While Kataoka's (2010, 2011) study focuses on the production and perception of English high vowels in different consonantal contexts, her findings nonetheless point to the feasibility of a perception-production feedback loop (Pierrehumbert 2001a; Oudeyer 2006) and to the idea that differences in perceptual norms attributed to differences in cognitive processing style would be reflected in differences in production norms as well.

10.5.1 *The cognitive profile of linguistic innovators*

Another vexing question that remains unaddressed so far is how the findings of this study shed light on our understanding of sound change. As alluded to earlier, many researchers of sound change, most notably Ohala (1993b) and Blevins (2004), attribute a primary endogenous source of innovative linguistic variants to listeners failing to properly compensate for variation from coarticulation (e.g. the vocalic effect on neighboring sibilants). Errors in perception may lead to adjustments in perceptual and production norms. Thus in the case of sibilants, speakers might mistake a lexical item, say /su/, for /ʃu/ by not taking the coarticulatory rounding effect of /u/ into account, and might subsequently start producing the same lexical item as [ʃu]. Repeated errors of this nature could result in a drastic reduction of /s/ exemplars before /u/ and an overwhelming number of /ʃ/ before /u/ and an s > ʃ/__u sound change would obtain.[3] However, it is not clear how perception and production norms driven by listener errors could acccumulte in a systematic fashion and result in sound

[3] An example of such a sound change can be found in certain speakers of Modern Cantonese. Underlying /s/ is palatalized before /y/ but not before /i/ (i.e. [ʃyː˥] 'book' vs. [siː˥] 'silk'), suggesting that *s*-palatalization

change, since many experimental investigations have shown that listeners are on average quite effective in 'compensating' for the effects of coarticulation (Mann and Repp 1980; Mitterer and Blomert 2003; Mitterer 2006; Beddor and Krakow 1999; Beddor et al. 2002; Viswanathana et al. 2010). This has led to the hypothesis that only listeners with minimal knowledge of the language, such as children and second language learners, are likely to repeatedly commit such perceptual errors (Ohala 1993b; see also Kiparsky 1995).

The H & H theory of phonetic variation (Lindblom 1990; Lindblom et al. 1995), on the other hand, advocates a more speaker-oriented approach to sound change. The H & H theory proposes that speakers adaptively tune their performance along the H(yper)–H(ypo) continuum according to their estimates of the listener's needs in that particular situation. These needs include preferences to maximize the distinctiveness of contrasts and to minimize articulatory effort. Speakers hyper-articulate when listeners require maximum acoustic information; they reduce articulatory efforts, hence hypo-articulate, when listeners can supplement the acoustic input with information from other sources. From this perspective, sound change occurs when intelligibility demands are redundantly met or when the listeners focus their attention on the 'how' (signal-dependent) mode rather than the 'what' (signal-independent) mode of listening (Lindblom et al. 1995). New phonetic variants accumulate during the 'how' mode of listening. When these newly accumulated variants are selected by the listener-turned-speaker, sound change obtains. However, little is known about the circumstances under which individuals would focus their attention on the signal-dependent 'how' mode of listening and away from the signal-independent 'what' mode.

The discovery of individuals with different 'autistic traits' exhibiting variable degrees of lexical influence in speech perception and perceptual compensation for coarticulation provides a promising solution to the seemingly opposing views of the H & H and the listener-misperception approaches to sound change. Recall that individuals who exhibit minimal compensation for coarticulation (i.e. low AQ individuals) also exhibit strong lexical effects in speech perception (Stewart and Ota 2008), while those who compensate for coarticulations strongly (high AQ individuals) tend to exhibit weak lexical influence. This trade-off between the influence from low-level phonetic variation and higher order lexical information is in concert with cognitive theories of autism that argue that autistic individuals 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, Happé and Frith 2006, Mottron et al. 2006). In light of these findings, from the perspective of the H & H model, high AQ individuals can be seen as individuals whose cognitive processing

is due to the rounding of the high front vowel, rather than frontness alone. Note, however, that this change is only triggered by high vowels since non-high rounded vowels do not trigger this palatalization (e.g. [sɔː˥] 'comb'). The high back rounded vowel /u/ is not permitted after coronals in Cantonese.

style favors attending to lower order information (i.e. the 'how' mode of listening), while low AQ individuals tend to focus more on higher order information, such as lexical information, and place less emphasis on the low-level detail of the incoming signal (i.e. the so-called 'what' mode of listening). From this point of view, individuals who favor attending to the 'what' mode of listening should be the ones who register more new variants in their phonetic memory 'pool', contrary to Lindblom et al.'s assumption, since the 'what' mode listeners (i.e. low AQ individuals) exhibit lesser perceptual compensation for coarticulation. That is, when a speaker produces /su/, perhaps intending to call out for her dog, but the utterance ends up sounding more like [ʃu], a high AQ individual (the 'how' mode listener) would compensate for the vocalic coarticulation and categorize the [ʃ] as another instance of /s/, as intended by the speaker. On the other hand, a low AQ individual (the 'what' mode listener) might be inclined to accept the percept [ʃu] at face value and treat /ʃu/ as an acceptable phonological variant for the name of this dog. Under this scenario, two individuals, one with high AQ and the other with low AQ, upon hearing the same utterance, might arrive at very different conclusions as to the name of the dog being called. For the low AQ individual, who starts calling the dog /ʃu/ regularly, this might be seen as a mini-sound change.

10.5.2 *The personality and social profile of the innovator*

The presence of a mini-sound change does not guarantee the eventual propagation of this sound change throughout the language. Given that propagation of linguistic innovation crucially hinges on how the linguistic innovator is embedded within his/her social environment, whether a minimal compensator (the low AQ 'what' mode listener) becomes the source of linguistic innovation ultimately depends on what social role she occupies within her social reality and how such roles could facilitate her potentials as a linguistic innovator. As noted earlier, sociolinguists have suggested that linguistic innovators tend to have weak social ties within the local speech community (Labov 1973; Milroy and Milroy 1985), while leaders in linguistic change, who might or might also be linguistic innovators themselves, are more often women rather than men who are centrally located in the socioeconomic hierarchy. Leaders also tend to have a diffused network structure, often with contacts throughout their local groups as well as in the wider neighborhood. The wider contacts often include people of different social statuses such that their influence spreads downward and upward from the central group (Labov 2001: 360). How might minimal compensators be distributed within the social network and hierarchy relative to the above-mentioned characteristics of linguistic innovators and leaders in change? Might the minimal compensators' personality profile and social distribution contribute to the socially-structured distribution of linguistic innovation (cf. Cheshire et al. 2008; Stuart-Smith and Timmins 2009)?

Recall that the individual-difference dimensions considered in this study are also significant indicators of personality traits and other social characteristics. For example, AQ is correlated positively with neuroticism and conscientiousness and negatively with extraversion and agreeableness (Austin 2005; Wakabayashi et al. 2006; see also discussion regarding Figure 10.1). Jobe and White (2007) found that, with a sample of non-clinical undergraduate students from a large, urban university (N = 97; mean age = 19.4 ± 2 years), overall AQ significantly negatively correlates with length of best friendship ($r = -0.23, p = 0.02$) and total AQ score is also a valid predictor in a linear regression of loneliness ($\beta = .48, p < .001$), as measured by the UCLA loneliness scale (version 3: Russell 1996). Given that Yu (2010) found that individuals with low AQ are more likely to compensate less for coarticulatory influences in speech, it suggests that such minimal compensators tend to be less neurotic and less conscientious but are more extraverted and agreeable. They also tend to have longer best friendship and stronger feelings of loneliness.

Similar inferences might be made with respect to other individual-difference dimensions. In the correlation study with 116 respondents discussed above (Figure 10.1), the Attention-Switching (AS) and Social Skills (SS) subcomponents of the AQ correlate significantly with various personality and social traits (Figure 10.5). The AS subscore, for example, significantly correlates positively with neuroticism but negatively with extraversion, suggesting that individuals who are easily distracted (a trait of minimal compensators) are not very neurotic and more extroverted. AS scores also correlate marginally significantly with agreeableness ($r = -0.202, p = 0.053$). The SS subscores significantly correlate negatively with agreeableness, conscientiousness, extraversion, openness, the size of sympathy group and the size of support clique. SS subscores also positively correlate with neuroticism. Taken together, individuals with low SS subscores (another trait of minimal compensators) tend to be more agreeable, less neurotic, more conscientious, more extraverted and more open to new ideas. Crucially, such individuals also have more social contacts (as measured by the size of the sympathy group) and more close friends (as measured by the size of the support clique).

Likewise, EQ correlates positively with agreeableness, conscientiousness, extraversion, and openness; SQ correlates positively with conscientiousness and openness but negatively with neuroticism (Nettle 2007). Recall also that individuals with higher EQ are also associated with a larger sympathy group and a larger support clique (see discussion with respect to Figure 10.1; see also Nettle 2007).

Finally, minimal compensators generally have imbalanced brain types, that is, of Type E/EE and Type S/ES. Type E and EE individuals, who have a stronger drive to empathize, are likely to be highly agreeable, extraverted, and neurotic, but may also be less conscientious and open; Type S and ES individuals, who are superb systemizers, are not likely to be neurotic and are likely to be conscientious and open, even though they might be quite introverted. To the extent that personality

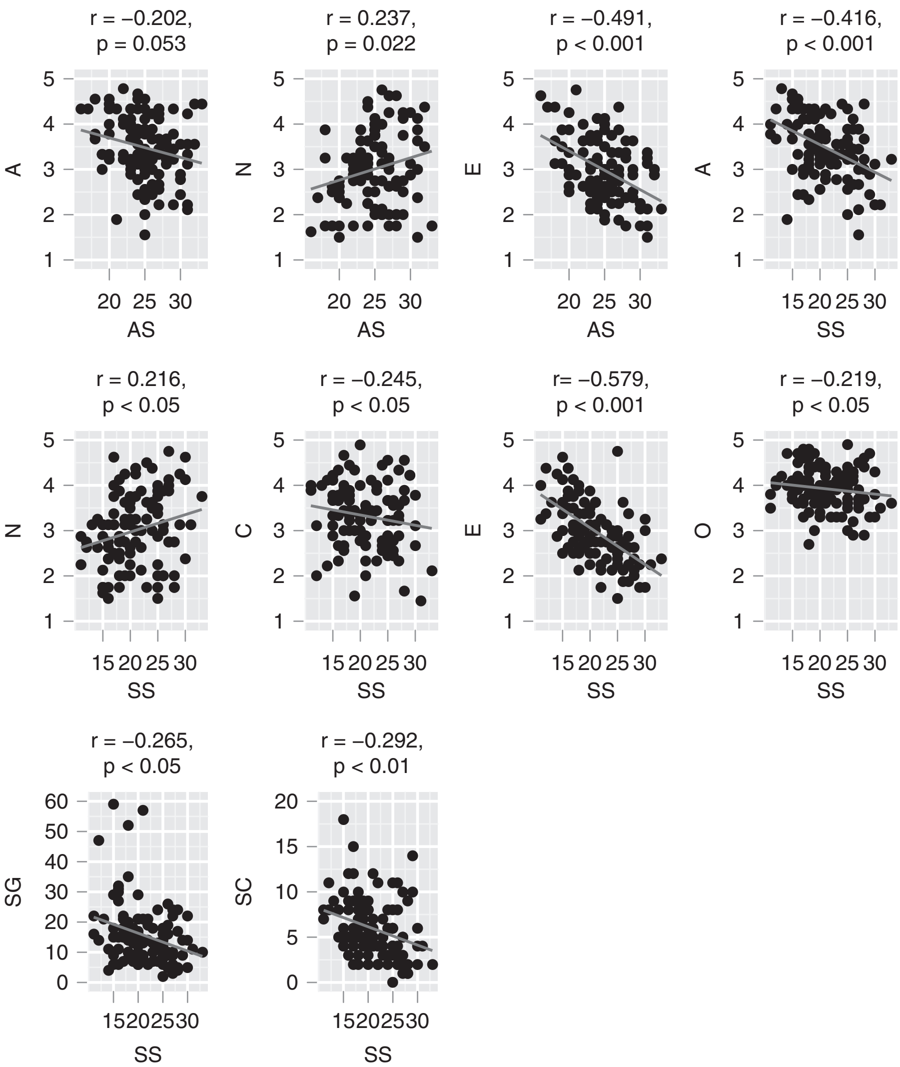

Figure 10.5 Significant correlations between the Attention-Switching (AS) and Social Skills (SS) subcomponents of the AQ and personality traits. Only significant correlations ($p < 0.05$) are shown here. A = Agreeableness, N = Neuroticism, C = Conscientiousness, E = Extraversion, O = Openness, SG = Sympathy Group, SC = Support Clique.

traits have consequences for how individuals interact in the social world, it seems at least plausible that individuals with imbalanced brain types might have different social network profiles than individuals with balanced brain types. In particular, I would conjecture that minimal compensators who are superior empathizers might be at an advantage in exerting their speech patterns on others within their social network(s).

That women have been argued to be superior empathizers than men (Baron-Cohen 2003) is, for example, consistent with the general characteristics of leaders in linguistic change. The fact that good empathizers tend to have a larger sympathy group and support clique is also consistent with the observation that leaders in change often have more contacts and have access to a wider network. What is not clear is to what extent highly systemizing individuals (i.e. Type S or ES individuals) also contribute to the propagation of sound change. Might the fact that Type S or ES individuals tend to be more introverted and less agreeable (on account of their low EQ) lead them to have fewer close friends and have less social contacts with others? If so, the speech patterns of Type S or ES minimal compensators are not likely to influence the speech patterns of the rest of the speech community. On the other hand, Type S/ES individuals are also likely to be more conscientious and open. Labov (1973) suggests that the 'lames' (i.e. individuals who are social outcasts or isolates during their formative years) tend to carry less local features in their speech and are least capable of evaluating the complexity of the in-group features on account of their exposure to more features of other dialects and varieties. Could these characteristics (i.e. using less local features and diminished capabilities in evaluating the complexity of the in-group features) be a reflection of their Type S/ES brain type? Perhaps paradoxically, Labov concludes that, to the extent that they are the kinds of 'lames' who eventually manage to break out of their own niche and succeed in life, they might still manage to propagate their speech patterns by virtue of having a wider network of contacts (cf. Milroy and Milroy 1985). It should also be noted that the innovators ultimately do not need to be socially central themselves. Provided that they play the right role in a social network and exert an effect on the influential individual(s) in that network, their innovations might still spread.

10.6 Conclusion

In this work, I have offered support for the idea that, in addition to differences in individual experiences, a major source of variability in speech comes from inherent differences in the individual's cognitive makeup (as measured by individual-difference dimensions such as AQ, EQ, and SQ). Crucially, variation in cognitive processing style can be shown to covary with differences in listener's response pattern during speech perception, particularly in the case of perceptual compensation for coarticulation. To the extent that such differences in perceptual response may ultimately lead to individual differences in perceptual and production norms, variability in cognitive processing style stands to be a major contributor to the creation of new linguistic variants in sound change. To be sure, covariation between differences in cognitive processing style and speech processing does not imply a direct causal link. Individual differences in cognitive processing style and variability in speech processing might ultimately be reflexes of deeper cognitive mechanisms. Further neuropsychological research might shed light on this issue.

Notwithstanding the significance of identifying a new source of linguistic variants, the present findings also shed light on how the creation of new variants might be tied to the sociolinguistic aspect of sound change propagation. Variationist research in the past decades has demonstrated time and again the ordered heterogeneity that exists in language. In particular, linguistic variables are found to covary with sociolinguistic variables. The research reported in this article shows that such covariation extends even to the level of speech perception. Whether and how robustly a person takes coarticulatory contexts into account in sound categorization covaries with differences in individual-difference dimensions, such as empathy and drive to systemize, as well as general 'autistic traits', such as attention-switching and social skills. These individual-difference dimensions are in turn associated with individual differences in personality and social traits. In particular, it is shown that, while low-AQ individuals are most likely to discount coarticulatory context in speech perception, their empathizing and systemizing drives seem to play a significant role as well. Crucially, the effect of empathy and the drive to systemize is not all or nothing. Whether perceptual compensation is ameliorated in low-AQ individuals is not determined by whether the person is or is not able to empathize or systemize. Rather, individuals showing an imbalance between empathizing and systemizing abilities (the so-called imbalanced brain types) are more likely to exhibit minimal perceptual compensation than individuals who exhibit balanced individual-difference dimensions.

To be sure, the discovery of significant associations between patterns of speech perception and sociolinguistically-relevant individual-difference dimensions must be treated with care. To begin with, the extent to which empathizing and systemizing abilities and general 'autistic traits' are appropriate proxies for capturing the social characteristics of an individual within a speech community must be investigated further. As noted earlier, differences in AQ, EQ, and SQ have been associated with different personality traits, and differences in EQ have also been found to significantly predict certain aspects of an individual's social network. Yet, it bears emphasizing that variation in social and cognitive processing style is undoubtedly only one of many factors contributing to the eventual emergence of a linguistic variant and its subsequent propagation. Many forces, as documented in the large body of literature in sociolinguistic and variationist research, may conspire to propel or restrict the propagation of a new variant. Individual variation in cognitive processing style may serve as only one of many potential earlier inputs toward what might be a long process of sound change actuation. Detailed ethnographic studies of individuals with different cognitive processing styles might be able to reveal in more detail how these individual-difference dimensions might manifest themselves during an individual's interpersonal interactions and how they facilitate sound change.

In addition, the identification of a variable as a significant predictor does not necessarily suggest a direct causal relation. What might be the causal relationship, if any, between the individual-difference dimensions measured in this study and variation in perceptual responses in speech? Might there be an adaptive significance of such linguistic variation? It seems reasonable to hypothesize that variations in cognitive processing style as captured by the various individual-difference dimensions reviewed here are not directed at creating linguistic variation *per se*. Rather, linguistic variation (as a consequence of variation in perceptual abilities) is likely an unintended by-product of this aspect of human diversity. After all, variation in cognitive processing manifests itself in domains far beyond the confines of language. For example, individual differences in AQ have been shown to predict performance in both typical and ASC populations on tasks such as self-focused attention (Lombardo et al. 2007), local versus global processing (Grinter et al. 2009), inferring others' mental states from the eyes (Baron-Cohen et al. 2001a), and attentional cueing from gaze (Bayliss and Tipper 2005). Individuals with high AQ have been found to show global perceptual hemineglect (i.e. a significant reduction in global perception when the stimulus was presented in left hemifield; Crewther et al. 2010). Variation in 'autistic traits' is associated with changes in structure and patterns of activation in typical participants' brains (von dem Hagen et al. 2010). Differences in perceptual compensation might just be another 'broader phenotype' (Bailey et al. 1995) that characterizes differences among individuals along the autism spectrum. Such facts point to an interpretation of linguistic variation as essentially an accidental by-product of the cognitive and biological diversity of humans. How might such a cognitive accident contribute to sound change that is sociolinguistically motivated? Sociolinguists have taught us to focus on the resources that are available in the linguistic marketplace (Eckert 2000; Chambers 2003). It is, however, equally important to attend to what type of resources the individual brings to the table. That is, not everyone is equally receptive to utilizing the linguistic resources put before him or her. The socio-cognitive processing abilities of an individual thus provides an important conduit through which the likelihood of propagation can be discerned. If a well-liked or well-respected individual happened to be a minimal compensator, the type of perceptual and production norms such an individual promulgates might be adopted more readily by fellow members of a speech community. Yu (2010) suggests that low AQ women are least likely to perceptually compensate for coarticulatory context in speech perception, and that might be associated with their increased likelihood to be leaders in change. However, such an interpretation might be unnecessarily overreaching, as suggested by the present work. That is, cognitive processing styles may vary along a highly multi-dimensional space.

The importance of isolating such differences in cognitive processing style is to discern what trait combinations might simultaneously underlie both individual variability in speech perception and individual differences in social behavior in the real world. Establishing such a correlation would strengthen the idea that sociolinguistically-motivated language change might ultimately have a cognitive biological foundation, to the extent that differences in cognitive processing style ultimately reflect differences in the neurobiological diversity in humans.