Title

Reduced Phonetic Convergence in Autism Spectrum Disorder

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Abstract

Previous research has demonstrated that speakers change phonetic forms in response to variability in their immediate linguistic milieu, such that they converge with an interlocutor. While much is known about the impact of social dynamics on this process, the impact of individual variability in cognition and perception is less well-explored. The present study seeks to examine the impact of these individual differences on phonetic convergence during a naturalistic conversation, comparing convergence in autism spectrum disorder (ASD) and typical development. Results showed a small effect of temporal convergence within typically developing dyads, compared with evidence of divergence within ASD dyads. While preliminary, this pattern of results suggests that social motivation may play a more important role in phonetic convergence than sensory accounts (such as self-monitoring).

Keywords: phonetic convergence; Communication Accommodation Theory (CAT); Autism Spectrum Disorder; ASD

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social communication, as well as the presence of restricted or repetitive behaviors and atypical sensory processing (American Psychiatric Association, 2013). Individuals with ASD display heterogeneous cognitive and linguistic outcomes.

Some research suggests that approximately 30% of individuals with ASD are functionally non-verbal into adulthood (Tager-Flusberg & Kasari, 2013). While the majority of individuals do acquire functional language over time, they may still exhibit subtle language deficits. Individuals with ASD may produce speech with less syntactic flexibility (Eigsti, Bennetto, & Dadlani, 2007), though evidence for impairments in syntax is mixed (Shulman & Guberman, 2007). Semantic processing may also be impacted, with deficits in the perception and production of mental state verbs (Kelley, Paul, Fein, & Naigles, 2006) and reduced semantic priming (Kamio, Robins, Kelley, Swainson, & Fein, 2007).

The most consistent communicative deficits in ASD are observed in the domain of pragmatics. Individuals with ASD often fail to respond appropriately to questions or comments (Capps, Kehres, & Sigman, 1998), leading to more potential communicative misunderstandings (Volden, 2004). Individuals with ASD also struggle to accurately and efficiently comprehend prosody (Diehl, Bennetto, Watson, Gunlogson, & Mcdonough, 2008; Diehl, Friedberg, Paul, & Snedeker, 2015), leading to difficulties resolving syntactic ambiguity or understanding a speaker's intentions (e.g.,

sarcasm). Deficits in prosodic comprehension are likely not the result of gross sensory differences, as individuals with ASD are typically reported to show heightened sensory acuity (Hubert, Mottron, Dawson, Soulie, & Burack, 2006; Plaisted, O'Riordan, & Baron-Cohen, 1998).

One potentially informative aspect of pragmatic language functioning in ASD is that of phonetic convergence. In order for interlocutors to understand one another, they must accurately map acoustic speech signals onto mental representations of *phonemes*, the sounds that make up a given language. This task is complicated by variability of this mapping between and within speakers. Over time, a pair of interlocutors may approximate each other's acoustic-phonetic mappings (Pardo, 2006; Shockley, Sabadini, & Fowler, 2004). This process is broadly referred to as phonetic accommodation. Typically this accommodation comes in the form of *convergence*, when the acoustic features of interlocutors become more similar over time. Phonetic convergence can be observed in several acoustic features, including duration, voice onset time, and F0 (i.e., pitch), and likely reflects broader processes of scaffolding (Pickering & Garrod, 2013).

Differences in sensory sensitivity may lead to greater salience of phonetic variability in individuals with ASD, leading to greater convergence. Eigsti & Fein (2013) demonstrated that greater accuracy in a tone discrimination task in adolescents with ASD was negatively related to later achievement of early language milestones, suggesting that auditory processing differences (specifically, perceiving small and non-contrastive or within-category phonetic variability) may lead to language delays by magnifying speaker variability. A number of auditory processes differ in ASD (see O'Connor, 2012). However it remains unclear whether sensory differences relate to communication skills in fluent speakers with ASD.

The degree to which a speaker converges with an interlocutor appears also to be influenced in part by social factors. For instance, Gregory & Webster (1996) demonstrated that speakers tend to display more communicative accommodation to individuals with higher social status (celebrities or politicians). Similarly Babel (2012) showed that phonetic accommodation was positively associated with perceptions of an interlocutor's attractiveness. Such findings are consistent with Communication Accommodation Theory, which posits that accommodation is the result of an individual's desire to fit in with the social group (Soliz & Giles, 2014).

The Social Motivation Theory of ASD proposes that reward circuitry is less engaged during social interactions in individuals with ASD (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). If social affiliation is central to phonetic convergence, we might expect diminished convergence for speakers with ASD as a result of reduced motivation.

The present study sought to examine whether individuals with ASD display a different pattern of phonetic convergence than their typically developing (TD) peers across a naturalistic conversation. We hypothesized that individuals with ASD would show less communicative convergence to their interlocutors due to differences in social motivation. Alternatively, heightened sensory sensitivity may lead to increased recognition of and convergence with acoustic variability of communication partners.

Methods

Participants

Adolescents ages 12-18 with ASD (n=15) and TD (n=15) were recruited for the study. All participants demonstrated hearing and IQ scores (>85) in the normal range. TD participants were excluded if they had first-degree family members with ASD or a history of developmental or neurological concerns. The two groups did not differ on age, gender, or non-verbal IQ (see Table 1).

Diagnoses for the ASD group were verified by trained clinicians using the Autism Diagnostic Observation Scales, 2nd edition (ADOS; Lord et al., 2012) and the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). The ADOS was completed only by members of the ASD group, to confirm the diagnosis of ASD. Depending on each participant's maturity, Module 3 or Module 4 was administered. The SCQ, a 40-item parent-report measure, served to confirm or rule out ASD diagnoses in both groups. Participants' parents completed the Lifetime version, which probes whether autism-related symptoms have ever been present for a child. Two parents in the TD group did not return the measure; one parent in the ASD group had many ambiguous responses which could not be scored, such that scorable data were available for 27 participants.

All participants in the ASD group scored above the ADOS cutoff score of 7 for autism spectrum; eleven participants in the ASD group scored above the ADOS cutoff score of 9 for autism. Furthermore, the ASD group scored significantly higher on the Social Communication Questionnaire, a parent-report measure of ASD symptoms (Rutter, Bailey, & Lord, 2003), indicating greater impairment. While four ASD participants scored below the SCQ cutoff of 15, we judged them to have ASD, given their reported history of an ASD diagnosis and expert clinical judgement on the ADOS.

Participants completed two subtests (Matrices and Vocabulary) of the Stanford-Binet Intelligence Scales, 5th Ed. (Roid, 2003). Together, these subtests provide a reliable estimate of full-scale IQ (FSIQ). Performance on each subtest provided estimates of non-verbal and verbal IQ.

Table 1: Participant Characteristics

	ASD	TD	p
n	15 (11 male)	15 (10 male)	
Age (years)	15.6 (2.0)	14.6 (1.8)	.17
Abbreviated IQ	105 (10)	111 (9)	.13
ADOS	9.7 (1.9)	-	-
SCQ	17.6 (8.1)	2.1 (1.6)	<.001

Materials

Maps Task (Anderson et al., 1991) The Maps Task is a social communication problem-solving task. Materials consist of six pairs of maps. For each pair, a "Guide" map (Figure 1, left) displays a route around a variety of landmarks; a "Tourist" map shows landmarks, but no route. All landmarks were labeled, as shown in Figure 1. Each pair of maps contained largely identical landmarks, with the exception of three unique (i.e., non-shared) landmarks in each map.

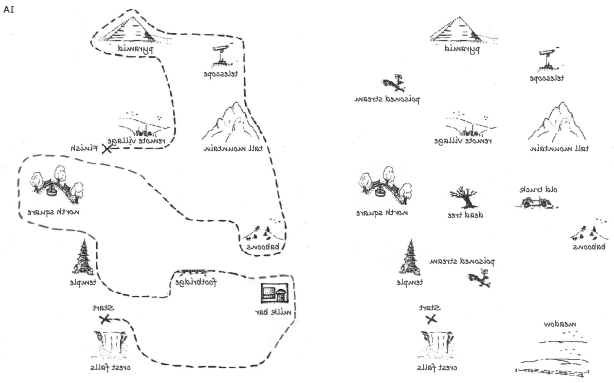


Figure 1: Guide (left) and Tourist (right) maps, showing shared and unique landmarks.

Short Sensory Profile (McIntosh, Miller, Shyu, & Dunn, 1999). The Short Sensory Profile is a 38-item parent-report measure which rates clinically relevant, sensory-related difficulties on a five-point scale from Always to Never. Items describe sensory seeking/avoiding behaviors across all sensory modalities, including items such as "Is distracted or has trouble functioning if there is a lot of noise around" or "Will only eat certain tastes." Higher scores on the Short Sensory Profile represent more *typical* sensory experiences; lower scores suggest greater atypicality of sensory responses.

Procedure

The present experiment was completed as part of a broader study of language in ASD. Testing was completed over approximately five hours across one or two sessions. Participants completed a number of characterizing measures, including screening to ensure normal IQ and hearing abilities.

Participants completed the six trials of the Maps Task with gender-matched confederates blind to the purpose of the study and participants' diagnosis. On a given trial, the "guide" described the route marked on their map to the "tourist," who attempted to draw this route on their own map with a pencil. After each trial, the participant and confederate alternated roles, such that participants served as "guide" and "tourist" three times each. Participants and confederates were able to freely converse throughout the task. An opaque barrier was placed between the participant and confederate to prevent nonverbal communication.

Before and after the maps task was completed, recordings were elicited from participants and confederates. Each member of the dyad read a list of sentences which contained lexical items labeled on the maps. Items were elicited in a standardized context (e.g. "*Number eight is the lighthouse*").

Data Analysis

Speech samples were coded in Praat (Boersma & Weenink, 2011) by trained coders, blind to study hypotheses, to assess the similarity of temporal and spectral speech properties of each dyad before and after the maps game; greater similarity for items produced after the game was taken as evidence of phonetic convergence. Coders marked regions of acoustic energy associated with 5 phonemes: /k/, /p/, /t/, /s/, and /ʃ/ ("*sh*") and for a standardized subset of ten sentence. These were the only five phonemes that occurred frequently enough to permit spectral analysis; and in fact, there were sufficient quality elicitations for only two phonemes, /s/ and /ʃ/. Praat scripts were used to analyze coded regions for duration, spectral center (for phonemes), and fundamental frequency (for sentences). The mean absolute difference (participant – confederate) was calculated before vs. after the maps game, for each of these measures, within each dyad. Three dyads were excluded from analysis of sentence-level measure because of insufficient data.

Results

Segmental Convergence

Differences in temporal convergence (duration) across diagnostic groups were assessed using a 2x2 repeated measures ANOVA (diagnosis x time) for both phoneme measurements. Results showed a significant diagnosis x time interaction for /s/, $F(1,27)=6.38$, $p=.02$, such that TD dyads showed more similarity in duration after the maps game compared to before (e.g., greater temporal *convergence*), while ASD dyads showed temporal *divergence* (though the latter within-group difference was not significant)*; see* Figure 2. For /ʃ/, there was a significant main effect of diagnosis on duration, $F(1,27)=4.67$, $p=.04$, such that ASD dyads produced /ʃ/ sounds with significantly longer duration than did TD dyads; see Figure 3. There was no significant diagnosis by time interaction for /ʃ/.

There were no main effects or interactions for spectral measures for either /s/ or /ʃ/, p's > .05.

Prosodic Convergence

Differences in prosodic convergence were assessed using 2x2 repeated measures ANOVAs (diagnosis x time) for sentence duration. Results indicated no main effects or interactions, p's > .05. There was a marginally significant diagnosis by

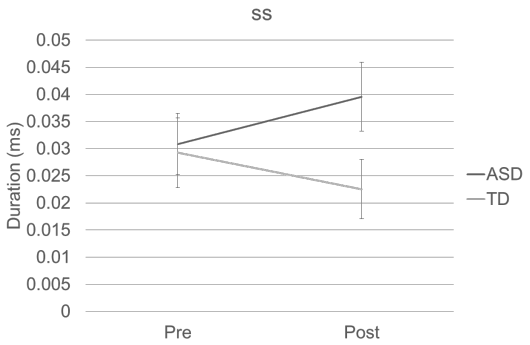


Figure 2: Mean difference (±SE) in /s/ duration between dyads. TD dyads displayed decreased difference in duration from pre- to post-task. ASD dyads showed the opposite effect.

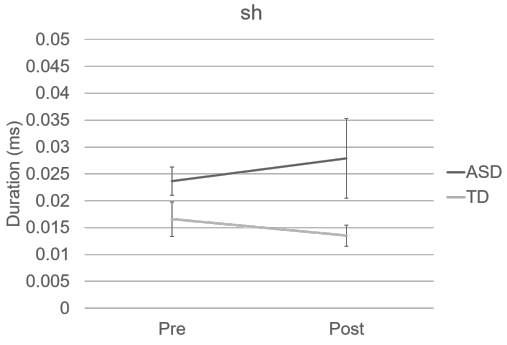
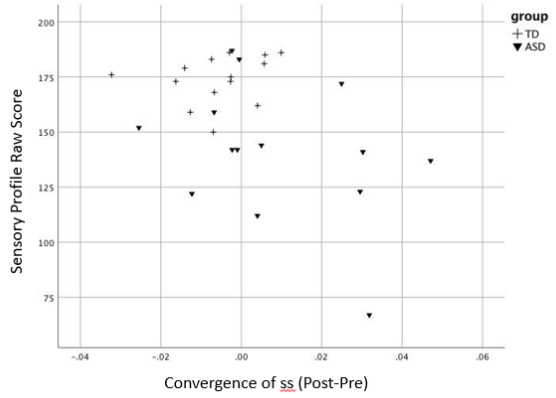


Figure 3: Mean difference (±SE) in /ʃ/ duration between dyads. ASD dyads showed greater overall difference in duration. There was no significant diagnosis by time interaction effect.

time interaction on average F0, p=.08, such that the difference in F0 increased in pre- to post-task recordings for TD dyads, while the opposite effect was observed for ASD dyads.

Convergence and ASD Symptoms

Planned analyses additionally assessed the relationship between ASD symptom severity as measured by the SCQ, available for both diagnostic groups, and the degree of convergence in /s/ duration (Pre-Post), as this was the most reliable measure of convergence in previous analyses. There was a significant negative relationship between SCQ and convergence, $r(26)$=-0.44, p=.03, such that more severe symptomatology was associated with less phonetic convergence. Convergence was also correlated with sensory sensitivity as measured by the Short Sensory Profile, $r(26)$=-0.43, p=.03, such that more atypical sensory sensitivities (i.e., lower scores) were related to *greater* convergence; see Figure 4.



convergence of /s/ duration and sensory profile score as a function of diagnosis. Lower sensory profile scores represent more atypicality. Larger convergence values indicate that the difference between productions differed more in the pre- versus post-task elicitation.

Discussion

This study examined the impact of sociolinguistic and perceptual differences in ASD on phonetic convergence. Teens with ASD and TD completed a collaborative task with TD confederates, in which they worked together to accomplish a goal. Verbal items were elicited before and after task completion, and subjected to extensive analysis in Praat. Participants' parents also completed measures of sensory processing and ASD-related symptom severity.

Results suggested less convergence with confederates in the ASD sample, compared to the TD group, though results were mixed across measures of convergence. Within the most robust measure of convergence (e.g., /ss/), *greater* ASD symptomatology was associated with *less* convergence. That is, typically developing individuals and their partners tended to mimic each other's speech after they had engaged in a cooperative task; in contrast, individuals with ASD showed no such increase in speech similarity. Interestingly, participants with an atypical sensory profile displayed greater phonetic convergence. Limitations in the measure of the Short Sensory Profile make it difficult to fully interpret this relationship (see Limitations, below).

These findings suggest that individuals with ASD do show diminished phonetic convergence, consistent with Communication Accommodation Theory. Indeed, there was a non-significant tendency towards divergence. This finding would suggest that social factors are an important contributor to speaker accommodation, and that either participants with ASD, or their conversational partners, may be inclined to accentuate *differences*. The lack of convergence within the ASD group in this study may be the result of diminished motivation for social affiliation, which has been suggested as a core deficit in ASD (Chevallier et al., 2012). Alternatively, differences in social perception may make individuals with ASD less likely to view interlocutors as socially desirable partners, especially when these interlocutors are strangers. Previous research has demonstrated that adults with ASD are more likely to rate happy faces as neutral and neutral faces as angry (Eack, Mazefsky, & Minshew, 2015). Such misperception of facial emotion may reflect the accuracy

with which individuals with ASD are able to appraise the social standing of an interlocutor. Future work must probe whether it was the participant or TD confederate whose speech shifted more.

The present results indicated that greater sensory atypicality was associated with more convergence. ASD symptom severity across groups was also strongly associated with sensory sensitivities; in fact, Figure 4 suggests that this correlation reflects group rather than individual differences in sensory processing, and thus that sensory processes are less likely to contribute to reduced phonetic convergence in ASD.

Limitations

Data analysis was limited by the speech samples obtained. The list of landmarks did not include sufficient exemplars of phonemes other than /s/ and /ʃ/ to provide robust and reliable estimates; as such, analyses were limited to spectral and temporal components of /s/ and /ʃ/. The results presented here should be replicated with a broader range of phonemes, especially in light of the inconsistent pattern of convergence for these two phonemes.

Another limitation of the study is the lack of a clear interpretation of the observed relationship between atypical sensory profile and increased convergence. The Short Sensory Profile includes items which indicate both sensory *hyper*- and *hypo*-sensitivity; low scores indicate the presence of sensory differences, but do not indicate the nature of these differences. Ongoing work in our laboratory aims to directly measure differences in auditory processing and correlate these differences to linguistic development.

It is important to note that the degree of convergence noted here was small (approximately 10ms). Given the imperceptibility of this change to a real-world interlocutor, it is unlikely that any difference between diagnostic groups within one measure would meaningfully impact communication. However, the convergence of these small changes across many aspects of speech may have more appreciable effects. The use of read rather than spontaneous speech samples may have reduced variability.

Finally, the mean IQ of participants in the ASD group is not representative of all individuals with ASD. Rather, our sample represents a high-functioning subset, and the results presented here may not generalize to the broader population.

Clinical Implications and Future Directions

The present study demonstrated diminished communicative convergence in individuals with ASD; one important next question is to determine the impact of such convergence on communication. It is possible that diminished communicative accommodation could lead to a less positive responses from a conversational partner, contributing to difficulties in the formation and maintenance of positive social relationships. Future research should examine the impact of reduced convergence, at multiple levels (phonology, lexicon, syntax, etc.), on social interactions within ASD (see e.g., Pickering & Garrod 2013).

Broad differences in communicative accommodation may also be important factors in the presentation of "frank" autism. De Marchena & Miller (2017) have discussed the construct of frankness in clinical diagnostic impressions. Expert clinicians reported that amongst other symptoms, reciprocity and prosody represent important components of frankness. While differences in phonetic convergence are relatively subtle, a difficulty in accommodating to multiple facets of communication, including phonetic qualities, non-verbal actions, or shared lexical items, may serve as signals of frank autism.

It also remains unclear to what extent communication accommodation is amenable to clinical intervention. Mayo (2014) demonstrated that a brief intervention was sufficient for individuals with ASD to improve their syntactic prosody. Direct interventions which teach individuals with ASD how to appropriately mimic conversational partners might address some of the differences observed here. Early intervention in facial emotion recognition has proven effective (Ofer et al., 2010), as it seems to improve the accuracy of perceptions of partner desirability and social status in individuals with ASD.

Conclusion

This study presented evidence of reduced phonetic accommodation in individuals with ASD, and an association between this phenomenon and the presence of social deficits. This effect was elicited over the course of a naturalistic conversation, rather than under instructions to explicitly mimic or shadow their partner. While results were limited by lack of reliable measures for several phonemes, findings are consistent with the hypothesis that individual differences in social cognition, rather than sensory processes, may be critical in phonetic convergence.

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