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Conversational adaptation in children and teens with autism: Differences in talkativeness across contexts

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Abstract

Successful social communication is complex; it relies on effectively deploying and continuously revising one's behavior to fit the needs of a given conversation, partner, and context. For example, a skilled conversationalist may instinctively become less talkative with a quiet partner and more talkative with a chattier one. Prior research suggests that behavioral flexibility across social contexts can be a particular challenge for individuals with autism spectrum condition (ASC), and that difficulty adapting to the changing needs of a conversation contributes to communicative breakdowns and poor social outcomes. In this study, we examine whether reduced conversational adaptation, as measured by talkativeness, differentiates 48 verbally fluent children and teens with ASC from 50 neurotypical (NT) peers matched on age, IQ, and sex ratio. Participants completed the Contextual Assessment of Social Skills with two novel conversation partners. The first acted interested in the conversation and talked more (Interested condition), while the second acted bored and talked less (Bored condition). Results revealed that NT participants emulated their conversation partner's behavior by being more talkative in the Interested condition as compared

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Author contributions.
MC and JPM conceived of the study hypotheses, conducted literature searches, collected, analyzed, and interpreted data, produced figures, and drafted the manuscript; SP, VP, KT, AR, and CJZ participated in study conceptualization, data collection and interpretation, and manuscript revisions; LY, JP, and RTS contributed to conceptualization, interpretation, and manuscript revisions. All authors had full access to all the data in the study and shared final responsibility for the decision to submit for publication.

Ethical approval.
The Institutional Review Board of the Children's Hospital of Philadelphia provided approval and oversight for this study. All participants provided consent (parental consent for participants under age 18) and assent when possible.

to the Bored condition ($z = 9.92$, $p < .001$). In contrast, the ASC group did not differentially adapt their behavior to the Bored vs. Interested context, instead remaining consistently talkative in both ($p = .88$). The results of this study have implications for understanding social communication and behavioral adaptation in ASC, and may be valuable for clinicians interested in improving conversational competence in verbally fluent individuals with autism.

Lay Summary

Social communication – including everyday conversations – can be challenging for individuals on the autism spectrum. In successful conversations, people tend to adjust aspects of their language to be more similar to their partners'. In this study, we found that children and teens with autism did not change their own talkativeness in response to a social partner who was more or less talkative, whereas neurotypical peers did. These findings have clinical implications for improving conversational competence in verbally fluent individuals with autism.

N.B. In line with variable preferences expressed by self-advocates, caregivers, and parents within the autism community (Brown, 2011; Dunn & Andrews, 2015; Kenny et al., 2016), this paper uses both identity-first language (i.e., autistic participants) and person-first language (i.e., participants with autism). This paper also uses the term Autism Spectrum Condition (ASC) instead of Autism Spectrum Disorder (ASD) to reflect the perspective that autism is a neurodevelopmental difference rather than a pathology (Bottema-Beutel et al., 2021). In this paper, our terminology is drawn from World Health Organization definitions, such that the word "sex" refers to genetic makeup, and "gender" refers to a socio-cultural construct (World Health Organization, 2015); we use the words "girl" and "boy" to refer to sex as reported by parents or caregivers. We acknowledge that the concepts of sex and gender are not binary and recognize that many autistic individuals identify as transgender, non-binary, or gender diverse (Strang et al., 2018, 2020).

Keywords

Autism Spectrum Disorder; Autism Spectrum Condition; conversational adaptation; social behavior; social communication; language

Introduction

Autism spectrum condition (ASC) is a neurodevelopmental condition characterized by social communication challenges that are present during early childhood and persist into adulthood (American Psychiatric Association, 2013; Yankowitz et al., 2019). For many verbally fluent individuals, these social communication challenges manifest most clearly during informal conversations (Müller et al., 2008). To maintain a successful conversation, individuals must read the fast-paced and often unpredictable verbal and nonverbal cues produced by conversation partners and adjust their own behaviors accordingly. For example, they may need to adapt their conversational behavior to talk less when their partners are quiet, but talk more with increasingly loquacious partners. This type of sensitivity to a partner's social cues is an important component of real-world conversational skills, which predict long-term social outcomes including friendships and vocational independence in ASC (Friedman et al., 2019), but are also challenging to achieve (Ratto et al., 2011; Romero et al., 2018; Tordjman et al., 2015). In this study, we measured talkativeness to explore how children and teens with ASC and matched neurotypical (NT) peers adapt their conversational contributions in response to their social partner's behavior during brief naturalistic interactions with new acquaintances.

Conversational Adaptation.

In successful conversations, speakers quickly read their partner's verbal and nonverbal cues (e.g., head nods, speech rate, smiling, increased volume, topic shifts, etc.; Figure 1) and respond by dynamically adjusting their own contributions to maintain or improve social flow. These online adjustments during interactions – which often result in convergence on the complementary processes that define "good" conversation – can be understood as forms of adaptation. *Conversational adaptation* – which is conceptually related to research on accommodation, alignment, convergence, entrainment, coordination, synchrony, and social adaptation – is a process by which individuals alter their communicative behaviors in response to cues emitted by a conversation partner (Borrie et al., 2019; McNaughton & Redcay, 2020; Pickering & Garrod, 2006; Ratto et al., 2011; Wynn et al., 2019; Zampella et al., 2020). In this paper, we operationalize the term conversational adaptation to refer to adjustments in the amount of language (talkativeness) produced by participants across two different interaction contexts (i.e., with an interested vs. bored partner who talks more or less).

A significant body of research has demonstrated the social benefits of conversational adaptation in neurotypical (NT) adults (i.e., Borrie et al., 2019; Garrod & Pickering, 2004; Manson et al., 2013; Pickering & Garrod, 2006). For example, research suggests that in the general population, speech rate convergence is associated with improved rapport, perceived warmth, and cooperation between social partners (Manson et al., 2013). Additionally, NT adults have been shown to alter their talkativeness in response to situational cues, such as interpersonal motivations (Burd, 2014). Variation in the degree to which individuals adapt their behavior to align with the speech patterns of their conversational partners correlates with social preference (or desired social closeness) for others, demonstrating the potential impact of these behaviors on immediate friendship prospects (Babel et al., 2014). In contrast, disruptions to the process of conversational adaptation during social interactions yields significant negative consequences and affects a person's ability to engage in mutually rewarding exchanges, communicate effectively with others, and build relationships. For example, difficulty reading and responding to a peer's social cues during conversations (and failure to adjust one's own contributions accordingly) has been shown to negatively impact an individual's ability to make and retain friends (Lakin et al., 2003).

Far less is known about the emergence and influence of conversational adaptation in NT children than adults. However, some building blocks for later adaptation in verbal behavior – like vocal turn-taking and pitch adjustment in response to parental voices during infancy – are present from an early age and considered foundational for neurotypical social development (Feldman et al., 2011; Harbison et al., 2018; Jaffe et al., 2001; E.-S. Ko et al., 2016; Northrup & Iverson, 2015; Oller, 2001; Warlaumont et al., 2014; Yankowitz et al., 2019). Given the limited research on conversational adaptation in neurotypical child development and the importance of this phenomenon to optimal long-term social functioning, additional studies are warranted.

Conversational Adaptation in ASC.

For many individuals on the autism spectrum, the ability to fluidly read and appropriately respond to dynamic verbal and nonverbal signals during spontaneous conversation poses a significant challenge that can lead to less successful interpersonal interactions with NT peers (Dolan et al., 2016; Feldstein et al., 1982; Grossman & Tager-Flusberg, 2009; J. A. Ko et al., 2019; Ruiz, 2019; Tordjman et al., 2015; White et al., 2015). Interestingly, reduced conversational adaptation in ASC can manifest quite differently from person-to-person; whereas some verbally fluent autistic people engage in monologuing (i.e., talking too much), others are overly reticent (i.e., talking too little) across conversations (Adams et al., 2002). Reduced conversational adaptation in ASC may also be driven by difficulties with behavioral inflexibility, which is widely acknowledged to be a core feature of the restricted and repetitive behaviors/interests domain of autism (Bertollo et al., 2020; Kanner, 1943; Lecavalier et al., 2020). Thus, for some autistic individuals, behavioral inflexibility may present as indiscriminate levels of talkativeness about a particular interest or preferred topic across a number of social settings, even when it is not appropriate.

Findings from research on conversational adaptation in individuals with ASC have been mixed. When structured tasks are used (e.g., an adult experimenter uses a certain phrase or label and then assesses the child's later use of that phrase or label), autistic children have been shown to successfully adapt their language to incorporate the new grammatical structures (Allen et al., 2011; Hopkins et al., 2016). Similarly, research on word choice suggests that autistic individuals and NT peers demonstrate comparable levels of spontaneous lexical adaptation or matching (Branigan et al., 2016; Hopkins et al., 2017). Consistent with this evidence of typical levels of grammatical and lexical adaptation in children, research has demonstrated that autistic adults also adapt these aspects of language and adjust their frame of reference when describing object locations to a conversation partner (Slocombe et al., 2013). Notably, these language-based adaptation studies in ASC typically used an NT adult as the conversation partner and utilized structured, goal-oriented tasks, which may mitigate some social challenges for the autistic group and significantly limits the ecological validity of study results.

In contrast to typical levels of alignment seen in structured tasks, results from less structured tasks suggest that individuals with ASC engage in atypical or reduced conversational adaptation. Research on the *pragmatic* aspects of conversation – which center on the use of appropriate communication in social situations – shows that children with ASC are less likely to successfully adapt their social language behavior according to context. Specifically, results from social interaction tasks suggest that children with ASC are less likely to develop a shared vocabulary (Nadig et al., 2010) and less likely to establish conversational "common ground" with NT adult conversation partners (de Marchena & Eigsti, 2016) compared to NT peers. Prior research has shown that although adolescents with ASC incorporate language elements of their conversation partner's previous utterance into their own utterances at similar levels as NT peers (Hobson et al., 2012), they are more likely to elaborate their responses in atypical ways (Du Bois et al., 2014; Hobson et al., 2012). Autistic individuals may also be less sensitive to *changes* in social context when adapting their conversational behaviors (e.g., switching to a new conversation partner). For example, when adults with ASC switch partners during a referential task, they are slower to adapt and relatively less likely than NT peers to incorporate new information produced by conversation partners (Nadig et al., 2015). Similarly, during spatial configuration tasks, autistic adults are less likely than NT peers to demonstrate interpersonal agreement on the meaning of their communicative behaviors, particularly when interacting with a new partner (Wadge et al., 2019). Given the importance of spontaneous, dyadic communication in everyday life, it is critical to examine conversational skills in less structured, naturalistic contexts. Further, in light of evidence of variability in the conversational skills of individuals with ASC across different partners, it may be especially informative to study how behavior changes across conversational contexts.

Contextual Assessment of Social Skills (CASS).

The social demands of naturalistic conversations are different than the demands of structured interviews or assessments, and these differing contexts can impact talkativeness, intelligibility, and narrative quality in autistic individuals (Hilvert et al., 2020; Kover et al., 2014; Lee et al., 2020; Sng et al., 2018). The Contextual Assessment of Social Skills (CASS; Ratto et al., 2011) is one way to assess how individuals with ASC respond to changes in conversational context. As a naturalistic laboratory-based measure designed to maximize ecological validity and generalizability, the CASS has been used to evaluate social competence in both youth (Corbett et al., 2020; Dolan et al., 2016; Rabin et al., 2018; Simmons et al., 2020) and adults with ASC (Parish-Morris et al., 2018; Ratto et al., 2011; White et al., 2015). It consists of two 3-minute conversations with novel conversation partners (confederates). The first confederate demonstrates social interest in the participant during the conversation (Interested condition; talks more), while the second confederate indicates boredom and disengagement (Bored condition; talks less). These two conversations provide a context for indexing social competence, including initiating an interaction with an unfamiliar partner, managing verbal and non-verbal skills to maintain a social interaction, assessing a conversational partner’s receptiveness, and what to do when he or she is uninterested (Ratto et al., 2011; White et al., 2015). Differences in the participants’ behavior between the Interested and Bored conditions are thought to capture participants’ awareness of their conversation partner and ability to respond accordingly (i.e., conversational adaptation).

Traditionally, behavior during the CASS is assessed using third-party observational ratings at a global level, which measure conversational skills across several dimensions and specifically focus on a person’s ability to *adapt* in response to changes in social context. The initial validation study (Ratto et al., 2011) found that autistic adults showed less engagement in the Interested condition compared to NT peers, as demonstrated by fewer questions asked, fewer topic changes, lower ratings of rapport, and reduced overall involvement in the conversation. Additionally, adaptation across the two conditions predicted participants’ diagnostic status; both autistic and NT adults made more of an effort to engage with the

Bored confederate compared to the Interested confederate across domains, but those with ASC adjusted their behavior *less*.

Prior research in adolescent samples has primarily utilized either the CASS Interested condition only (not Bored) and/or the CASS behavior rating scheme in the context of intervention outcomes (Corbett et al., 2020; Dolan et al., 2016; Rabin et al., 2018; Simmons et al., 2020; Van Pelt et al., 2020). Results showed significant intervention effects for conversational involvement and overall quality of rapport, with participants asking more questions and showing more balanced conversational contributions relative to their partner after a social skills treatment. Notably, increased conversational involvement was the only significant predictor of parent-reported social skills improvement, suggesting it may be the most salient component of laboratory-based social interactions (Rabin et al., 2018). Taken together, these results indicate that language produced during the CASS has clinical significance – with conversational involvement (or "talkativeness") and contribution relative to partner (or "adaptation") being particularly meaningful with regard to intervention effects and real-world social functioning.

To the authors' knowledge, only one study of adolescents to date has included participants' behavior during the CASS Bored condition in their analysis (Simmons et al., 2020). Other studies have chosen to exclude the Bored condition either for logistical reasons or due to concerns that it could be a poorer treatment outcome measure than the Interested condition (Corbett et al., 2020; Dolan et al., 2016; Rabin et al., 2018; Van Pelt et al., 2020). However, by eliminating engagement with both an Interested and Bored conversation partner, researchers forfeit the opportunity to assess conversational adaptation across contexts. Simmons and colleagues (2020) analyzed participants' ratings of confederate behavior and found that autistic adolescents were generally able to discriminate between Interested and Bored conversation partners. In line with this result, it is possible to use the CASS conversations to assess intra-individual adaptation across social contexts (with an Interested vs. Bored partner) in adolescents with ASC. Notably, the study by Simmons and colleagues (2020) did not include a matched neurotypical comparison group, meaning authors were unable to assess potential diagnostic group differences in participants' behavioral adaptation across social contexts.

Research gap.

Despite a growing body of research focused on conversational behaviors in ASC across settings, significant knowledge gaps remain. For example, little is known about how youth with ASC change their behavior from the Interested to the Bored conditions of the CASS. Analyzing participants' behavior across both CASS conditions would provide a multiple-context assessment method for evaluating conversational skills across two interactions. Measurement could also be improved; the global-level observational third-party coding systems used in the extant CASS research provide useful information about dyadic interactions as a whole, but they often fail to disentangle *which specific effects are driven by each conversation partner*. Identifying exactly *who* contributes *what* to a conversation is critical for refining personalized treatment targets, and could be achieved using alternative measurement approaches (e.g., an objective language measure such as word count). Most behavioral coding schemes also rely – to some degree – on subjective assessments of behavior that leave room for human error or biases; these sources of noise may obscure potential effects. Finally, some ratings within the CASS coding system include multiple aspects of behavior in a single code, rendering it difficult to identify *precisely which feature* is driving the effect (e.g., the "vocal expressiveness" rating evaluates participants' ability to appropriately vary the rate and rhythm of their speech, as well as their vocal tone, to communicate ideas or emotions (Ratto et al. 2011, p. 5)). Given the complex nature of these nuanced conversational behaviors, assessing conversational adaptation during the CASS using more quantitative and objective measures such as word count or relative word frequency could prove fruitful. In line with recent reviews highlighting the importance of understanding interpersonal coordination in the context of ASC (Bottema-Beutel, 2017), reliable measures of conversational adaptation could also provide critical insight into the real-world functioning of individuals with social communication challenges.

Interestingly, prior research on conversational skills in individuals with traumatic brain injury (TBI) has utilized the *number of words produced during an interaction,* or talkativeness, to measure adaptation. Differences in the number of words produced by individuals with TBI relative to NT controls resulted in conversations that were rated as lower quality by third-person observers, suggesting a link between word count and conversation quality (Gordon et al., 2015). Additionally, raters were less likely to want to converse with participants who did not adjust their number of words to match their interlocutor's contribution, highlighting the potential downstream effects of atypical talkativeness on social success.

The current study.

In this study, we evaluate the effect of a conversational partner's behavior on the talkativeness (as measured by number of words produced or word count) of school-aged children and adolescents with ASC and matched NT peers during brief experimentally manipulated conversations with new acquaintances (the CASS). In contrast to prior research that relied on human judgement to produce CASS ratings at a global level, our study employs an *objective* frequency-based approach to measuring conversational adaptation across Interested and Bored conditions. This method, focused on word count, allows us to concretely and clearly separate the two sides of the conversation into discrete variables. Our primary research question is focused on conversational adaptation in talkativeness: do children with and without ASC adjust the number of words they produce in response to a more- or less-talkative partner? Based on prior research suggesting that autistic individuals are less likely to modulate various aspects of their own behavior according to context (Chevallier et al., 2014; Lehnert-LeHouillier et al., 2020; Morett et al., 2016; Parish-Morris et al., 2019; Ratto et al., 2011; Wynn et al., 2018), we hypothesized that autistic participants would demonstrate reduced conversational adaptation compared to NT participants.

Methods

Participants.

Ninety-eight participants with ASC (n=48, 28 males, 20 females) or NT (n=50, 28 males, 22 females) aged 7-17 years old were selected from a pool of verbally fluent individuals who participated in at least one study that included our primary experimental task (CASS), during a visit to a large academic medical research center. The larger studies also included ASC diagnostic assessments, IQ testing, and behavioral tasks. To match groups, participants with complete data (age, sex, race, autism diagnostic tests, and IQ testing) were first selected from the larger pool; participants were excluded if they had full-scale IQ estimates below 80, if they were younger than 7-years-old, or if they were older than 17-years-old (see Supplemental Materials, S1). ASC and NT groups were matched group-wise on mean chronological age, mean IQ, and sex ratio. Additionally, given growing recognition of various sex differences in autism symptomology (Beggiato et al., 2017; Boorse et al., 2019; Harrop et al., 2019; Rynkiewicz et al., 2016), autistic girls and boys were matched on autism symptom severity as measured by the Autism Diagnostic Observation Schedule – Second Edition (ADOS-2; Lord et al., 2012) and Social Communication Questionnaire (SCQ) "Lifetime" version (Rutter et al., 2003). Verbal fluency was defined by expressive language skills at or above a typical four-year-old level, including the ability to demonstrate regular use of complex sentences, produce a range of sentence types and grammatical forms, provide information beyond immediate context, and use logical connections such as "but" and "because" (Lord et al., 2012). Group matching was completed before performing any analyses on participants' language. Participant characteristics and matching statistics are provided in Table 1.

Participants were recruited using a variety of methods, including public advertising, word of mouth, and re-recruiting from previous studies. Participants were excluded if they had a known genetic syndrome, history of concussion or brain injury that impacted current functioning, history of medication use that caused permanent changes in motor behavior (e.g., amphetamines), gestational age below 34 weeks, or if English was not their primary language. Parents of participants provided written informed consent to participate in this study, which was overseen by the Institutional Review Board.

Measures.

All participants received the ADOS-2 (Lord et al., 2012), a clinician-administered assessment of the presence and severity of autism symptoms. Participants received Module 3 or Module 4, which require fluent verbal skills, depending on their chronological age and the examiner's clinical judgment. Overall scores were calculated, and calibrated severity scores (CSS) were generated for the domains of Social Affect and Restricted and Repetitive Behaviors (Hus et al., 2014). Parents also completed the SCQ (Rutter et al., 2003) to assess the presence of ASC symptoms. ASC and NT group determinations were made by expert PhD-level clinicians using the clinical best estimate (CBE) approach (Lord et al., 2012). The CBE method prioritizes DSM-5 criteria informed by developmental/medical history and an evaluation by an autism specialist. The Center for Autism Research does not rely solely on ADOS cutoff scores when diagnosing ASC, nor do subthreshold scores lead to automatic exclusion. This is because many clinical presentations can result in elevated scores on autism diagnostic metrics (e.g., ADHD; (Grzadzinski et al., 2016), and the behavioral snapshot afforded by the ADOS may not capture the full scope or impact of an individual's symptoms.

All participants also received a cognitive assessment. Clinicians administered either the Differential Ability Scales-2nd Edition (DAS-II; Elliott, 2007), the Wechsler Abbreviated Scale of Intelligence-2nd Edition (WASI-II; Wechsler, 2011), the Stanford-Binet Intelligence Scales-5th Edition, Abbreviated Battery (SB5; Roid, 2003), or the Wechsler Intelligence Scale for Children-5th Edition (WISC-V; Wechsler, 2014), according to the protocol of the larger studies from which the current sample was drawn. Composite scores across these assessments were standardized and reduced to a single cognitive estimate (Full Scale IQ) with verbal and nonverbal subscores by an expert licensed neuropsychologist (J. Pandey), to allow for comparison across tests.

Study procedure: Contextual Assessment of Social Skills.

Participants engaged in two 3-minute conversations with different novel conversation partners (confederates) as part of the Contextual Assessment of Social Skills (CASS; Ratto et al., 2011). Twenty-five young adult confederates (19 females; undergraduate students and research assistants) were trained to administer the CASS. Confederates had some basic knowledge about working with autistic youth, but were purposefully not informed of participant diagnostic status or study hypotheses. All confederates received ongoing fidelity oversight to ensure that they administered the CASS according to the protocol. Confederates were assigned to each participant based on availability, and there were no significant differences in confederate sex distribution by participant sex ($\chi^2 < .01$, $p = 1.00$) or diagnostic group ($\chi^2 = .90$, $p = .34$). Conversations were audio/video recorded using a device with two HD video cameras facing opposite directions, placed on a stand between participants and confederates seated across from one another, for simultaneous capture of both speakers (Parish-Morris et al., 2018).

At the start of each CASS conversation, a research assistant introduced the task using a variation of the phrase, "Thank you both for coming in today. Right now, you'll have a few minutes to talk and get to know each other, and then I'll come back in the room." The first confederate demonstrated social interest in the participant during the conversation (Interested condition; talked more), while the second confederate indicated boredom and disengagement (Bored condition; talked less). Confederates in the Interested condition were instructed to display engaged facial affect, posture, gestures, and eye contact, and to elaborate on statements made by the participant to encourage conversation. In contrast, confederates in the Bored condition were instructed to display disengaged affect, posture, gestures, and eye contact, and to provide terse responses to participants. Thus, the confederate's behavior in the Interested condition represents expected friendliness, while the Bored condition represents a violation of social expectations (Le Poire & Yoshimura, 1999; Ratto et al., 2011). Following the CASS procedures, the Interested condition was administered first and the Bored condition second, with less than one minute between conversations. Each participant interacted with novel Interested and Bored confederates (i.e., confederates were not co-present).

In both conditions, confederates were instructed to speak for no more than 50% of the conversation but were not provided with specific topics or prompts. If conversational lapses occurred, confederates in the Interested condition were instructed to wait 5 seconds before reinitiating the conversation, while confederates in the Bored condition waited 7 seconds. Research suggests that conversational pauses longer than 3 seconds are perceived as awkward by NT individuals and are often quickly filled during most conversations (McLaughlin & Cody, 1982; Tree, 2002). Extended wait times in the CASS are used to allow for variable processing speed in ASC, and to keep the conversational burden on the participant (Ratto et al., 2011). Slightly longer wait times are used in the Bored condition to maintain differences between Bored and Interested conversational contexts. This experimental manipulation is particularly important in light of evidence that individuals with ASC tolerate longer silences during conversational turn-taking (Ochi et al., 2019). As a result of the confederate behavioral constraints in the Bored condition (e.g., providing terse responses, allowing for longer pauses, displaying general disengagement), versus encouragement to “act interested” in the Interested condition, confederates produced more words in the Interested condition compared to the Bored condition (see Results). Conversation length across conditions did not differ, and there was no interactive effect of diagnosis and condition on the total length of the conversation (estimate: −2.70, SE: 3.84, $p = .48$; overall mean = 189.38 seconds, overall SD = 13.47 seconds).

Data processing.

Audio recordings of each conversation were orthographically transcribed using XTrans (S2; Linguistic Data Consortium, 2018). Annotators were undergraduate student research assistants, trained on a modified Quick Transcription protocol for XTrans (Kimball et al., 2004; Linguistic Data Consortium, 2018); all were trained on segmenting and transcription, with a minimum 92% word-level reliability criteria that must be met consistently before beginning to transcribe (Parish-Morris et al., 2016). Both junior and senior annotators worked on the transcription process. Junior annotators were allowed to segment or transcribe, but only senior annotators with at least six months of XTrans transcription experience were allowed to check and approve final transcripts. In addition to all transcribers achieving a minimum 92% reliability on training files before beginning official study transcription, we routinely calculate word-level reliability for 20% of participant samples as part of our standard processing pipeline and require the same 92% benchmark for ongoing transcription, as our research questions are focused primarily on word-level analyses. After transcription, final transcript files were converted to basic text format, imported into R, and processed for analysis using the “quantitative discourse analysis” (qdap) package (Rinker, 2018).

Dependent variables.

The primary dependent variable, talkativeness (defined as word count), was calculated by qdap individually for each speaker in each condition across the whole conversation. To further characterize the linguistic contributions of each speaker, additional language variables – characters per word, total number of syllables, total time speaking, and type-token ratio – were also calculated using qdap and in-house R scripts (see Tables 2 and 3). Type-token ratio (TTR) is a measure of lexical diversity, defined as the total number of unique words (types) divided by the total number of words (tokens, or word count) in a given segment of language. The closer the TTR is to 1, the greater the lexical richness of the segment. In this study, characters per word was used as a measure of the average length of words speakers produced (e.g., the word "no" has two characters while "corporation" has eleven). The average word length provides a proxy for measuring vocabulary complexity. Word count, number of syllables, and total time speaking variables measured how much a speaker was talking across the course of the conversation and were thus predicted to differ for participants between the Interested and Bored conditions. In contrast, characters per word and type-token ratio variables measures aspects of core language and thus were not predicted to differ for participants between the Interested and Bored conditions.

Statistical approach.

First, to assess differences in confederate behavior across diagnostic groups and CASS conditions (Interested vs. Bored), a generalized linear mixed effects regression (GLMER) modeled confederate word count using diagnosis and condition as predictors, with random effects of participant ID and confederate ID included to account for repeated measures. Including participant age, IQ, and sex as covariates did not change the overall pattern of results in the confederate model, and thus the simpler model is reported. Then, a GLMER modeled participant word count, using participant age (centered), full-scale IQ (centered), sex (male=0, female=1), diagnostic group (NT=0, ASC=1), and condition (Interested=0, Bored=1) as predictors, along with the interactive effect of diagnostic group and condition, with random effects for participant ID and confederate ID. Models used in the present analyses were tested progressively and selected using fit statistic parameters (AIC and BIC). GLMER models were specified using the "Poisson" distribution for positive count data. Tukey-corrected comparisons of estimated marginal means (EMM) were used to examine pairwise contrasts in the presence of significant interactions. Effect sizes are reported for GLMER as estimates (Pek & Flora, 2017), and as Cohen's *d* (Cohen, 2009) for group differences on clinical and demographic variables.

Results

Confederate word count.

To examine confederate talkativeness across diagnostic groups and conditions, we first measured the interactive effect of condition and diagnosis on confederate word count. GLMER revealed no significant interactive effect (estimate: .01, SE: .03, $z = .26$, $p = .79$), so the interaction effect was removed from the model. A final model including separate conditional main effects of diagnosis and condition revealed no significant effect of diagnosis on confederate word count, indicating that confederates' talkativeness was similar across diagnostic groups (estimate: .09, SE: .06, $z = 1.59$, $p = .11$; Figure 2). As expected, confederates produced fewer words in the Bored condition versus the Interested condition for both diagnostic groups (net difference in ASC = −97.8, NT = −103.1), leading to a significant main effect of condition (estimate: −.81, SE: .01, $z = -59.83$, $p < .001$).

The extent to which participants adjusted their talkativeness in response to this change in confederate behavior from Interested to Bored (i.e., reduced their own word count in response to reduced word count from their conversation partner) is the primary focus of subsequent analyses. Additional characteristics of confederate language by condition and diagnosis are presented in Table 2, with results mirroring those for word count (i.e., no significant interactions).

Participant word count.

To assess differences in participant behavior across diagnostic groups and CASS conditions (Interested vs. Bored), a GLMER modeled participant word count using age (centered), IQ (centered), and sex, along with the interactive effect of diagnostic group and condition, with random effects for participant ID and confederate ID. This regression revealed a significant interactive effect of condition and diagnosis on participant word count (estimate: −.14, SE: .019, $z = -7.09$, $p < .001$). Tukey-corrected pairwise comparisons of EMM revealed that the interaction was driven by significantly different word counts across Interested and Bored conditions in the NT group, but not the ASC group (Figure 2, Table 3). NT participants produced significantly fewer words in the Bored condition compared to the Interested condition ($z = 9.92$, $p < .001$; average net difference = −30.3 words), suggesting adaptation to the behavioral context provided by the confederate, who also produced fewer words in the Bored condition compared to the Interested condition (see above). In the ASC group, there was no such evidence of conversational adaptation ($z = .99$, $p = .97$; average net difference = 1.3 words).

Additional participant language features.

To further characterize participants' core language and determine whether conversational adaptation can be detected in other features, a series of separate GLMER were conducted that controlled for age (centered), IQ (centered), and sex, with participant and confederate IDs as random effects to account for repeated measures (Table 3). Word count, number of syllables, and total time speaking variables measured how much a speaker was talking across the course of the conversation and were thus predicted to differ for participants between the Interested and Bored conditions. In contrast, characters per word and type-token ratio variables measure aspects of core language and thus were not predicted to differ for participants between the Interested and Bored conditions. GLMER results revealed similar *core* language abilities in ASC and NT participants, as measured by similar type-token ratios and mean number of characters per word (Table 3), and may be expected when participant groups are matched on verbal IQ. However, the pattern of conversational adaptation found in word count also appeared in two related variables: total syllables produced and total time speaking. A GLMER predicting the total number of syllables participants produced revealed a significant interaction between condition and diagnosis (estimate: −.12, SE: .017, $z = -6.89$, $p < .001$; S4), with NT participants producing significantly fewer syllables in the Bored condition compared to the Interested condition ($z = 9.75$, $p < .001$). In contrast, the ASC group did not produce a significantly different number of syllables across the Interested and Bored conditions ($z = -.28$, $p = .99$). A GLMER predicting participant time speaking (sum of all participant utterances, in seconds) also revealed a significant interaction between condition and diagnosis (estimate: −.08, SE: .032, $z = -2.76$, $p = .006$; S5). This effect was again driven by NT participants, who spoke for less total time in the Bored condition compared to the Interested condition ($z = 6.16$, $p < .001$), whereas there was no difference in total time speaking across conditions in the ASC group ($z = 2.14$, $p = .14$). These results lend additional support to our primary finding of reduced conversational adaptation in ASC compared to NT.

Heterogeneity within ASC.

To examine variability within ASC, an exploratory data-driven, latent class modeling approach was used to identify homogeneous trajectories of talkativeness across conditions (Bored vs. Interested). Word count in both conditions was entered into a general latent class mixed model fitted using maximum likelihood. The optimal number of classes was detected using goodness-of-fit statistics (AIC and BIC). Posterior classification probabilities (Table 4) and demographics for class membership are reported (Table 5). To assess the relationship between class membership and clinical phenotype, class was used to predict ADOS-2 calibrated severity scores (CSS) using logistic regression.

Both two (AIC = 1127.15; BIC = 1138.38) and three class solutions (AIC = 1112.1; BIC = 1128.94) were considered. Results revealed the optimal number of classes in this dataset was three (Table 4; Figure 3). The most talkative class (10.42%) used more than 100 additional words in both the Interested and Bored conditions, compared to the other classes. The participants in the moderately talkative class (52.08%) produced word counts most similar to those of the NT group in both conditions. The least talkative class (37.5%) used fewer words in both the Interested and Bored conditions compared to the other classes. Notably, members of the moderately talkative class in ASC spoke as much as the NT group in the Interested condition (ASC = 238.76 words, NT = 247.68 words), but more than the NT group in the Bored condition (ASC = 250.20 words, NT = 217.42 words). Classes did not differ on a variety of variables (i.e., age, IQ, VIQ, NVIQ). Class membership significantly predicted ADOS-2 Total CSS ($F = 5.17$, $p <.001$) and ADOS-2 SA CSS ($F = 6.96$, $p = .002$), but not ADOS-2 RRB CSS ($F = .58$, $p = .56$), suggesting specificity within the social communication domain.

Heterogeneity within NT.

To explore variability within the NT group, an exploratory data-driven, latent class approach was used to identify homogeneous trajectories of talkativeness across two conversational contexts (Bored vs. Interested). Word count in both conditions was entered into a general latent class mixed model fitted using maximum likelihood. Notably, this analysis resulted in Class 1 containing 2 participants and Class 2 containing 48 participants. Thus, the word count of the NT group was remarkably consistent across participants and is best represented as a single class.

Discussion

Complex, dynamic social interactions are an everyday challenge for individuals with ASC, and the extent to which conversation partners adapt to each other's behavior has been shown to predict a variety of positive social outcomes (Borrie et al., 2019; Condon &

Sander, 1974; Jaffe et al., 2001; Schweitzer et al., 2017). This study is the first to test whether children and adolescents with ASC and neurotypical (NT) peers adjust the number of words they produce (talkativeness) in response to the differential behavior of a novel non-expert partner, across two different experimentally-manipulated naturalistic conversational contexts. Our primary finding was that as a group, NT participants significantly adapted their language contributions in response to changing conversational conditions: they spoke more when their conversational partners acted interested (and produced more words), and spoke relatively less when conversational partners acted bored (and produced fewer words). In contrast, autistic participants did not significantly adapt their conversational contributions to match their partners' behavior. That is, even when conversation partners acted bored and spoke less, as a group, participants with ASC spoke as much as when their conversation partners acted interested and spoke more. Thus, the NT group demonstrated conversational adaptation, as measured by talkativeness (word count), while the ASC group did not – rather, their behavior remained consistent regardless of the confederate's behavior. This pattern of adaptation in the NT group – and lack of adaptation in the ASC group – was also discernable in other language features, including total syllables produced and total time speaking.

Diminished conversational adaptation in ASC aligns with reports of reduced behavioral adaptation (or robust behavioral consistency) across a variety of social contexts, including language (Hilvert et al., 2020; Lehnert-LeHouillier et al., 2020), conversational involvement (Ratto et al., 2011; White et al., 2015), and eye gaze (Chevallier et al., 2015; Parish-Morris et al., 2019). Our main finding – that children and adolescents with ASC, in contrast to NT peers, did not tailor the amount of language they use to specific listeners – adds to extant literature that has characterized the expressive language profiles of autistic individuals during semi-structured assessments (e.g., ADOS-2; Hilvert et al., 2020) in the service of developing personalized language interventions. Notably, the methodology used in the current study (i.e., the CASS) has greater ecological validity than those used in prior research (i.e., assessments with an expert clinician) and includes the added dimension of an experimental manipulation. Additionally, our primary result aligns well with clinical descriptions of autistic youth who struggle to "read the room" and instead talk at length about preferred topics, with limited regard for their partners' feedback or input, as well as the phenomenon of "info-dumping" as described by autistic adults (Whelan, 2020).

The results from our secondary analysis revealed important areas of variability within the ASC group through an exploratory data-driven, latent class approach used to identify homogeneous trajectories of talkativeness across two conversational contexts. Results revealed the optimal number of classes in this dataset was three. Notably, members of the <u>moderately</u> talkative class in ASC spoke as much as the NT group in the Interested condition (ASC = 238.76 words, NT = 247.68 words), but more than the NT group in the Bored condition (ASC = 250.20 words, NT = 217.42 words). This pattern of results supports our primary finding that ASC participants did not adjust their conversational contributions as much as their NT peers in response to context. However, the <u>most</u> talkative class in ASC spoke more than the NT group overall and also *increased* their word count in the Bored condition. This pattern of results is consistent with previous research findings of "extreme verbosity" in a subset of autistic youth (Adams et al., 2002). Notably, autistic girls were disproportionately represented in the most talkative class (80% female), which may reflect a subgroup of autistic girls with an increased level of social motivation, as described in previous research (Sedgewick et al., 2016; Song et al., 2020).

Combined with prior research demonstrating that adaptation during the CASS (measured via third-party behavioral ratings) predicts adult participants' diagnostic status (Ratto et al., 2011), our findings suggest that reduced conversational adaptation in language behavior across social contexts could distinguish children and adolescents with ASC from NT peers in a way that is ecologically valid and clinically meaningful. However, our study does not shed light on *why* individuals with ASC adapt less during conversation. One potential explanation is that autistic participants – who produced similar amounts of words across conditions in our study – missed or misinterpreted cues to their conversation partner's interest level during the conversation (i.e., confederates' facial affect, body language, and verbal responses). Alternatively, participants with ASC may have noticed the changes in their conversation partner but (1) felt unmotivated to change their own behavior, or (2) may have felt motivated but then lacked the skills to quickly pivot. In contrast, NT participants – as a group – smoothly used these cues to guide and adjust their conversational contributions (Prelock & Nelson, 2012). In addition, it is possible that autistic participants' conversational adaptation was impacted by their level of social anxiety, theory of mind skills, or receptive language. Since conversations involve a complex interplay of social, cognitive, and linguistic factors, future research should include targeted measures of these constructs to explore potential relationships with conversational adaptation.

Another explanation for this pattern of results is that autistic participants may have adequately perceived their conversation partner's level of engagement and adjusted their own contributions accordingly in the Interested condition, but then struggled to flexibly shift their own behavior in response to the conversational context provided by their partner in the Bored condition. In this view, reduced conversational adaptation may have resulted from participants with ASC getting "stuck" on the social demands of the Interested condition. This explanation aligns well with descriptions of cognitive and behavioral inflexibility in ASC, which can range in severity and present in diverse ways across individuals (Bertollo et al., 2020; Bodfish et al., 2021; Lecavalier et al., 2020). Prior research that has investigated the impact of cognitive flexibility on language use through an object description task found that when autistic children were required to be cognitively flexible (e.g., use a different referential label) during an experimental task, their descriptions were less appropriately informative compared to those of NT peers (Malkin & Abbot-Smith, 2021). As such, adapting conversational behaviors for new listeners and contexts – as required by the CASS – may be particularly challenging for youth with ASC.

Notably, the Interested and Bored conversations occurred in quick sucession, with less than one minute between interactions. Accordingly, it is possible that autistic participants may have been able to shift their behavior more easily if given more time between conversations. Research in adult samples using a goal-oriented task has shown that autistic adults demonstrate qualitatively typical patterns of language adaptation (e.g., lexical entrainment), but take longer in this process compared to NT peers (Nadig et al., 2015). Thus, it is also possible that the autistic participants in our sample may have been able to demonstrate adaptation across CASS conditions if the conversations were longer. Either way, reduced conversational adaptation across contexts may represent one example of behavioral inflexibility that can occur in real-world social settings, with potentially significant functional impacts. Future research including participant report measures of confederate behavior (Simmons et al., 2020) in combination with objective measures of language could shed light on relationships between reduced conversational adaptation and awareness of social context. As such, quantifying subtle differences in conversational adaptation across contexts in verbally fluent children on the autism spectrum is an important step toward developing contextually-informed social skills interventions for individuals who might benefit from personalized support in this domain.

The effects of conversational adaptation challenges on the social success of individuals on the spectrum are potentially far reaching. The very benefits derived from successful conversational adaptation according to the NT literature – such as friendships, romantic relationships, and social inclusion – often pose significant challenges for individuals with ASC (Bauminger & Kasari, 2000; Billstedt et al., 2011; Holwerda et al., 2013; Lasgaard et al., 2010; Levy & Perry, 2011; Renty & Roeyers, 2007; Shattuck et al., 2012). It is likely that these difficulties arise over time, in part, due to communication breakdowns during social interactions with NT individuals. Longitudinal research in autistic adults has shown that conversational language skills significantly predict functional outcomes, including vocational independence and friendships (Friedman et al., 2019). Thus, targeted interventions to improve contextually-informed conversational skills – including behavioral adaptation – may have cascading downstream effects on both functional outcomes and on quality of life for verbally fluent autistic individuals. In addition, improving conversational adaptation skills could promote autistic individuals' self-esteem and perceived interpersonal competence. A nuanced understanding of this phenomenon could provide a helpful explanation for how and why a certain behavioral presentation can lead to a successful interaction with one partner, but may not translate well to another partner or conversational context.

This study adds to the literature in two important ways. First, to the authors' knowledge, this is the first study to examine conversational adaptation – as measured by talkativeness – in children and adolescents during live, experimentally-manipulated naturalistic conversations (CASS; Ratto et al., 2011) using *objective* measures that concretely index the contributions of both conversation partners (i.e., word count, type-token ratio) rather than subjective third-party behavioral ratings at a global level. Second, to our knowledge, this is also the first study to explore diagnostic group differences in ASC using a computational linguistics approach combined with a *multiple-context assessment method*. In line with prior CASS research demonstrating that autistic adults adjusted their behavior less across conversational contexts compared to NT peers (Ratto et al., 2011; White et al., 2015), our results revealed reduced conversational adaptation in the ASC group as measured by talkativeness. Taken together with previous research on the potential social consequences of atypical talkativeness in other clinical populations (Gordon et al., 2015), the results of the current study contribute to the field's understanding of conversational adaptation across social contexts in verbally fluent children and adolescents on the autism spectrum.

Limitations.

This study has significant strengths, including one of the largest samples of verbal children and adolescents with ASC in the conversational adaptation literature and a well-matched NT control group, but it also has notable limitations. First, we examined only a few aspects of conversational adaptation in language behavior, with a primary focus on the number of words produced (talkativeness). Future research should explore other aspects of verbal behavior, such as pitch adaptation measured via fundamental frequency, the alignment of grammatical structures or word meaning, moving average type-token ratio, and language content. Of note, ASC and NT participants in our sample had comparable core language abilities (as measured by verbal IQ estimates, type-token ratio, and average word complexity metrics; see Tables 1 and 3). Thus, the results of this study are unlikely to be driven by poorer core language in the ASC group. Intriguingly, the ASC group even had a slightly higher type-token ratio compared to the NT group in both the Interested and Bored conditions, indicating greater diversity in the words they used in both conversations. Second, we measured conversational behavior over the course of the entire 3-minute interaction, so our results cannot speak to how adaptation may unfold differently over time within each conversation. Future research should explore dynamic measures of conversational adaptation to assess the time course of emergent differences. For example, subsequent research should explore how an individuals' propensity to adapt conversational turn length may vary differentially by diagnostic group and could impact broader conversational adaptation across the course of an interaction. Third, our current methods are unable to parse the precise causal effects of confederates' verbal and nonverbal behavior on participants' speech. Future research using audio- and visual-only stimuli should explore the extent to which these cues may differentially impact conversational adaptation. Finally, the Interested and Bored conditions were not counterbalanced in this study (e.g., Interested was always administered first). Future research on the CASS paradigm should utilized a counterbalanced design to explore possible order effects.

Despite being one of the larger studies of conversational behavior in autism that utilizes direct behavioral assessment, the sample we report here is still small and limits our ability to assess subgroups (e.g., girls and boys), highlighting the need for future research with larger cohorts. Relatedly, conversational partners in this study were primarily female undergraduate students, which limited our ability to assess patterns that might emerge during opposite-sex conversations in girls and same-sex conversations in boys (Turkstra, 2001). Future studies with confederates of both sexes will explore how sex impacts conversational adaptation in males and females with and without ASC. The topic of gender diversity in this domain is critically important and remains unexplored, as this study utilized parent-reported natal sex to characterize participants; this is clearly only a first step toward understanding the complex intersecting effects of sex and gender on social behaviors like conversation. Finally, although we employed a semi-naturalistic conversation task, our method still utilized non-autistic young adult interlocutors (undergraduate students and research assistants), which limits the generalizability of our findings and may have important implications for developing contextually-informed interventions. Future work examining conversations between autistic children and same-aged peers, or other neurodiverse individuals, has great potential to inform our understanding of peer relationships and the foundations of emergent friendships.

Demographic characteristics of our study sample further limit the generalizability of these results. Participants were verbally fluent children and adolescents aged 7-17 years old, so this study cannot speak to the ways in which conversational adaptation may differ for younger children, adults, or individuals who are not verbally fluent. Understanding the developmental pathways that lead to successful conversational adaptation is key for developing appropriate social interventions and supporting individuals who struggle with conversational skills. Importantly, the manifestation of conversational adaptation skills likely changes drastically across the course of development. Future research with larger samples of children and adolescents should explore how best to operationalize and measure this construct across different ages and levels of verbal fluency. Importantly, diagnostic groups in this study were not matched on race, with the NT group containing greater racial diversity than the ASC group. Confederates did not self-report race, leaving an open question about the effect of same- vs. difference-race dyads on conversational adaptation in ASC. It is critical that future studies with very large samples be conducted with racially diverse participants and confederates to examine potential ways in which conversational adaptation in ASC may differ by race or enculturation. Indeed, a significant literature on “linguistic code-switching” suggests that non-white individuals in Western samples may have greater experience with behavioral adjustment than individuals from non-minority backgrounds due to the inequitable requirements of functioning within predominantly white majority institutions (Daniels, 2018; Hibbler, 2020; Koch et al., 2001).

Future directions.

Given the vast heterogeneity that characterizes ASC and our nascent ability to meaningfully measure linguistic features in naturalistic settings, many future studies are possible. For example, a multitude of demographic factors associated with appearance and behavior (e.g., race, ethnicity, gender, SES, cultural background, and bodily characteristics) may contribute to successful conversational adaptation and have yet to be explored in the context of ASC. Additional family- and environmental-level factors that contribute to social behavior should also be explored (e.g., being from a multilingual family or community, or living in a multi-generational home). Future studies should also investigate how conversational adaptation progresses and changes over the course of development using well-powered cross-sectional and longitudinal samples.

Finally, research using dimensional measures of social phenotype (e.g., a targeted questionnaire about social interest and motivation, or a behavioral measure like attention to social stimuli during eye tracking) should explore the extent to which conversational adaptation skills may differentially correlate with social motivation vs. social attention in ASC. Future research should also examine how *objective* measures of conversational adaptation, such as the one used in this study, map onto the third-party behavioral ratings of participants’ behavior used in most research, including in the extant CASS literature. Additional research should investigate potential relationships between specific ratings within the CASS coding scheme (e.g., topic changes, overall quality of rapport) and the computational linguistic variables used in this study. Specifically, given the results of prior studies suggesting that vocal expressiveness and overall conversational involvement may be particularly meaningful with regard to intervention effects and real-world social functioning, future research should focus on these features. In summary, understanding how conversational adaptation skills deployed during natural conversations differ in children and teens with ASC – and whether these differences are more prominent for specific subgroups like girls or boys or individuals who are gender diverse – could shed light on the clinical heterogeneity currently complicating our efforts to effectively support and nurture social development in children and adolescents with ASC.

Conclusions.

Subtle features of a conversation can influence whether social communication is successful, and this study highlighted one potential driver of communication challenges in ASC: reduced conversational adaptation as measured via talkativeness. While NT participants adjusted their word count in response to the verbal and nonverbal social cues emitted by their conversational partner, the ASC group did not. Failure to adjust communicative behaviors could have downstream effects: for example, diminished conversational adaptation in everyday communications may lead to fewer mutually rewarding social interactions, reduced opportunities for social learning, and subsequent long-term reductions in social knowledge and skill (Chevallier et al., 2012). Naturalistic measures of behavioral adaptation across verbal and nonverbal domains could help identify areas of need for individuals learning about the social world, and potentially become treatment targets to improve everyday social learning, rendering these findings valuable for clinicians interested in improving conversational competence in verbally fluent individuals on the autism spectrum.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data availability statement.

The datasets generated and/or analyzed during the current study are not publicly available due to privacy concerns for minors with disabilities.

List of abbreviations.

ADOS-2	Autism Diagnostic Observation Schedule – 2nd Edition
ASC	Autism Spectrum Condition
EMM	Estimated marginal mean

IQ	Intelligence quotient
M	Mean
SCQ	Social Communication Questionnaire
SD	Standard deviation
NT	Neurotypical
WC	Word count

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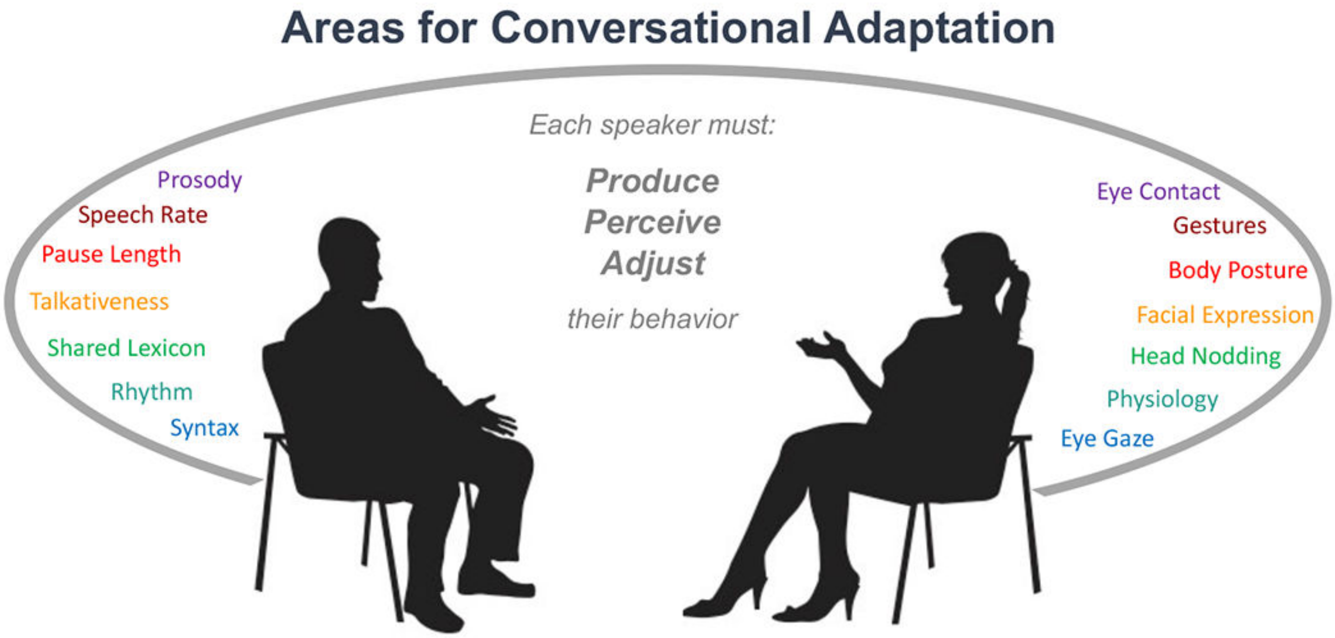

Figure 1.
Examples of areas of communication behavior in which conversational adaptation may occur (Wynn & Borrie, 2020).

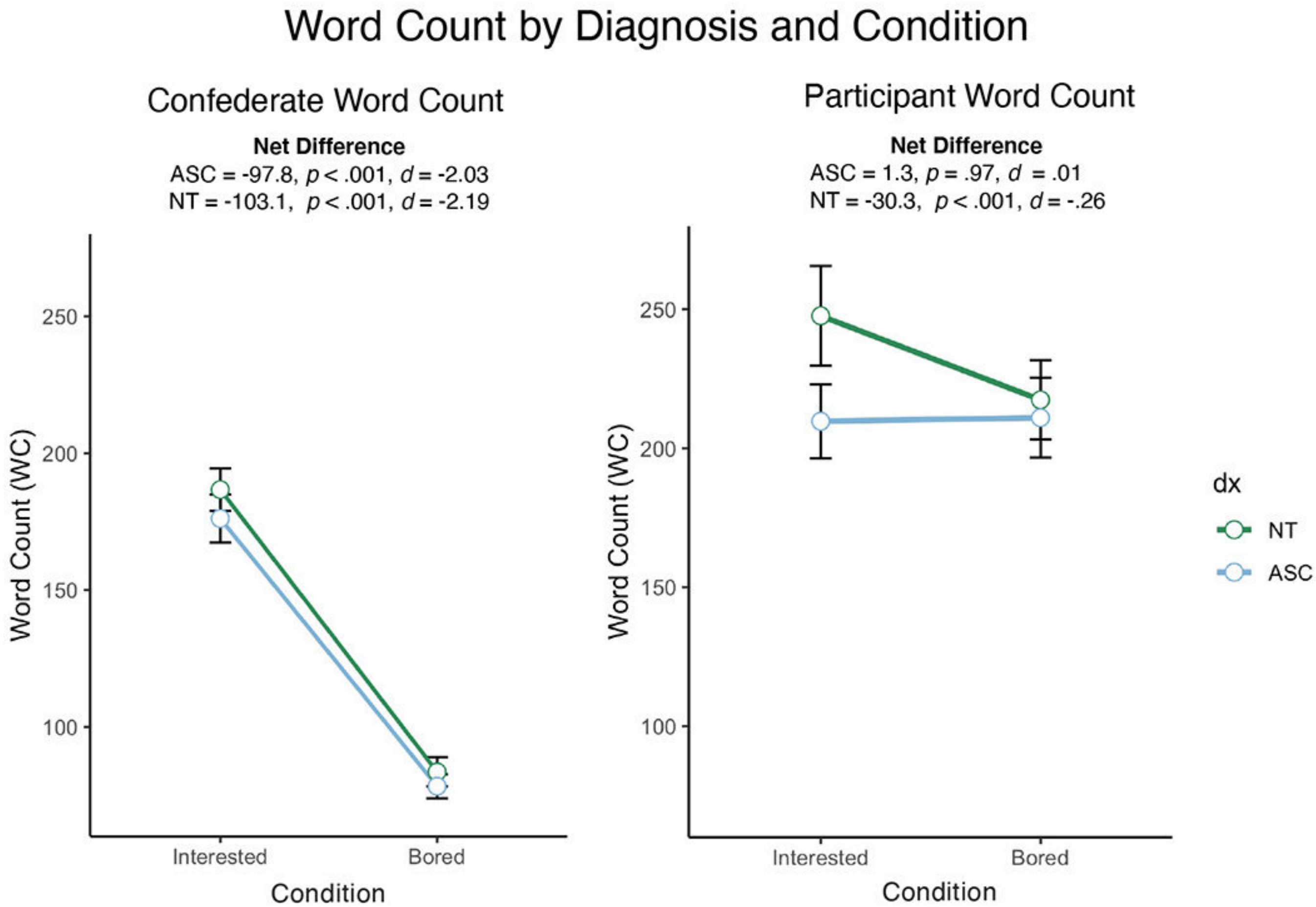

Figure 2.
Word count by diagnosis and condition. Both participant and confederate word count data presented as raw means ± SEM. Net difference scores were calculated by subtracting the word count produced in the Interested condition from word count produced in the Bored condition (*p* and *d* values reported here are for the main effects of condition within diagnostic groups).

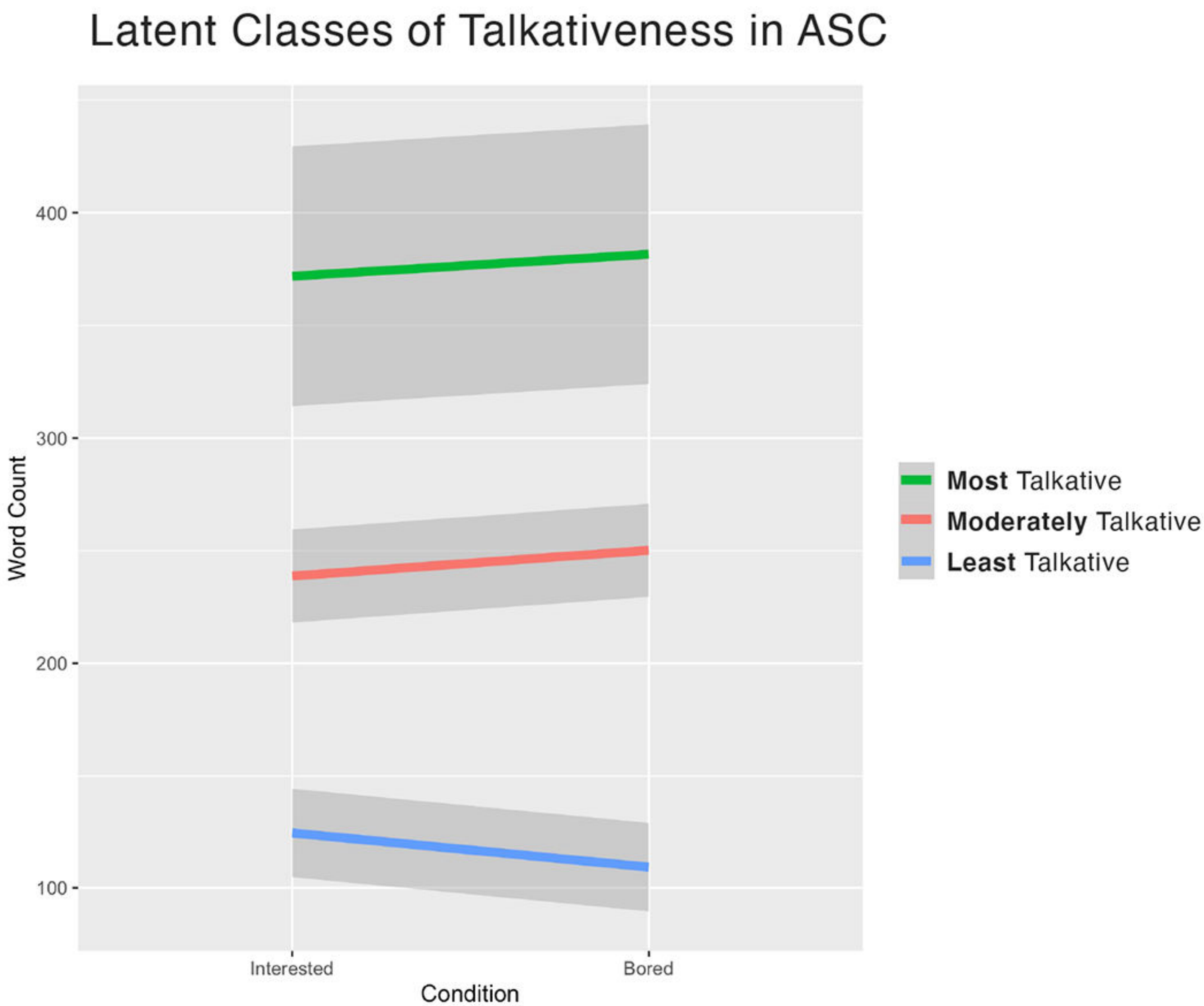

Figure 3.
Latent classes of talkativeness in ASC by condition

Table 1.

Demographic and clinical characteristics of participants (means, standard deviations, and ranges).

	ASC (n=48)		NT (n=50)		Effects		
Sex ratio	20f, 28m (58.3% Male)		22f, 28m (56% Male)		χ^2 = .0009, p = .98		
Race	Black or African American: 2 White/Caucasian: 40 Asian or Pacific Islander: 1 Multiracial: 4 Other: 1		Black or African American: 14 White/Caucasian: 27 Asian or Pacific Islander: 2 Multiracial: 7 Other: 0		χ^2 = 13.63, p < .001		
Maternal Education	High school or less: 10.4% (n=5) Bachelor's or less: 31.1% (n=15) Graduate degree: 56.3% (n=27) Not reported: 2.1% (n=1)		High school or less: 8% (n=4) Bachelor's or less: 54% (n=27) Graduate degree: 38% (n=19) Not reported: 0% (n=0)		χ^2 = 4.84, p = .09		
	Female	**Male**	**Female**	**Male**	**Sex**	**Dx**	**Sex in ASC**
Age (years)	11.03 (2.67) 7.5-17.3	11.38 (2.30) 7.2-15.7	10.82 (2.35) 7.3-15.5	10.26 (2.50) 7.2-16.6	p = .84 d = −.04	p = .14 d = −.30	p = .63 d = .14
Full-Scale IQ	109.4 (8.09) 95-124	105.18 (12.31) 84-131	106.77 (12.92) 86-134	108.86 (11.72) 86-129	p = .66 d = −.09	p = .68 d = .98	p = .18 d = −.39
Verbal IQ	107.90 (9.10) 89-123	104.71 (11.91) 85-127	107.59 (13.03) 80-128	107.04 (13.10) 86-131	p = .45 d = −.16	p = .61 d = .10	p = .32 d = −.29
Non-verbal IQ	108.25 (12.04) 85-130	104.64 (12.45) 83-130	104.14 (14.59) 81-140	106.64 (1.69) 82-130	p = .86 d = −.04	p = .81 d = −.05	p = .32 d = −.29
ADOS-2 CSS Total	6.40 (2.70) 1-10	6.79 (1.96) 2-10	1.05 (0.21) 1-2	1.29 (0.46) 1-2	p = .50 d = .14	p < .001 d = −3.36	p = .57 d = .17
ADOS-2 SA CSS	6.15 (2.48) 1-10	7.00 (1.81) 3-10	1.45 (0.80) 1-3	1.82 (0.86) 1-3	p = .24 d = .24	p < .001 d = −3.10	p = .19 d = .40
ADOS-2 RRB CSS	7.40 (1.76) 5-10	6.54 (2.36) 1-10	1.18 (0.85) 1-5	1.86 (1.92) 1-7	p = .94 d = .02	p < .001 d = −2.84	p = .17 d = −.40
SCQ Total	17.35 (6.98) 6-31	19.75 (7.51) 5-33	2.23 (2.27) 0-8	2.46 (3.01) 0-14	p = .40 d = .17	p < .001 d = −3.10	p = .25 d = .34

***Notes*:** CSS = ADOS-2 calibrated severity score; SA CSS = Social affect calibrated severity score; RRB CSS = Repetitive behaviors/restricted interests calibrated severity score.

Chi-squared tests with Yates' continuity correction were used to test for diagnostic group differences in sex ratio, race composition, and maternal educational attainment. *p*-values and Cohen's *d* values for main effects of sex and diagnosis across the entire sample are shown, as well as *p* and Cohen's *d* values for sex differences in the ASC group only.

Table 2.

Characteristics of confederate speech across the entire conversation by diagnosis and condition (means, standard deviations, and ranges). Effect sizes for GLMER are reported as unstandardized effects (estimates; Pek & Flora, 2018). The final GLM model included participant and confederate IDs as random effects to account for repeated measures.

	Confederate Speech Behavior				
	Interested Condition		Bored Condition		Effects
	NT	ASC	NT	ASC	Condition by Dx
Word Count	186.70 (54.97) 85-359	176.13 (61.15) 74-404	83.60 (37.50) 9-178	78.31 (30.37) 30-176	p = .79 est: .01
Characters per word	3.87 (0.14) 3.4-4.2	3.87 (0.15) 3.5-4.2	3.79 (0.26) 3.2-4.5	3.78 (0.26) 3.1-4.3	p = .91 est: .02
Total # of syllables	220.70 (66.39) 91-410	206.58 (71.05) 94-475	100.36 (45.67) 11-224	91.63 (37.83) 32-214	p = .32 est: .02
Total time speaking (s)	57.41 (16.24) 29.0-97.0	51.81 (17.36) 25.6-111.5	27.48 (12.03) 4.5-58.9	24.77 (9.46) 12.4-57.8	p = .94 est: .004
Type-Token Ratio	0.53 (0.07) .37-.68	0.52 (0.06) .41-.70	0.64 (0.11) .44-1.0	0.62 (0.08) .46-.78	p = .81 est: .004

Table 3.

Characteristics of participant speech across the entire conversation by diagnosis and condition (raw means, standard deviations, and ranges). Effect sizes for GLMER are reported as unstandardized effects (estimates; Pek & Flora, 2018). The final GLMER modeled participant language using age (centered), IQ (centered), and sex, along with the interactive effect of diagnostic group and condition, with random effects for participant ID and confederate ID.

Participant Speech Behavior					
	Interested Condition		Bored Condition		Effects
	NT	ASC	NT	ASC	Condition by Dx
Word Count	247.68 (126.98) 41-773	209.73 (92.41) 64-495	217.42 (100.55) 28-499	211.0 (99.11) 33-408	$p < .001$ * est: −.14
Total # of syllables	295.58 (149.98) 52-906	257.35 (111.68) 79-617	263.00 (122.52) 35-617	258.27 (119.31) 38-528	$p < .001$ * est: −.12
Total time speaking (s)	83.89 (33.71) 23.2-212.4	78.36 (29.18) 24.8-152.5	72.90 (29.94) 11.7-150.7	74.60 (32.79) 12.6-150.7	$p = .006$ * est: −.09
Characters per word	3.82 (0.17) 3.5-4.1	3.89 (0.15) 3.6-4.2	3.78 (0.16) 3.4-4.1	3.85 (0.22) 3.4-4.3	$p = .91$ est: .02
Type-Token Ratio	0.50 (0.09) .31-.71	0.54 (0.08) .38-.71	0.51 (0.09) .35-.75	0.54 (0.11) .37-.82	$p = .56$ est: .02

* Condition by diagnosis interaction is significant, p<.01.

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Table 4.

Posterior Classification Table: Mean of Posterior Probabilities in Each Class in ASC.

	Most Talkative	Moderately Talkative	Least Talkative
Posterior Probability of being in the Most talkative class	0.95	0.05	0.00
Posterior Probability of being in the Moderately talkative class	0.03	0.93	0.02
Posterior Probability of being in the Least talkative class	0.00	0.05	0.95

Table 5.

Descriptives of participant characteristics (Mean, SD) by class and condition, and Estimated Marginal Means (EMM) for Word Count.

	Most Talkative	Moderately Talkative	Least Talkative	*p*-value
N (female, male) % of the ASC sample % male	5 (4, 1) 10.42% 20% male	25 (11, 14) 52.08% 56% male	18 (5, 13) 37.5% 72% male	.11
Age	11.64 (3.33)	11.07 (2.35)	11.38 (2.39)	.86
Full-scale IQ	104.60 (7.37)	106.64 (10.54)	108.06 (12.40)	.81
Verbal IQ	109.80 (8.44)	103.88 (11.19)	108.0 (10.77)	.34
Nonverbal IQ	98.20 (4.27)	107.48 (11.30)	106.50 (14.54)	.31
ADOS-2 CSS	4.20 (3.11)	6.44 (2.22)	7.56 (1.58)	<.001**
ADOS-2 SA CSS	4.00 (2.83)	6.52 (2.00)	7.56 (1.42)	.002*
ADOS-2 RRB CSS	6.60 (1.67)	6.64 (2.29)	7.33 (2.11)	.56
SCQ Score	16.80 (6.38)	20.56 (8.07)	16.78 (5.01)	.08*
Word Count Interested Condition	371.80 (74.06)	238.76 (54.42)	124.39 (38.22)	<.001**
Word Count Bored Condition	381.60 (27.54)	250.20 (48.15)	109.17 (43.62)	<.001**