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Prosodic Phrasing in Adolescents with High Functioning Autism: Production Following Intervention and Under Dual Load Conditions

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Atypical expressive prosody is reported as a consistent challenge for individuals with Autism Spectrum Disorder (ASD) and is associated with a broad set of clinical impairments including perceptions of oddness from others. Theories of atypical prosody in ASD have attributed these impairments to the broader symptoms of ASD, particularly in the social domain. Using precise analysis of speech timing, the current study examined associations between expressive prosodic phrasing and more general cognitive processes in a group of adolescents with High Functioning Autism (HFA) and an age- and IQ- matched typically developing (TD) control group. Participants completed a psycholinguistics task during which they produced expressive prosody to disambiguate syntactically ambiguous phrases. In addition, they participated in a brief instructive intervention on prosodic phrasing, after which they completed a second prosodic disambiguation task. Results indicated that both HFA and TD groups were competent in using expressive prosodic phrasing to enhance communication. After a brief intervention, both groups increased their use of prosodic phrasing, even when challenged with additional verbal and non-verbal cognitive load tasks. Across groups, the ability to articulate a "good" strategy for managing the tasks' ambiguity was associated with better performance. In the TD group only, a measure of verbal working memory was also associated with greater use of prosodic phrasing. Implications for current findings are discussed.

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Introduction

Autism is a pervasive developmental disorder that is marked by impairments in social communication and relatedness. For some, impairments in communication include failure to develop functional spoken language; however, with early diagnosis and intervention, many individuals with autism develop average vocabulary, syntax, and articulation (Lord & Paul, 1997; Kjelgaard & Tager-Flusberg, 2001). Despite these important achievements in communication, individuals with autism have persistent difficulty with pragmatic aspects of language. For instance, these individuals tend to speak in an odd or idiosyncratic manner or demonstrate impairments in the ability to initiate or sustain conversations with others (Tager-Flusberg, 1995). Additionally, individuals with autism have been described as having atypical prosody (Kanner, 1943; Tager-Flusberg, 2001; McCann & Peppé, 2003).

Prosody refers to suprasegmental aspects of speech including modulation of pitch, volume, sound quality, and rhythm that are used to enhance communication. Since the earliest descriptions of autism, atypical prosody has been reported as a problem (Kanner, 1971; DeMyer et al., 1973; Simmons & Baltaxe, 1975); however, descriptions of prosody in this group have varied dramatically. Individuals have been reported to sound robotic, stilted, wooden, and “monotonous,” but also “exaggerated” and sing-song-like (Peppé, Cleland, Gibbon, O’Hare, & Castilla, 2011).

Abnormal prosody is particularly problematic for individuals with autism, who are challenged by social interactions and communication broadly. First, atypical prosody and vocal presentation negatively impact the likelihood of mainstream social integration and decrease the likelihood of gaining and keeping employment; indeed unusual prosody is among the first features that elicit an impression of oddness from others (Mesibov, 1992; Shriberg & Widder, 1990; VanBourgondien & Woods, 1992). Second, abnormal prosody appears to be a persistent problem. Even high functioning individuals with autism (HFA) who develop average expressive and receptive language skills as tested by standardized measures often continue to have difficulty using normal prosody (Shriberg, Paul, Black, & Van Santen, 2011).

Because prosody refers to a number of suprasegmental speech strategies, which serve a range of overlapping expressive and receptive communicative functions, examinations of prosody have varied greatly in their focus. For instance, Shriberg and colleagues reported primarily on speech characteristics and speech quality. Their results indicated that on average, speakers with ASD had more articulation errors and less fluent speech than typically developing (TD) peers, during spontaneous and more circumscribed speech. Additionally, speakers with ASD were more likely to make utterances that were judged as too loud, and had a nasal quality to the sound of their voice (Shriberg, et al., 2001).

Others have focused on the use of prosody for specific communicative functions. For instance, individuals with ASD tend to have reduced accuracy for the linguistic communication of affective states when judged by subjective listeners (McCann, Peppé, Gibbon, O'Hare, & Rutherford, 2007; Peppé et al., 2011; Tager-Flusberg, 2005). A focus on function has also yielded consistent reports regarding the difficulties using prosody to communicate contrastive stress (i.e., prosodic behavior that shifts the stress from the expected syllables or words to elsewhere in the utterance) among individuals with ASD (Shriberg et al., 2001; Baltaxe, 1984; Fine, Bartolucci, Ginsberg, & Szatmari, 1991; Paul, Augustyn, Klin, & Volkmar, 2005).

Atypical expressive prosody during communication of affect or contrastive stress is perhaps not surprising given the core deficits of ASD. Namely, it is reasonable to imagine that difficulty with communication of affect may be a component of impaired social and emotional reciprocity associated with autism. Similarly, contrastive stress is fundamentally a pragmatic language tool used to highlight the importance of one part of the utterance over another. For example, consider conversational responses to the ambiguous question: "What did you do?" Responding, "Then I bought the *berries*," versus "*Then* I bought the berries," communicates different understanding of the question's intention and should correspond to what the speaker and listener have both agreed is important. A fundamental impairment in social relatedness may make this mutual understanding difficult to achieve for individuals with autism and lead to problems in prosodic communication of contrastive stress.

Although deficits in expressive prosody for affective communication and contrastive stress have been well established, there is a lack of consensus regarding how autism affects the use of prosody to communicate grammar. Baltaxe & Guthrie (1987) suggest that high functioning individuals with autism have deficits in the ability to use prosodic cues for grammatical purposes (e.g. to differentiate RE-call vs. re-CALL, or pre-SENT vs. PRE-sent). Additionally, Paul and colleagues (2008) reported that individuals with ASD did not use typical prosodic cues to differentiate stressed vs. non-stressed syllables during a non-word repetition task.

Beyond the appropriate placement stress within a word, grammatical prosody is also used to mark boundaries between phrases. McCann and Peppé (2003) referred to this prosodic segmentation as "phrasing" or "chunking." For example, consider the ambiguous phrase, "I would like chocolate milk and cookies." In this example, in which punctuation has been intentionally omitted, it is unclear if the word "chocolate" has been used to describe the type of milk (i.e., "chocolate milk") or if "chocolate" is one of three items that have been requested (i.e., "chocolate, milk, and cookies"). Although in most cases this ambiguity could be clarified by the context of the conversation, McCann and Peppé note that failure to use appropriate prosodic chunking or phrasing may lead to momentary confusion for the listener.

Efforts to understand the prosodic abilities of individuals with autism have yielded mixed results with regard to grammatical phrasing, including multiple reports of weaknesses in this prosodic ability. For instance, using a standardized assessment of expressive and receptive prosody, the Profiling Elements of Prosodic Systems – Child version test (PEPS-C, Peppé & McCann, 2003), Peppé and colleagues reported that children with HFA and a second group of children with Asperger's Disorder failed to achieve a level of competency in expressive prosodic phrasing (Peppé et al., 2011). Additionally, in an attempt to understand prosodic comprehension among individuals with HFA, Diehl and colleagues used a carefully controlled psycholinguistic paradigm to examine how adolescents with HFA harness information provided by prosodic cues to disambiguate syntactically ambiguous sentences (Diehl, Bennetto, Watson, Gunlogson, & McDonough, 2008). Findings suggested that individuals with HFA were significantly less likely to use prosodic cues to help them understand ambiguous sentences than TD adolescents who were matched for age, IQ, and receptive language. Specifically, the HFA group failed to appreciate the expression of stress and timing cues in their interpretation of ambiguous sentences. Together, these studies suggest that individuals with ASD may have a limited ability to harness prosodic information about grammar to disambiguate syntactically ambiguous language.

However, several studies have suggested that prosodic phrasing is relatively well-preserved. In a separate study using the PEPS-C, McCann et al. (2007) found no significant differences on tests of expressive or receptive prosodic phrasing between children with HFA and a group of TD children who were matched by verbal mental age. Similarly, Paul and colleagues reported no group differences on production or perception of grammatical phrasing between a group of adolescents with ASD and an age-matched TD control group (Paul et al., 2005). Importantly though, in each of these studies, subjective listeners were responsible for coding expressive prosody as either *correct* or *incorrect*. Although this rating system likely captures gross differences in prosodic production, subtle differences between the groups may not be detected without more fine-grained analysis.

Additionally, Thurber and Tager-Flusberg (1993) examined grammatical pausing in children with Autism, low IQ, or typical development who were matched on receptive language. They found no significant differences between the groups in the frequency of these pauses as the children narrated a picture book, though the means appeared to approach difference: Mean (SD) for groups with Autism; Low IQ; and typical development were, respectively, 13.1 (7.4); 13.8 (5.2); 9.1 (3.7)). However, groups in the study were small (n = 10); as such, differences in the average number of pauses in each group may have failed to reach significance due to low statistical power. Moreover, the authors did not report data about the appropriateness of the duration or placement of these pauses within the narratives – only that the *frequency* of pauses within the speech was similar.

The debate regarding the capacity to use prosodic phrasing for grammatical functions is important for several reasons. *First*, a more complete understanding of prosodic capacities among individuals with autism contributes to efforts to conceptualize atypical prosody as a product of more general impairments associated with ASD. *Second*, a greater understanding of the nature and extent of prosodic problems may inform the creation of interventions that harness relative strengths and target relative weaknesses in communication. *Finally*, clarifying the prosodic abilities associated with ASD contributes to questions about the nature of communication impairments in ASD broadly. For instance, although "qualitative impairments in communication" listed as a core feature of Autism in the DSM-IV (American Psychological Association, 2000) have been re-conceptualized as impairments in "social communication/ interaction" in the DSM-5 (APA, 2013), many have argued that language deficits in this group extend beyond those can be considered as purely "social" or pragmatic (Condouris, Meyer, & Tager-Flusberg, 2003; Rapin & Dunn, 2003; Kjelgaard & Tager-Flusberg, 2001).

Theoretical Links Between Autism and Prosody

With ASD deficits in expressive prosody reported in the literature, it is critical to explore the mechanisms underlying prosodic difficulty. In addition to raising important theoretical issues, understanding these mechanisms has important clinical implications; effective interventions could be tailored to address specific underlying deficits. Several theories of underlying prosodic deficits have been proposed, including deficits in Theory of Mind, inattention to the nuances of social communication, and weaknesses in executive functioning. A brief review of the rationale of each of these theories is presented here.

Theory of mind. Impairments in prosody have been conceptualized by some as a result of deficits in theory of mind (ToM; Baron-Cohen, 1995). This ToM rationale has been used to explain poor performance on tests of prosody (Kleinman, Marciano, & Ault, 2001; Rutherford, Baron-Cohen, & Wheelwright, 2002; McCann et al., 2007). Generally, the ToM account suggests that impaired access to the full range of mental states and efficient mind reading leads to abnormal communicative development, which requires taking other people's perspective. More specifically, this account suggests that individuals with ASD fail to recognize their conversational partner's needs and thus fail to provide or understand the prosodic cues that would facilitate clear communication. Psycholinguistic research with typically developing children and adults highlights the role that speaker awareness of a listener's knowledge plays in the production of prosodic cues. For instance, Snedeker & Trueswell (2003) report that typically developing adults used expressive prosody to clarify ambiguous sentences only if they were aware that their conversational partner would find their verbalization confusing. Ferreira & Dell (2000) reported similar conclusions, suggesting that speakers are not inclined to express prosodic cues if unaware that their verbalization could be ambiguous for their conversational partner. Following this logic, individuals with ASD might fail to use appropriate prosody because they are unaware that their interlocutor requires specific prosodic cues for better comprehension. Indeed, McCann, and colleagues (2007) suggest atypical prosody is understandable in individuals with ASD who present with typical language skills if some aspects of prosody can be viewed as challenges to theory of mind rather than as a purely language skill.

Attention to social language. Others have suggested that difficulties with aspects of language, including atypical prosody may be related to deficits in basic and social orienting. Specifically, children and adolescents with ASD may exhibit difficulties with aspects of language, including prosody because they are less attentive to social language. Beginning as infants, typically developing children demonstrate a keen interest in listening to human speech, especially to motherese, which is characterized by child-directed language with higher pitch, slower tempo, and exaggerated intonation contours (Kuhl et al., 1997). Children with ASD do not show the typical preference for the sounds of their mother's voice over a recording of superimposed voices (Klin, 1992) and preschool children with ASD have been shown to be less sensitive and responsive to motherese than TD children (Kuhl, Coffey-Corina, Padden, & Dawson, 2005). Given that motherese seems to be a particularly useful language-teaching device (Kuhl et al., 1997), failure to attend to this child-directed speech is likely to inhibit typical language development. Theoretically, diminished attention to language from an early age could weaken appreciation for acoustic subtleties in speech, making prosodic cues difficult to perceive, interpret, and use in communication. Even in the presence of intact theory of mind abilities, failure to orient and attend to language could account for delays in language development, and atypical expression and comprehension of prosody. As Diehl & Paul (2009) suggest, failure to pay attention to vocal characteristics in speech may contribute to prosody processing deficits in some children with ASD.

Shriberg et al. (2011) also suggested that a failure to attend to and conform to social standards for communication is at the root of prosodic impairments in individuals with ASD. In a series of imitation studies using the PEPS-C, children with ASD were consistently judged to have “incorrect” word and phrase level imitation (McCann et al., 2007; Peppé, McCann, Gibbon, O’Hare, & Rutherford, 2006; Peppé et al., 2007). Similarly, using acoustic analysis of the PEPS-C, Diehl & Paul (2012) found that children and adolescents with ASD used a slower rate of speech as they imitated one- and two-word utterances when compared to either TD or Learning Disordered (LD) control groups. These authors hypothesized that a lack of attunement to prosody used by others may contribute to atypical prosodic production. Indeed, individuals with HFA have more difficulty responding to prosodic cues meant to disambiguate syntactically ambiguous sentences, suggesting that HFA is associated with difficulty recognizing this aspect of prosody in the linguistic environment (Diehl et al., 2008).

Executive functioning. Weaknesses in executive functioning among individuals with ASD have been well-established through behavioral testing (Ozonoff & Jensen, 1999; Ciesielski & Harris, 1997; Ozonoff, 1995) and findings have been strengthened with evidence from functional imaging studies (Just, Cherkassky, Keller, Kana, Minshew, 2007). Early linguistic theorists including Miller and Chomsky (1963) argued that linguistic competence is constrained by the limits of the cognitive system to access knowledge during production. Since then, executive functioning has been identified as a key constraint on linguistic processing. Theoretically then, individuals with ASD may demonstrate atypical aspects of prosody because of difficulty managing the executive demands of conversation.

For instance, research suggests that working memory constraints explain the extent to which various sources of linguistic information can be integrated during processing (Just & Carpenter, 1992; MacDonald et al., 1992; Pearlmutter & MacDonald, 1995). In a study of adults with typical development, Swets and colleagues (2007) demonstrated that both domain-specific (i.e., verbal) working memory and domain-general (i.e. non-verbal) working memory (measured by out-of-task standardized assessments) impact linguistic processing of ambiguous sentences (Swets, Desmet, Hambrick & Ferreira, 2007). In the domain of ASD, Schuh and colleagues found that individuals rely on working memory ability to integrate syntactic and supra-segmental information, such as prosody, during linguistic processing. Interestingly, they found that working memory demands impact pragmatic language performance in adolescents with HFA significantly more than their TD peers (Schuh, Mirman & Eigsti, in revisions).

Additionally, cognitive load and executive functioning has been used as one explanation for observed difficulty in referential communication tasks that require children to track shared knowledge, or “common ground” (Clark, 1992). Specifically, Nadig & Sedivy (2002) argued that the cognitive burden of considering another’s perspective while engaging in conversation may be too complex for children, leading them to have difficulty or to fail “common ground” tasks (Nadig & Sedivy, 2002). In a study of 6-year old TD children participating in a communication task, children demonstrated more unambiguous, less ego-centric utterances when cognitive load was minimized (Nadig & Sedivy, 2002). Similarly, research from the adult literature suggests that increased cognitive demands significantly impact the ability to take others' perspectives during communication tasks. For instance, under time constraints, adults used "common ground" information less, with the result of more frequent ambiguous communication, than when their communication was temporally unpressured (Horton & Keysar, 1996). When cognitive load was directly manipulated in a task that required adults to create instructions for building a machine when the machine was either present (low cognitive load) or absent (high cognitive load), TD adults failed to adapt their explanation for their audience (child vs. adult) during the high cognitive load condition (Roßnagel, 2000). Together, these studies highlight the important role of executive functioning in managing cognitive load for effective communication. The relative weaknesses in aspects of executive functioning among the ASD population, may account for problematic prosody reported in this group.

Overall then, it appears that general deficits observed in children with ASD (i.e., theory of mind, attention to social aspects of language, and executive functioning) may contribute to difficulties in prosody that are reported. The present study aims to examine the role of these three potential mechanisms and to consider implications for intervention.

Prosodic Interventions

Intervention for children with ASD, especially for those who have significant language delay, has traditionally focused on increasing meaningful verbal communication. To this end, treatment regularly focuses on encouraging children to use words, phrases, and eventually more complex sentence structures. For children who accomplish these language goals, learning varied strategies to enhance their expressive communication is a natural next step. Given the social and communicative implications of atypical prosody, targeting this area of expressive language is critical for children with ASD.

Several studies report improved expressive prosody in children after targeted interventions. Multiple strategies have been employed for varied amounts of time and intensity. Commonly reported techniques for intervention include providing children with *explicit explanation* about the nature and use of supra-linguistic techniques and prosody. Bellon-Harn, Harn, & Watson (2007) report improved expressive prosody in an eight-year-old boy with HFA after 10 treatment sessions. During these treatment sessions, the child was taught “rules for good speech” and was provided with auditory, visual, and tactile materials to enhance his learning. Over the course of treatment, the boy demonstrated fewer disruptive pauses in his speech, and became better able to regulate the length of syllables within his speech. Similarly, improvements were reported in an adolescent boy who presented with mild apraxia, articulation problems, morphosyntactic errors, poor topic maintenance, turn-taking problems, and atypically loud volume (Bellon-Harn, 2011). His 24-week intervention consisted of both individual and group treatments in which he learned to define aspects of prosody and voice (e.g. pitch, loudness, stress, resonance, tempo, rate) and their roles in communication. After the intervention, the adolescent had improved performance on a structured assessment of prosodic production and perception (Paul et al., 2005).

In addition to explicit teaching strategies, several treatment protocols provide opportunities for children to practice *imitating words or phrases* with varied prosody. Samuelson (2011) described improved prosody in a four-year-old Swedish boy who presented with word- and phrase-level dysprosody. During treatment, which consisted of a weekly 60-minute session across six weeks, the boy practiced imitating words, non-words, phrases, and various rhythms.

He also listened to recordings of his voice and made judgments about the intention of his vocalization based on the prosody he used during the recording. After the intervention, the boy had improvements on word-level expressive prosody, as measured by an assessment of Swedish prosody created by the study author (Samuelson, Scocco, & Nettelbladt, 2003).

Using *intensive practice and feedback*, three children (ages seven to ten years) characterized as having Childhood Apraxia of Speech (CAS) were treated for dysprosody, including the particular difficulty they had in using lexical and phrasal stress (Ballard, Robin, McCabe, & McDonald, 2010). The three-week treatment included four 60-minute sessions per week and was focused on improving the relative duration of syllables within words to differentiate stress patterns. Initially, treatment providers taught key aspects of prosody using tactile and kinesthetic cues for learning. During treatment, each child practiced saying between 100-120 multi-syllable non-words with varying stress patterns (i.e., strong-weak or weak-strong stress patterns). Treatment providers gave feedback regarding the use of *emphasis, fluency,* and *loudness*. Across time, all children improved the relative durations of syllables within practiced non-words, and demonstrated more appropriate pitch and loudness. Although the treatment generalized to non-practiced non-words, there was little evidence of generalization to the production of real words.

Although atypical expressive prosody is common in individuals with ASD, there are relatively few targeted interventions and little research on the efficacy of prosodic treatments for children or adolescents. Several interventions include software designed to provide visual feedback that corresponds to speech output, such as IBM SpeechViewer, (e.g., Thomas-Stonell, McClean, & Dolman, 1991). Furthermore, some clinicians have utilized music therapy to facilitate better prosody (Lim, 2008; Staum, 1987). To date, however, there is limited empirical evidence regarding the efficacy of these interventions.

Statement of Purpose

Given the social and linguistic implications of atypical prosody, it is critical to understand the nature of these deficits in individuals with ASD and to increase efforts toward the development of treatment strategies. The current study aims to clarify how general deficits associated with ASD (i.e. difficulty with theory of mind tasks, social attention, and executive functioning) contribute to prosodic phrasing, and to identify neuropsychological functions that are associated with expressive prosody. Additionally, a brief intervention using explicit explanation about prosody, prosodic imitation, and practice was created. The current study will explore the utility of this brief intervention.

Methods

Participants

High functioning adolescents with and without autism took part in this study of prosodic expression. Participants included 15 adolescents diagnosed with HFA (mean age, 14.4 years) and 14 adolescents with typical development (mean age, 14.1 years) matched for chronological age and full scale IQ. Participants in both the HFA and the TD groups demonstrated average to high average performance on standardized language measures; all data are shown in Table 1.

ASD diagnoses were confirmed using the Autism Diagnostic Observation Schedule, (ADOS; Lord et al., 2000), selected sections of the Autism Diagnostic Interview, Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994), and clinical judgment, based on DSM-IV-TR criteria checklist (APA, 2000). Participants were excluded if they had a history of traumatic brain injury or known neurological or genetic disorder. All participants were native English speakers and had a Full Scale IQ greater than 80, in order to insure that any differences in performance were specific to ASD rather than a reflection of general intellectual variability. Participants were recruited from the community through flyers and word of mouth. These data were collected as part of a larger study that included a battery of standardized and experimental tests. Testing was generally conducted over the course of two non-consecutive days. This study was approved by the University of Connecticut Institutional Review Board; all participants and their parents provided informed assent and consent.

Standardized Measures

Cognitive abilities. In order to assess the cognitive, language, and neuropsychological functioning of the subjects, subjects completed a battery of tests, including a measure of estimated intelligence. The *Stanford-Binet Intelligence Scales: Fifth Edition* (Roid, 2003) routing tests were used to provide a brief but reliable estimate of verbal and nonverbal cognitive functioning.

Language. A variety of tests were used to assess language abilities, including the *Clinical Evaluation of Language Fundamentals, Fourth Edition* (CELF-4; Semel et al., 2003), which was used to assess syntax and morphological abilities. High reliability for the CELF-4 has been well established using several methods including test-retest stability, internal consistency, and inter-rater reliability (Semel, Wiig, Secord, 2003). Subtests from the *Test of Language Competence* (TLC; Wiig & Secord, 1989) were used to assess the ability to recognize and interpret the alternative meanings of lexical and structural ambiguities (Ambiguous Sentences subtest) and the ability to interpret figurative expressions (Figurative Language subtest). The TLC has adequate reliability with good test-retest and inter-rater reliability (Wiig & Secord, 1989).

Executive Functioning. Executive functioning (EF) refers to a set of cognitive processes, which involve higher level metacognitive capacities that allow an individual to perceive stimuli from his/ her environment, respond adaptively, anticipate future goals, consider consequences, and respond in an integrated manner to serve a purpose or goal. The *Delis-Kaplan Executive Functioning System* (D-KEFS; Delis, Kaplan, & Kramer, 2001) is a standardized set of tests used to assess key components of EF. Subjects completed subtests from the D-KEFS including the Verbal Fluency, Color-Word Interference Test, Sorting Test, and Tower Test. The D-KEFS has adequate convergent and divergent validity; reliability is adequate to good across age groups (Homack, Lee, & Riccio, 2005). Additional measures of Working Memory were also collected, including two subtests from the Wechsler Intelligence Scales for Children, Fourth Edition (WISC-IV; Wechsler, 2003), Digit Span and Letter-Number Sequencing.

Social Skills. Social and communication skills were reported by parents using the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003).

Table 1. Participant Characteristics

	HFA, *n* = 15	TD, *n* = 14	*p*	Cohen's *d*
Age (years)	14.4 (1.9) *12.0 – 17.67*	14.1 (1.4) *12.5 – 17.25*	.69	.15
Abbreviated Verbal IQ	9.73 (2.7) *5 – 13*	11.57 (2.2) *9 – 16*	.05	.77
Abbreviated Non-Verbal IQ	11.13 (2.3) *7 – 15*	9.64 (2.0) *6 – 13*	.08	.69
CELF-4 Core Language Index	108.64 (10.27) *93 – 123*	115.29 (9.83) *93 – 129*	.09	.68
TLC Ambiguous Sentences	9.4 (4.08) *0 – 14*	11.00 (2.8) *6 – 16*	.24	.46
TLC Figurative Language	8.2 (3.84) *3 – 16*	11.07 (2.9) *6 – 15*	.03	.87
WAIS-IV/ WISC-IV -Working Memory Index	103.4 (18.56) *80 – 141*	106.75 (16.9) *88 – 145*	.63	.19
DKEFS Verbal Fluency, Switching	11.27 (3.17) *8 – 19*	10.71 (3.05) *6 – 17*	.64	.18
DKEFS Color-Word, Inhibition	10.07 (2.5) *8 – 13*	12.36 (1.73) *5 – 16*	.11	.63
DKEFS Sorting	10.07 (2.5) *5 – 13*	12.36 (1.7) *9 – 15*	<.01	1.08
DKEFS Tower	9.4 (2.2) *5 – 13*	11.5 (1.89) *9 – 15*	.01	1.04
SCQ	22.38 (4.7) *16 – 33*	2.31 (2.21) *0 – 7*	<.001	5.53
ADOS Total	10.08 (2.06) *7 – 14*	NA	NA	NA

Note: Data are presented as Mean (SD), *Range*.

Experimental Design

To isolate the mechanisms that contribute to prosodic production, subjects participated in a series of experimental tasks that were based on the psycholinguistic paradigm described by Snedeker and colleagues (Snedeker, & Trueswell, 2003; Snedeker & Yuan, 2008). Specifically, participants instructed a "partner" to perform actions using small toys. Critical trials contained ambiguous wording; in order to disambiguate instructions to their partner, subjects had to use prosodic cues. Disambiguation was operationalized as *lengthened pauses* and *clause duration* (defined below).

In each of four experimental conditions (described in detail below under the Experimental Conditions heading), subjects and a partner (a research assistant) participated in an instruction-giving activity. They were told, "This is an experiment about talking and listening." The expressed goal of the activities was for the subject to communicate instructions to the partner so that the partner would complete a specific action. Subjects and their partners sat across from one another at a table, but were separated by an opaque divider to prevent visual information from being exchanged.

For each of 12 trials within each of the four experimental conditions (for a total of 48 trials), the experimenter presented identical sets of five toys to the participant and partner. The experimenter labeled each toy as the toys were placed on the table (e.g. "Here is a ball. Here is a cup."). After the toys were handed out, the experimenter demonstrated an action with the toys to the subject only (e.g., picking up the ball and placing it in the cup). After the subject watched the experimenter's action, he or she was handed an index card with an instruction that described the experimenter's action (e.g., "Put the ball in the cup."). After the subject memorized the instruction on the card, the subject returned the card to the experimenter, and performed the same action with the toys to facilitate memory for the appropriate action. Subjects then instructed the partner to perform this action, using the exact words on the index card (e.g., "Put the ball in the cup"). Requiring subjects to use the exact wording from the cards ensured that subjects were forced to rely on suprasegmental cues, including prosody, rather than wording to make any ambiguous instructions (described below) clear for their partner.

On eight critical trials (of 12 total trials) in each block, the toy set included:

(1) A stuffed animal holding an object (e.g., a lamb holding a flower);
(2) A stuffed animal identical to the first but without the object (e.g., a lamb);
(3) A large version of the object the stuffed animal was holding (e.g., a flower);
(4) A distracter stuffed animal (e.g., a cow);
(5) A distracter toy (e.g., a ball).

Instructions for critical trials were designed to be syntactically ambiguous. For instance, the instruction, "Hit the lamb with the flower," could be understood with an *instrumental* interpretation, where the flower is used as an *instrument* for hitting the lamb. Alternatively the same instruction, "Hit the lamb with the flower," could be understood with a *modifier* interpretation, where the flower is meant to *modify* the instruction by identifying which lamb should be hit (i.e., the lamb that is holding the flower). In order to differentiate between these two interpretations outside of the experiment, most people would vary the wording of their instructions, saying, "Use the flower to hit the lamb," to indicate an instrument interpretation and, "Hit the lamb that is holding the flower," to indicate a modifier interpretation. However, during the current study, subjects were told that they could only instruct their partner by using the words on the card (e.g., "Hit the lamb with the flower"). By constraining the wording that subjects could include in their instruction to their partner, subjects were forced to rely on prosodic cues to disambiguate these ambiguous sentences. In previous studies using a similar paradigm typically developing adults and children reliably used prosodic cues to disambiguate these types of phrases (Snedeker, & Trueswell, 2003; Snedeker & Yuan, 2008). Specifically, acoustic analysis suggested that in order to communicate the *instrument* interpretation, TD subjects made systematic prosodic adjustments including increased utterance duration of the direct object noun, the noun pause, the noun composite, and the prepositional phrase relative to these durations in the *modifier* interpretation; changes also included decreased utterance duration of the verb length, verb pause, and verb composite during instruction versus modifier phrases.

To reiterate, participants were provided with a set of animals and objects, a printed script, and a specified action to enact (which could take on a *modifier* or an *instrument* interpretation). Each of the four conditions in the current experiment (described below) included eight critical trials: four trials that prompted the subject to communicate an instrument interpretation, and four trials that prompted a modifier interpretation. In addition to the eight critical trials, four filler trials were included in each block to ensure that subjects understood the task and to avoid explicit attention to the purpose of the task. Filler trials had unambiguous instructions. In two filler trials, subjects instructed the partner to use a toy as an instrument; in two other filler trials, subjects instructed the partner to act upon an animal with a modifier (see Appendix A). The ratio of critical trials to filler trials was consistent with that of previous similar experiments (e.g., Snedeker & Trueswell, 2003), in which 16 critical trials and 30 filler trials were presented. Because the focus here was on the ability to produce the critical distinction, and the underlying mechanisms, rather than on the spontaneous production, the number of trials was reduced in order to permit the inclusion of a larger number of experimental contrasts.

Each trial was recorded using a *Marantz Professional* Model PMD660 audio recorder for subsequent acoustic analyses (detailed below).

Experimental Conditions

Baseline. To establish how adolescents with HFA and TD spontaneously use expressive prosody to disambiguate syntactically ambiguous sentences, participants completed a Baseline block of trials. The Baseline condition was comprised of 12 sentences (four syntactically ambiguous critical trials, with an instrumental interpretation; four ambiguous trials with a modifier interpretation; and four unambiguous filler trials). Based on previous literature, we expected that subjects would systematically vary timing of the pauses and clauses within instructions of the instrument versus modifier instructions.

Post-intervention block. In baseline trials, participants had to spontaneously produce appropriate prosodic cues in order to communicate an unambiguous instruction. Following the Baseline condition, subjects responded to a series of questions designed to assess their awareness of the syntactic ambiguity. They were also asked if they employed any specific strategy to help their partner. Then, participants participated in a brief "prosody intervention," which included increasing attention towards the ambiguity, explicit instruction about prosodic phrasing, and opportunities to imitate prosodic phrasing. This intervention was provided via a five-minute video, which gave a brief introduction of how prosody (especially speech rate and pause length) can help to disambiguate syntactically ambiguous phrases (see Appendix B for transcript of video intervention). In this video, subjects were alerted to the ambiguity and were directly instructed to use their voices to help their partner perform the correct action. All subjects watched the video and had an opportunity to ask questions about it. Immediately after viewing the video, subjects completed twelve "post-intervention" trials using a second set of stimuli and novel instructions. As in the Baseline condition, the Post-Intervention condition consisted of 12 sentences (eight syntactically ambiguous critical trials and four filler sentences with unambiguous instructions); specific lexical items, sentences and toys were different in each trial.

Verbal cognitive load block. The verbal cognitive load condition was designed to examine how executive functions (specifically: verbal cognitive load) impacts the ability to use prosodic phrasing to clarify syntactically ambiguous sentences. The Verbal Load condition used the same design as the Baseline condition, with one addition: subjects were given a string of random consonant letters before each trial and instructed to remember them. The subjects verbally recalled the letters immediately after giving the instruction to his or her partner.

To create a load condition that was "titrated" to each individual participant's working memory abilities, the number of letters to recall was determined by the subject's individual performance on the WISC-IV or WAIS-IV *Digit Span* subtest. Specifically, the length of the letter string was equal to the longest correctly remembered digit span minus two; this length was determined based on pilot testing. Thus, a subject with a digit span of 7 was asked to remember 5 letters in each trial in this condition.

Non-verbal cognitive load. The non-verbal cognitive load condition was designed to examine how non-verbal cognitive load impacts the ability to use prosodic phrasing to clarify syntactically ambiguous sentences; it used the same basic design as the Verbal Load block, but imposed a visuospatial memory demand rather than a verbal one. Specifically, prior to giving the instruction to their partners, subjects were presented with a board of small holes, similar to the board used to administer the Fingers Window subtest of the WRAML-2 (Sheslow & Adams, 1999), and were asked to remember the spatial pattern presented to them. Immediately after giving the instruction to the partner, subjects were asked to recall the pattern.

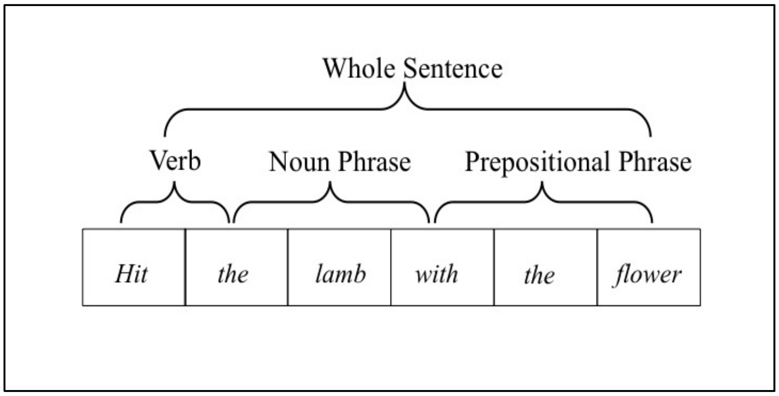
Again, in order to create a load condition that would tax working memory capacities equally across individuals, the length of the spatial span was individually determined based on subject's longest correctly remembered digit span. In this case, however, the length of the spatial span was equal to the longest correctly remembered digit span minus three. Performance on similar non-verbal span tasks, such as the WAIS-RNI and WMS-III *Spatial Span* is typically one to two items below digit span (Kaplan, Fein, Morris, & Delis, 1991).

These four task conditions were developed and tested via extensive pilot data collection, described in the Pilot Data results section.

Coding and Analyses

Acoustic information about each verbalization was analyzed using *Praat* (Boersma & Weenink, 2012) software. Key variables of interest included duration of: whole sentence utterance, verb pause, noun phrase, and prepositional phrase (see Figure 1). Because auditory pauses do not reliably occur between spoken words (Cole, Jakimik, & Cooper, 1980), word boundaries are difficult to measure precisely. Thus, instead of estimating word boundaries, an analysis of the length of time between moments of acoustic stress within each word was used. Specifically, using *Praat,* the intensity (decibels) corresponding to every 0.005 seconds of each critical trial was reported. Using this output, the rate of change in intensity (i.e. velocity) was determined for each time point (i.e., each 0.005 seconds). Maximum intensity or "peak" moments were identified when the velocity of intensity crossed from a positive to negative direction. In cases of multiple "peak" moments within a word, the time corresponding to the typically stressed syllable was recorded. For instance, if a subject produced two "peaks" within the word "flower," only the peak corresponding to the first syllable was recorded. Thus, a single "peak" was identified for each word in each critical trial.

Figure 1. Sentence Variables of Interest



Results

In order to assess the feasibility of the experimental task, pilot data were collected on a group of college students described below. These data were checked for outliers and assumptions of statistical normality were confirmed. Paired t-tests were used to compare subjects' timing during utterances of modifier- versus instrument-biased instructions. Results from the pilot data are described below. Following a description of the pilot experiment and results, an analytic plan for primary experiment is presented, followed by results from the primary experiment.

Pilot Experiment and Results

Pilot data was collected to ensure task feasibility. Participants included 15 English-speaking, college-aged students. Subjects volunteered to participate in a study of "Language by Eye and Ear" in order to receive credit for an introductory Psychology course. In addition to completing the Baseline condition as explained above, subjects completed the WAIS-IV Digit Span subtest. Digit Span is one of three subtests that comprise the Working Memory Index of the WAIS-IV. Digit Span yields scaled scores with mean scores of 10 and standard deviation of 3.

Results indicated that, as anticipated, subjects spontaneously varied their prosodic phrase timing based on trial type (i.e., instrument versus modifier sentences). Paired *t*-tests indicated significant differences in the length of time (in seconds) subjects used to express several components of their sentences; all data are reported in Table 2 and shown in Figure 2. Specifically, instrumental trials were significantly longer than modifier trials at the level of: 1) the entire sentence (e.g. "Hit the lamb with the flower") and 2) the noun phrase (e.g. "the lamb") and 3) showed a trend towards a longer prepositional phrase ("with the flower"). Also, as anticipated, the verb (e.g. "hit") was significantly longer in the modifier condition.

Results of correlational analyses indicated that Digit Span scaled scores were significantly correlated with the difference between verb lengths in instrument versus modifier sentences, *r* (15) = .718, *p* = .003, with better performance on Digit Span associated with more differentiation between modifier and instrument trials.

These pilot data demonstrated proof of concept: Typically developing adults spontaneously demonstrated the ability to use prosodic phrasing to disambiguate syntactically ambiguous sentences in the context of the experimental design. Further, the relationship between performance on a test of working memory and use of successful prosodic phrasing suggests that cognitive skills outside of language or social domains are likely to contribute to the tendency to express this type of prosody.

Figure 2. Pilot Study Results

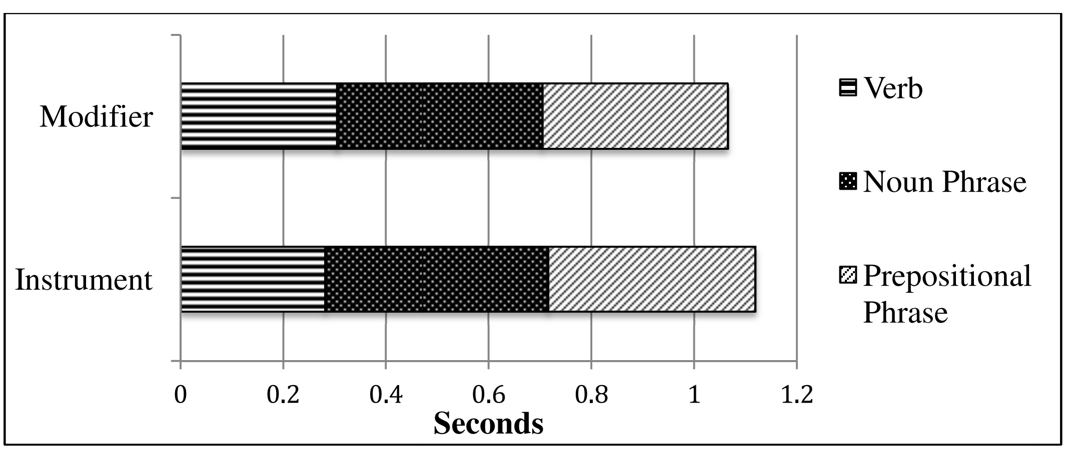


Table 2. Pilot study: Sentence variables during modifier versus instrument sentences

	Modifier	Instrument	t	*p*	Cohen's *d*
Whole Sentence	1.0409 (.11)	1.1420 (.13)	3.45	.004	.91
Verb	0.3044 (.036)	0.2810 (.043)	2.36	.034	.62
Noun Phrase	0.3998 (.071)	0.4346 (.085)	2.12	.052	.56
Prepositional Phrase	0.3601 (.036)	0.4027 (.052)	3.74	.002	1.02

Note: Data are presented as *Mean* (*SD*), in seconds.

Primary Experiment

To examine how participants with HFA and TD use expressive prosody to disambiguate syntactically ambiguous sentences, during each of the four experimental conditions (Baseline, Post-Intervention, Verbal Cognitive Load, and Non-Verbal Cognitive Load), an initial omnibus MANOVA was used determined the impact of diagnostic group and experimental condition on prosodic phrasing. Independent variables included diagnostic group (HFA and TD) and experimental condition; dependent variables were difference scores (calculated as the difference in utterance length between the modifier and instrument sentences) for entire sentences, verb, noun phrase, and prepositional phrase. There were no statistically significant differences between HFA and TD groups on the combined dependent variables, F (4, 92) = 1.147, p =0.34; Wilk's λ= 0.941; ή^2 = 0.06, suggesting an overall similar pattern of performance between the TD and HFA groups. There was a significant main effect of condition, F (4, 254) = 0.205, p < 0.001; Wilk's λ= 0.205; ή^2 = 0.411, suggesting that subjects' performance varied based on experimental condition. Given the significance of the omnibus MANOVA for experimental conditions, additional MANOVAs were used to analyze variables within the four conditions.

To examine how participants with HFA and TD spontaneously use expressive prosody to disambiguate syntactically ambiguous sentences, MANOVA and planned post hoc analyses evaluated the impact of phrase type (i.e., modifier versus instrument) on prosodic phrasing (i.e., length of utterance in seconds) while subjects instructed their partner during the Baseline condition. Additional MANOVA and planned post hoc tests investigated how experimental condition (i.e., Baseline, Post-Intervention, Verbal Load, Non-Verbal Load) interacted with group differences. Correlational statistics were used to probe associations among prosodic phrasing (timing) during the Baseline condition, cognitive ability, language skills, executive functioning, and social skills. All variables were examined for deviations from assumptions underlying statistical analyses (e.g., sphericity, homoschedasticity, etc.).

Baseline condition. To examine the impact of diagnostic group and sentence type on prosodic phrasing, two-way between-groups multivariate analysis of variance was performed (MANOVA). Independent variables included diagnostic group (HFA and TD) and sentence trial type (Modifier and Instrument); dependent variables were utterance length for entire sentences, verb, noun phrase, and prepositional phrase. Omnibus MANOVA indicated significant differences between modifier and instrument trials, indicating that subjects varied the duration of their utterances and pauses to communicate a modifier- versus an instrument-interpretation of their instruction; F (4, 51) = 3.22, p =0.02; Wilk's λ= 0.799; $\acute{\eta}^2$ = 0.20. Consistent with studies of TD adults and children using a similar design (Snedeker & Trueswell, 2003), paired *t*-tests indicated that subjects in both groups took significantly longer to utter the *entire sentence* and the *noun phrase* when communicating an instrument interpretation of the instruction. For both groups, there was a trend for a difference between the length of the *prepositional phrase* (e.g. "with the flower") in instrument versus modifier trials, with longer utterances during the instrument trials (see Figure 3).

Additionally, the HFA and TD groups differed on the combined dependent variables F (4, 45) = 2.79, p =0.04; Wilk's λ= 0.82; $\acute{\eta}^2$ = 0.18. Post hoc analyses suggest that this significant result reflected a group difference on only a single variable. Specifically, the HFA group uttered significantly *slower* prepositional phrases than the TD group during modifier trials, and the effect size of this difference was small; *F* (3, 54) = 5.64, *p* =0.02; $ή^2 = 0.09$. Prior research suggests that the prepositional phrase would typically be *faster* for modifier phrases. However, this finding is of limited importance, as the timing of each utterance is informative only as it relates to the timing of the same utterance in the alternative sentence type. That is, although the HFA group was slower in their utterance of prepositional phrases in the modifier sentences, both groups demonstrated the same pattern of *relatively* shorter prepositional phrase in the modifier trials as compared to prepositional phrase in the instrument trials. The interaction between diagnostic group (HFA or TD) and sentence type (Modifier or Instrument) was not significant *F* (4, 45) = .283, *p* =0.88; Wilk's λ= 0.978; $ή^2 = 0.02$. (See Figure 3 and Table 3 for group means.)

Figure 3. HFA and TD Results: Baseline Condition

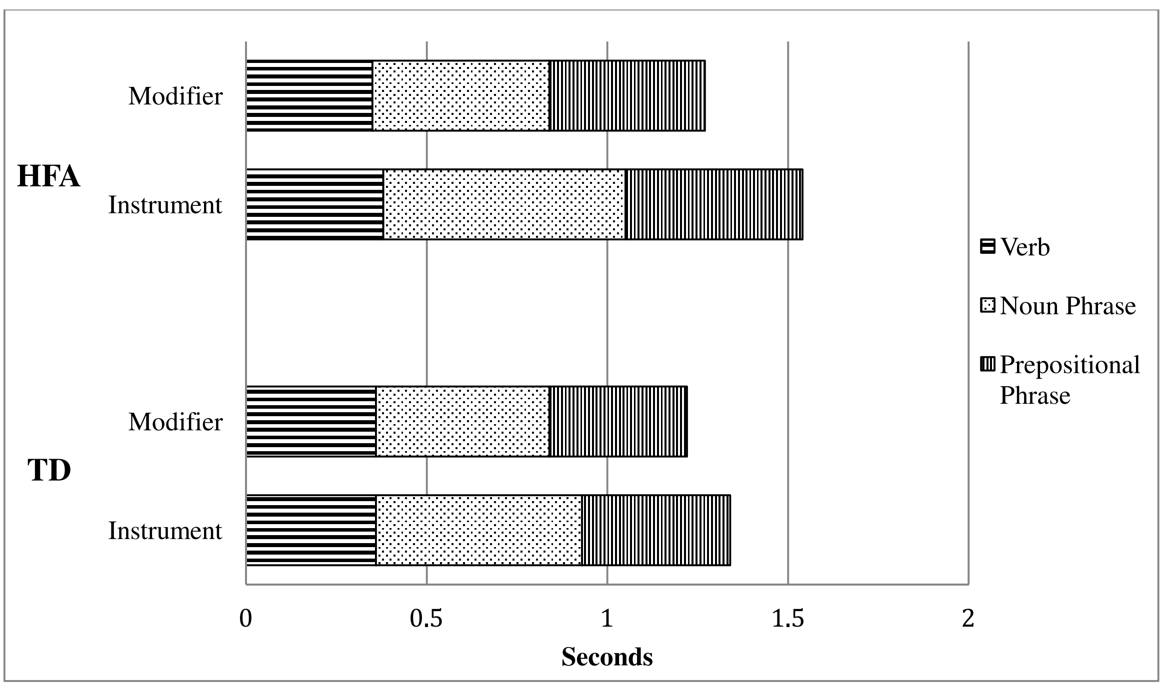


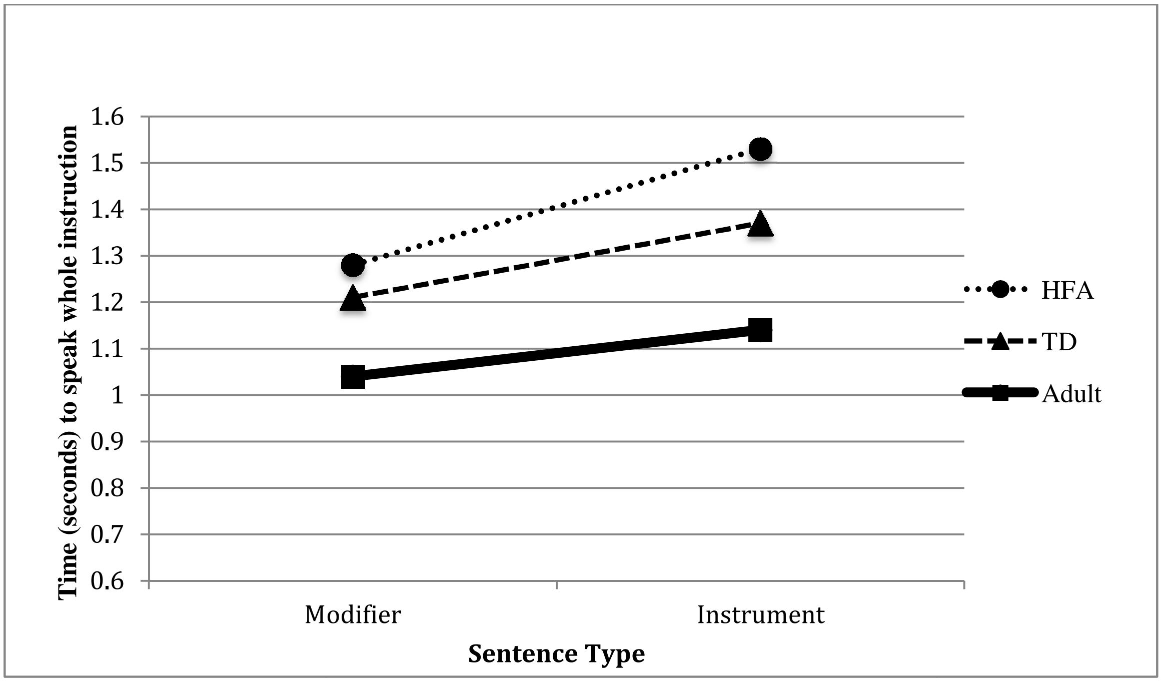
Table 3. Baseline: Prosodic phrasing during modifier and instrument sentences

	Modifier	Instrument	t	*p*	Cohen's *d*
HFA group					
Whole Sentence	1.28 (.28)	1.53 (.42)	2.47	0.03	.64
Verb	0.35 (.08)	0.38 (.11)	1.14	0.27	.26
Noun Phrase	0.49 (.13)	0.67 (.23)	3.14	<0.01	.83
Prepositional Phrase	0.43 (.08)	0.49 (.14)	1.79	0.09	.62
TD group					
Whole Sentence	1.21 (.41)	1.37 (.40)	3.28	<0.01	.89
Verb	0.36 (.14)	0.36 (.15)	0.02	0.98	<.01
Noun Phrase	0.48 (.17)	0.57 (.18)	2.51	0.03	.64
Prepositional Phrase	0.38 (.08)	0.41 (.12)	1.96	0.07	.55

Note: Data are presented as *Mean* (*SD*), in seconds.

ANOVA was also used to compare overall rate of speech used by the adolescent groups during the baseline condition in comparison to the adults in the pilot study (see Figure 4). Consistent with results presented thus far, ANOVA indicated a significant main effect of sentence type F (1, 41) = 18.074, p =0.01; $ή^2$ = 0.306, suggesting that across groups, participants were faster in their utterances of modifier-biased sentences as compared to instrument-biased sentences. Additionally, there was a main effect of group, F (2, 41) = 4.79, p =0.01; $ή^2$ = 0.189. Post hoc analyses indicate that the adult participants had a significantly faster rate of speech as compared to the HFA adolescents, p = 0.01. The differences between the adults and TD adolescents were not significant (p = .25) nor were the differences between the TD adolescents and HFA adolescents significantly different (p = .67). There was no significant interaction between group and sentence type, F (2, 41) = 1.387, p =0.261; $ή^2$ = 0.063.

Figure 4. Rate of speech during baseline condition: group comparison



Post-intervention. MANOVA was used again to explore the impact of diagnostic group and sentence type on prosodic timing after the video intervention, including the same variables as for the Baseline analysis. Omnibus MANOVA indicated significant differences between modifier and instrument trials with a large effect size. F (4, 45) = 24.11, p <0.001; Wilk's λ= 0.32; $ή^2 = 0.68$. There were no statistically significant differences between HFA and TD groups on the combined dependent variables F (4, 45) = 1.09, p =0.38; Wilk's λ= 0.912; $ή^2 = 0.09$. The interaction between diagnostic group (HFA or TD) and sentence type (Modifier or Instrument) was not significant, F (4, 45) = .336, p =0.85; Wilk's λ= 0.971; $ή^2 = 0.06$.

Together, these results of performance following the intervention indicate that the HFA and TD group performed similarly to one another: both groups varied their prosodic phrasing according to sentence type (modifier versus instrument). An inspection of mean scores for modifier versus instrument trials via planned t-tests, suggests that, across groups, subjects took longer to utter the entire phrase, the noun phrase, and the prepositional phrase during instrument trials. These results are consistent with prior research of prosodic phrasing in children and adults with typical development (Snedeker & Trueswell, 2003). Also consistent with prior research, groups took longer to express the verb during modifier trials (see Table 4 and Figure 5).

Figure 5: HFA and TD Results: Post-Intervention

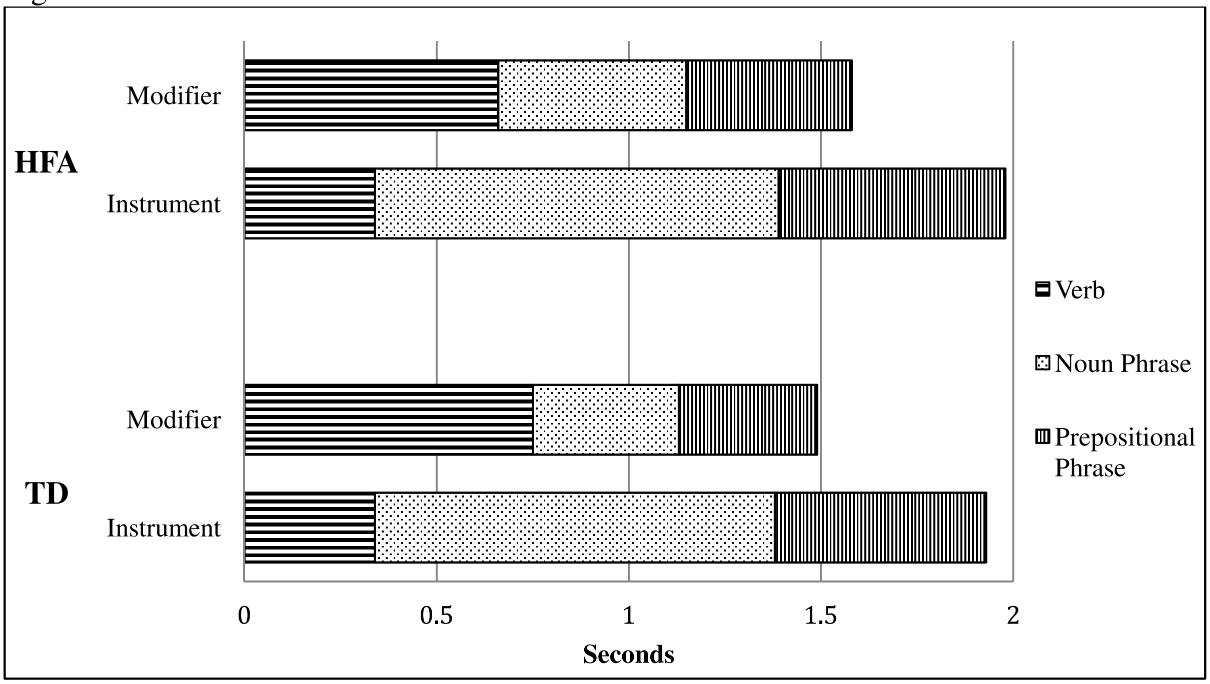


Table 4. Post Intervention: Prosodic phrasing during modifier and instrument sentences

	Modifier	Instrument	t	*p*	*Cohen's d*
HFA group					
Whole Sentence	1.59 (.37)	1.99 (.29)	6.49	<0.001	1.94
Verb	0.66 (.41)	0.34 (.06)	2.76	0.02	1.02
Noun Phrase	0.49 (.19)	1.05 (.29)	5.04	<0.001	1.99
Prepositional Phrase	0.43 (.11)	0.59 (.18)	4.39	0.0901	1.38
TD group					
Whole Sentence	1.51 (.29)	1.92 (.46)	4.384	0.001	1.40
Verb	0.75 (.28)	0.34 (.17)	4.73	<0.001	1.40
Noun Phrase	0.38 (.17)	1.04 (.32)	7.53	<0.001	2.05
Prepositional Phrase	0.36 (.05)	0.55 (.14)	4.76	0.001	1.51

Note: Data are presented as *Mean* (*SD*), in seconds.

Verbal and non-verbal cognitive load. MANOVA for the Verbal and Non-Verbal Cognitive Load conditions was conducted in a similar fashion. For both conditions, results indicated no significant main effect of group (Verbal Load condition, F (5, 44) = 0.33, p = .892; Wilk's λ= 0.331; ή^2 = 0.036; Non-Verbal condition, F (5, 44) = 0.560, p = .730; Wilk's λ= 0.940, ή^2 = 0.06). In both load conditions, there was a significant main effect of sentence type suggesting utterance lengths were significantly different in modifier versus instrument sentences (Verbal Load condition, F (5, 44) = 16.257, p < .001; Wilk's λ= 0.351; ή^2 = 0.649; Non Verbal condition, F (5, 44) =24.841, p < .001; Wilk's λ= 0.262; ή^2 = 0.738). Inspection of mean scores for modifier versus instrument trials again suggests that subjects across groups used a pattern of prosodic phrasing that is consistent with prior literature (i.e. longer entire sentence, noun phrase, and prepositional phrase during instrument-trials, and longer utterance of the verb during modifier-trials).

Analysis of performance of the respective cognitive "load" tasks during the verbal and non-verbal conditions (i.e., recall of a string of letters during the Verbal Load condition and recall of a visual pattern during the Non-Verbal Load condition) indicates that the HFA and TD groups were similarly able to respond to the task of recalling the string of letters during the Verbal Load condition. That is, out of 12 possible correct responses, the HFA and TD groups correctly recalled the string of letters with similar accuracy (HFA Mean = 6.8, SD = 3.15; TD Mean = 7.5, SD = 3.03; p = 0.59). Higher accuracy for letter recall was not correlated with differences in timing during modifier versus instrument sentences (i.e., the sum of the timing differences in verb, noun phrase, and prepositional phrase during modifier versus instrument sentences) during the Verbal Load condition, all p's > 0.4, suggesting that the TD and HFA groups were equally able to maintain correct prosodic phrasing while managing a verbal interference task.

During the Non-Verbal Load condition, the HFA group was significantly less able to recall the visual pattern than the TD group (HFA Mean = 6.69, SD = 3.6; TD Mean = 9.1, SD = 1.7; $p = 0.44$). Higher accuracy for recall of the visual pattern was not correlated with differences in timing during modifier versus instrument sentences in either group, suggesting that the HFA group may have sacrificed accurate recall for the visual pattern in order to maintain prosodic phrasing.

Together, these results suggest that across conditions, HFA and TD groups performed similarly to one another, and tended to vary their prosody in the expected directions. That is, they took longer to express the entire sentence, the noun phrase, and prepositional phrase during instrument trials. During the Baseline condition, groups had a similar pattern of failing to shorten their verb utterance during modifier versus instrument trials. Although both groups demonstrated the ability to use prosodic phrasing spontaneously to disambiguate syntactically ambiguous sentences prior to the intervention, both groups demonstrated increased differentiation after the video intervention (as measured by increases in absolute differences between utterance length during modifier versus instrument trials and reflected in the increases in the effect size of differences). The impact of the intervention was quite robust; effects were maintained across both the verbal and non-verbal cognitive load conditions. During the Verbal Load condition, the HFA and TD groups were equally able to manage the verbal interference task while reliably using prosodic cues. However, during the Non-Verbal Load condition, the HFA group was less able to manage the interference task while maintaining their use of prosodic cues. That is, the HFA group appeared to sacrifice performance on the non-verbal interference task for reliable use of prosodic cues, suggesting that they may have relied more on non-verbal processes to support prosodic production than the TD group.

Correlations between expressive prosody and standardized assessment. In order to explore the relationship between subjects' cognitive, linguistic, and diagnostic profiles and their use of spontaneous expressive prosody, correlational analyses were conducted for data from the Baseline condition (see Table 5), separately for each group. The difference between components of prosodic phrasing in the modifier and instrument sentence types were aggregated (i.e., the sum of the differences between modifier and instrument verb, noun phrase, and prepositional phrase utterance lengths) to determine the extent to which each subject varied his or her prosodic phrasing based on sentence type.

Additionally, subjects' responses to debriefing questions were examined. Of all of the subjects (n = 29), 26 articulated awareness that their instructions were syntactically ambiguous. The three children who were not aware of the ambiguity were all from the HFA group. Compared to the rest of the HFA group, these three children were similar in age, non-verbal IQ, measures of social skills (i.e., the SCQ and ADOS scores), and measures of executive functioning (WISC-IV/ WAIS-IV Digit Span), all p-values > 0.4, but had significantly lower Verbal IQ (Unaware HFA Mean = 5.3, SD = .57; Aware HFA Mean = 10.73, SD = 1.6; t (12) = 9.38; p < .001), suggesting that this small "Unaware" group was similar to the larger HFA group except for their Verbal IQ. Compared to the larger Aware-HFA group, the Unaware-HFA group had significantly smaller changes in prosodic timing (Unaware Mean = 0.02, SD = .08; Aware Mean = 0.27, SD = 0.24; t (10) = 2.8; p = .02), suggesting that awareness of and ability to express the ambiguity was important for using prosodic phrasing for syntactic disambiguation.

Additionally, although the majority of subjects articulated an awareness of the ambiguity in their utterances, there was more variability in the debriefing question, "How hard did you try to make sure your partner was correct? What did you do to make yourself clear?" Responses to the latter component of this question yielded a mix of expressed strategies. Subjects' responses were split into two categories: "Good" strategies included any articulation of a component of prosody (e.g., pausing, tone of voice, speed, an example of expressive prosody), whereas "Bad" strategies included strategies that did not include any mention of components of prosody (see a list of responses in Appendix C). Five subjects in the HFA group and seven subjects in the TD group offered "Good" strategies. Note that data was unavailable for two adolescents in the HFA group because data were not recorded. A Chi-square test indicated no significant association between groups in the ability to articulate a "good" strategy, χ^2 (1, n = 27) = 0.363, p = 0.83.

For the HFA group, spontaneous use of expressive prosody to differentiate modifier versus instrument interpretations of the utterances was not correlated with age, IQ, measures of language, social skills, or executive functioning. Rather, a greater difference in utterance timing for modifier vs. instrument sentences was associated with the ability to express a "good" strategy for managing the ambiguity, F (1, 11) = 16.22, p =0.002; $\acute{\eta}^2$ = 0.596. Subjects who expressed a "good" strategy for managing the ambiguity responded by appropriately changing the timing of components of their sentences, resulting in more differentiation between the differences in utterance duration, and clearer prosodic phrasing.

Use of spontaneous expressive prosody in the TD group was associated with performance during the WISC-IV/ WAIS-IV subtest: Digit Span r (14) = .614, p = 0.03, such that better performance on Digit Span corresponded to greater differentiation between instrument and modifier sentences. Additionally, greater differentiation between modifier and instrument sentences was also associated with an ability to articulate a "good" strategy, F (1, 11) = 7.457, p =0.02; $ή^2$ = 0.404. Like the HFA group, TD subjects who articulated a "good" strategy for managing the syntactic ambiguity responded by changing the duration of their utterances in the modifier versus instrument sentences.

Table 5. Correlation Matrix: Baseline Timing Differences (Modifier vs. Instrument) and Subject Characteristics

	Timing Difference	Age	VIQ	NVIQ	CELF-4 CLI	SCQ Total	Digit Span
Timing Difference		.393 .17	.527 .05	-.078 .80	-0.02 .94	-0.149 .63	.614 .03
Age	.214 .44		.346 .23	.280 .33	.116 .69	.106 .73	.660 .02
VIQ	.439 .11	-.105 .71		.101 .73	.615 .02	-.023 .94	.580 .05
NVIQ	.291 .29	.030 .92	-.163 .56		-.041 .89	-.492 .09	.434 .16
CELF-4 CLI	.491 .08	.043 .89	.547 .04	.211 .47		.055 .86	.396 .20
SCQ Total	.260 .41	.695 .01	-.004 .99	.128 .69	.170 .60		-.225 .48
Digit Span	.051 .86	.216 .44	-.133 .64	-.029 .92	.436 .12	.347 .27	

NOTE: Table lists Pearson's r and p-values. TD correlations are above diagonal; HFA correlations are below diagonal. Combined Timing Differences = sum of differences during modifier vs. instrument sentences; VIQ = Stanford Binet Verbal Routing scaled score; NVIQ = Stanford Binet, Non-Verbal Routing scaled score; CELF-4 CLI = Core Language Index; SCQ = Social Communication Questionnaire; Digit Span = WISC-IV/ WAIS Digit Span, scaled score.

Task-naïve comprehension of prosodic phrases. For a subset of participants with HFA (n = 13) or TD (n = 13), a set of 50 utterances (25 modifier and 25 instrumental trial sentences) from the Baseline condition was presented to a set of 15 undergraduate students. The undergraduates saw two pictures (depicting either the modifier or the instrumental action) and heard an utterance from an HFA or a TD participant, and were asked to "choose which picture went best with the sentence." The undergraduate students performed this task in exchange for extra credit in an undergraduate psychology course.

Results indicated that across participants, raters were not reliably able to identify the correct phrase interpretation based on prosodic cues that were provided by the participant speakers during the Baseline condition. Raters were at or below chance in their efforts to differentiate the sentence types. There was no significant difference in accuracy between sentence type (instrumental versus modifier), $F\ (1, 23) = 0.64$, $p = 0.43$, $\eta^2 = 0.03$, and no interaction between sentence type and group, $F\ (1, 23) = 0.36$, $p = 0.85$, $\eta^2 = 0.002$. There was however a main effect of group, $F\ (1, 23) = 5.21$, $p = 0.03$, $\eta^2 = 0.19$, with a small effect size, such that the naïve raters were more accurate in choosing the correct response for the utterances by individuals with HFA, across sentence types. However, this apparent group difference was mooted by the fact that in general, raters were at or below chance. These results suggest that although each group demonstrated measurable differences in timing of their prosodic phrasing according to sentence type, these changes were difficult to perceive and/ or difficult to interpret by task-naïve listeners.

Discussion

The present study examined the relationships between expressive grammatical prosody and more general cognitive and social processes. We first investigated the relationships between these general processes and expressive prosody in healthy college students, and then explored the contributions of cognitive and social abilities on prosody in adolescents with high functioning autism. Understanding the skills and abilities that support typical prosody is a critical step toward clinical intervention. Given the relative dearth of interventions related to improving prosody in children with autism, we also designed a brief intervention targeting expressive prosody and examined its effects. Results from the current studies offer several insights.

First, similar to previous suggestions that atypical prosody may not be universally present in ASD (Simmons & Baltaxe, 1975; Shriberg et al., 2001), the current results suggest nearly identical group performance between the HFA and TD groups on a task of expressive prosodic phrasing, though subtlety different reliance on underlying working memory processes. Acoustic analysis of duration and timing of prosodic phrasing indicated few differences between the HFA and TD groups during the Baseline condition, after the video intervention, or when verbal or non-verbal cognitive challenges were presented. During each condition, both groups appreciated the ambiguity in their utterances and used prosodic phrasing accordingly in order to facilitate clearer communication. These results are consistent with subjective perceptions of similar performance between ASD groups and controls on prosodic phrasing tasks (McCann et al., 2007; Peppé et al., 2006; Paul et al., 2005) and strengthen these findings by relying on objective timing data. Consistent with multiple reports of differences in utterance length in TD versus ASD groups (Grossman, Bemis, Plesa Skwerer, & Tager-Flusberg, 2010; Van Santen, Prud'hommeaux, Black, & Mitchell, 2010; Diehl & Paul, 2012), the HFA group in the current study spoke with a slower rate of speech as compared to the adults who participated in the pilot study. The slowing may be related to a difference in relative difficulty of this task, whereby the HFA group experienced this task as somewhat more challenging and slowed their speech to compensate. Alternatively, Diehl & Paul (2012) hypothesize that slowed speech may reflect motor difficulties among ASD individuals, or may reflect general insensitivity to typical timing of duration and pauses during speech among individuals with ASD.

Second, the data presented here suggest that non-social cognitive processes contribute to an appreciation of ambiguity and subsequent expression prosodic phrasing. Differentiating between the types of sentences (i.e., modifier versus instrument sentences) with changes in expressive prosodic phrasing was associated with an explicit awareness of the ambiguity. The small number of children who did not notice or express awareness of the ambiguity all failed to differentiate between sentence types with prosodic phrasing. These children were all from the HFA group, but had similar social skills as the larger HFA group according to the SCQ and ADOS. They differed from the larger HFA group only in having significantly lower verbal IQ than the larger HFA group. In both the HFA and TD groups, an ability to articulate a reasonable strategy for better communication was associated with greater prosodic differentiation between sentence types. Together, these results reflect the importance of top-down processing for pragmatic skills; verbal IQ appears to have supported awareness of ambiguity, which in turn, led to a generation of a reasonable strategy for using supra-segmental aspects of language for better communication.

In both the TD adult pilot study and in the TD adolescent groups, changes in prosodic phrasing to express the different sentence types was positively correlated with a measure of verbal working memory: Digit Span. This association was not found in the HFA group and may reflect a greater reliance on inner speech or working memory for successful prosodic phrasing among the TD adolescents. Indeed, children with HFA have been shown to be less reliant on inner speech when completing tests of executive functioning (Wallace, Silvers, Martin, & Kenworthy, 2009). Additionally, although the HFA and TD groups maintained similar prosodic phrasing during each of the cognitive load tasks, the HFA group was unable to maintain the same level of accuracy during the visual recall interference task during the Non-Verbal Load condition. As a group, the adolescents with HFA seemed to sacrifice accurate visual recall for prosodic phrasing. This finding is consistent with the fMRI data that suggests greater reliance on visualization for language comprehension in ASD as compared to non-ASD groups (Kana, Keller, Cherkassky, Minshew & Just, 2006). Given that video was used as a medium for the intervention, this finding may suggest that the HFA group was relying relatively more heavily on the visual cues provided by the video as compared to the TD group.

Third, although timing data suggest that both the TD and HFA groups significantly varied their prosodic phrasing during baseline trials, naïve listeners were unable to detect the subtle differences in their timing. These listeners were unable to determine which interpretation the subjects intended and performance was at or below chance for both groups. These data suggest that future studies may benefit from the use of timing data to detect and changes in prosodic phrasing rather than reliance on broad “correct” versus “incorrect” judgments.

Fourth, although both the TD and HFA groups varied their prosodic phrasing at baseline according to sentence type, a brief, targeted intervention led to a significant change in their expression. That is, both groups demonstrated more differentiation between sentence types after the five-minute-long intervention, particularly of the noun phrase. Importantly, groups continued to demonstrate mastery of the prosodic phrasing even when they were challenged with increased cognitive demands during the verbal and non-verbal load conditions. The differences in prosodic phrasing used in the two sentence types (modifier and instrument-biased sentences) represented large effect sizes during the verbal load condition and the non-verbal load condition. While we anticipated that increasing cognitive demands would illuminate conditions under which prosodic phrasing was likely to be challenged, we found that after this targeted intervention, participants maintained appropriate use of prosodic phrasing. That said, within the HFA group, there was a strong correlation between prosodic phrasing during the non-verbal condition and their ability to recall the visual pattern, suggesting a heavier reliance on a non-verbal process in the HFA group only.

The intervention video included a variety of intervention techniques: raising awareness about ways to change aspects of voice, drawing attention to situations that are syntactically ambiguous, explaining how prosody can help disambiguate syntactic ambiguity, and providing opportunities for participants to listen and practice expressing changes in prosodic phrasing. Given that awareness of the syntactic ambiguity and expression of a broadly “good” strategy for addressing the ambiguity was correlated with greater spontaneous differentiation, it is likely that raising awareness to ambiguity and provision of explicit strategies for managing the ambiguity were among the most critical components of intervention.

The current findings may be expanded with further research. Importantly, the current sample of adolescents with Autism, were high functioning and had generally average core language skills. Studying a sample of adolescents who have a wider range of cognitive, language, and social abilities is likely to illuminate important patterns regarding the nature of expressive prosodic phrasing. Additionally, although the current study offers precise findings regarding the timing of prosodic phrasing, other components of prosody including vocal pitch, stress, and resonance were not examined here. Analysis of these voice characteristics is likely to offer additional insights in to the nature of prosody in the ASD population. Finally, isolating the key ingredients necessary to effect change and studying the generalizability of brief interventions will be important next steps for understanding the effectiveness of such prosodic interventions.

Appendix A

Baseline Condition Stimuli

Trial	**Sentence Type**	**Sentence**
1	Modifier (Filler)	Look at the lamb with socks.
2	Instrument (Filler)	Poke the duck with the tube.
3	Modifier	Point at the lamb with the flower.
4	Instrument	Tap the cow with the lollipop.
5	Modifier (Filler)	Listen to the pig with the tube.
6	Instrument	Touch the pig with the feather.
7	Modifier	Scratch the duck with the paper.
8	Instrument (Filler)	Hit the cat with the flower.
9	Modifier	Tap the cow with the lollipop.
10	Instrument	Point at the lamb with the flower.
11	Modifier	Touch the pig with the feather.
12	Instrument	Scratch the duck with the paper.

Appendix B

Video Intervention Transcript

People spend a lot of time talking to each other. But sometimes, our words are confusing to the person we're talking to. It turns out there are special things we can do to help – we can use our voice. There are actually lots of ways you can change your voice. For example, sometimes, you might use a very loud voice, like when you're cheering at a football game; and other times, you'd use a very quiet voice, like this little boy at the library.

We can also change the speed our voice. We can talk very fast… like a cheetah. Or we can talk verrrrry sloooowly… like a turtle. We also choose "when… to…. pause…. as… we… talk," or "when to pause… as we talk"

Read this phrase to yourself: chocolate milk and cookies. It could mean two different things. That phrase could mean this [picture of a bar of chocolate, a glass of white milk, and a plate of cookies] or this [picture of a glass of chocolate milk and a plate of cookies]. You could use your voice to make it clear. Let's think about the speed of your voice and your pauses can help make it clear.

If you mean to talk about three things: some chocolate, a glass of milk, and some cookies, use pauses to separate the words like this: chocolate… milk… and cookies. If you only mean to talk about two things: chocolate flavored milk, and some cookies, use one big pause, like this: chocolate milk… and cookies.

You can also help make the distinction clear by changing the speed of your voice. Talking slowly when you're talking about only one thing, and then speeding up when you want to group words together can help. Listen to this: "chocolate…milk… and cookies." The first two words are slow, and the last bit was faster. Now listen to this: "Chocolate milk,"… "and cookies." I said "chocolate milk" fast because those words go together, and then I said "and cookies" fast because those words go together. Listen again: "chocolate milk"… "and cookies"

Now read this phrase to yourself: This phrase could mean this [picture of someone holding a flower to hit a toy cat] or this [someone hitting a toy cat that is holding a flower]. Let's think about how to use the speed of your voice and your pauses to help make this one clear.

First, let's think about how to pauses can help. If we mean this: Hitting the cat that is holding the flower, the main points are "Hitting" and "the cat that is holding the flower." We can use pauses to separate these main points. Listen: Hit… the cat with the flower. I start the sentence with "hit" and then take a pause - before grouping the rest of the words together.

Now let's think about what to do if we mean this: Using the flower to hit the cat. In this sentence, the main points are "Hitting the cat" and "using the flower." Listen how pauses can help separate these main points. "Hit the cat… with the flower." I started the sentence with "Hit the cat" and then took a pause - before grouping the rest of the words together. Listen again: Hit the cat…with the flower.

Changing the speed of your voice can help too. Listen: Hit… the cat with the flower. Start slow and then go faster to group words together. Now listen to this: Hit the cat… with the flower.

Now that you know the tricks, see if you can hear the difference. Listen carefully – and guess which one I mean? Pat the lamb… with the flower. Listen again: "Pat the lamb…with the flower." Which one do I mean? I meant this one – "Pat the lamb … with the flower." See if you can use pauses and the speed of your voice just like I do. Repeat it right after me. "Pat the lamb… with the flower." Listen again: "Pat the lamb… with the flower." Now try repeating the one on top. "Pat… the lamb with the flower." Listen and repeat again: "Pat… the lamb with the flower."

Nice job! You learned some tricks about how to use your voice. Now you know how to change the speed of your voice and when to pause… as you talk to make yourself clear. See if you and your partner can use these tricks to do even better on the next activity.

Appendix C

Responses to debriefing question, "What did you do to make yourself clear?"

"Good" Strategy, *n* = 12	**"Bad" Strategy, *n* = 15**
Just had to use different tones of voice.	*I just said the words on the card.*
I tried to put in a beat – like from drama class.	*I didn't really know how.*
I think I slowed down my speech.	*I just had to memorize like 6 words, so I was just doing that. What was I supposed to do? Emphasize different words? That wouldn't do anything.*
I was trying to pause at different places.	*I don't know – I just memorized the words.*
I was inserting pauses and commas.	*I wasn't trying at all because I couldn't see her.*
I was trying to really say it so that she could understand me.	*I was pronouncing the words.* [Subject was not aware of ambiguity]
I tried to use pauses sometimes to talk about the different things.	*I was trying to memorize the exact words.*
I made sure to pause to make it clearer.	*I was trying to say it clearly so she could hear me.*
Well, you have to say it in a certain way, like put breaks in.	*I was just reading…not really doing anything special to be clear.*
I tried to put some emphasis on some of the parts.	*I was just reading and then telling her what to do.* [Subject was not aware of ambiguity]
I would try to say like, 'THE paper' or just "the paper" depending on if the animal was holding the thing.	*I was trying to pronounce every word right.*
I tried to make the rhythm smooth at different places.	*I had to just read off the card so I couldn't really do anything… I realize now that I could've made a noise with the toys on the table.*
	Maybe. Well, nothing really to be extra clear.
	Speaking clearly and fluently.
	[Subject was not aware of ambiguity and unable to answer question]

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text revision.). Washington, DC: Author.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Baddeley, A., & Wilson, B. A. (1993). A developmental deficit in short-term phonological memory: Implications for language and reading. *Memory, 1* (1), 65-78.

Ballard, K. J., Robin, D. A., McCabe, P., & McDonald, J. (2010) A treatment for dysprosody in childhood apraxia of speech. *Journal of Speech, Language, and Hearing Research, 53,* 1227-1245.

Baltaxe, C., & Guthrie, D. (1987). The use of primary sentence stress by normal, aphasic, and autistic children. *Journal of Autism and Developmental Disorders, 17*, 255–271.

Baltaxe, C. (1984) Use of contrastive stress in normal, aphasic, and autistic children. *Journal of Speech and Hearing Research, 27* (1), 97-105.

Baron-Cohen, S. (1995). *Mind blindness.* Cambridge, MA: MIT Press.

Baron-Cohen. S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a 'theory of mind'? *Cognition*. 2L 37-46.

Bellon-Harn, M. L. (2011) Targeting prosody: a case study of an adolescent. *Communication Disorders Quarterly, 32* (2), 109-117.

Bellon-Harn, M. L., Harn, W. E., & Watson, G. D. (2007) Targeting prosody in an eight-year-old child with high-functioning autism during an interactive approach to therapy. *Child Language Teaching and Therapy, 23* (2), 157-179.

Berkmoes, C., & Vingerhoets, G. (2004). Neural foundations of emotional speech processing. *Current Directions in Psychological Science, 13*, 182 – 185.

Biklen, D. (1990). Communication unbound: Autism and praxis. *Harvard Educational Review, 60* (3), 291-314.

Boersma, P., & Weenink, D. (2009). Praat: Doing phonetics by computer (version 5.1.20) [computer program] Retrieved from http://www.praat.org/.

Boucher, J., Lewis, V., & Collis, G. (1998). Familiar face and voice matching and recognition in children with autism. *Journal of Child Psychology and Psychiatry, 39,* 171 – 182.

Ciesielski, K. T., & Harris, R. J. (1997). Factors related to performance failure on executive tasks in autism. *Child Neuropsychology, 3*, 1-12.

Clark, H. (1992). *Arenas of Language Use*. Chicago, IL: University of Chicago Press.

Cole, R. A., Jakimik, J., & Cooper, W. E. (1980). Segmenting speech into words. *Journal of the Acoustical Society of America, 67* (4), 1323–1332.

Condouris, K., Meyer, E., & Tager-Flusberg, H. (2003). The relationship between standardized measures of language and measures of spontaneous speech in children with autism. *American Journal of Speech–Language Pathology, 12* (3), 349–358.

Constantino, J. N., Davis, S. A., Todd, R. D., Schindler, M. K., Gross, M. M., Brophy, S. L., Metzger, L. M., Shoushtari, C. S., Splinter, R., & Reich, W. (2003). Validation of a brief quantitative measure of autistic traits: Comparison of the social responsiveness scale with the autism diagnostic interview-revised. *Journal of Autism and Developmental Disorders, 33* (4), 427 – 433.

Delis, D.C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Functioning System (D-KEFS).* San Antonio, TX: The Psychological Corporation.

DeMyer, M., Barton, S., DeMyer, W., Norton, J., Allen, J., & Stelle, R. (1973). Prognosis in autism: A follow-up study. *Journal of Autism and Childhood Schizophrenia, 3*, 199–246.

Diehl, J., Bennetto, L., Watson, D., Gunlogson, C., & McDonough, J. (2008). Resolving ambiguity: A psycholinguistic approach to understanding prosody processing in high-functioning autism. *Brain and Language, 106* (2), 144-152.

Diehl, J., & Paul, R. (2009). The assessment and treatment of prosodic disorders and neurological theories of prosody. *International Journal of Speech-Language Pathology, 11* (4), 287-292.

Diehl, J., & Paul, R. (2012) Acoustic differences in the imitation of prosodic patterns in children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 6* (1), 123-134.

Emmorey, K. (1987). The neurological substrates for prosodic aspects of speech. *Brain and Language, 30*, 305–320.

Ferreira, V., & Dell, G. (2000). Effects of ambiguity and lexical availability on syntactic and lexical production. *Cognitive Psychology, 40*, 296–340.

Fine, J., Bartolucci, G., Ginsberg, G., & Szatmari, P. (1991). The use of intonation to communicate in pervasive developmental disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 32* (5), 771-782.

Friederici, A., & Alter, K. (2004). Lateralization of auditory language functions: a dynamic dual pathway model. *Brain and Language, 89*, 267 – 276.

Gioia, G.A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *Behavior Rating Inventory of Executive Function.* Lutx, FL: Psychological Assessment Resources, Inc.

Grossman, R. B., Bemis, R. H., Plesa Skwerer, D., & Tager-Flusberg, H. (2010). Lexical and affective prosody in children with high-functioning autism. *Journal of Speech, Language & Hearing Research, 53*, 778–793.

Heilman, K., Bowers, D., Speedie, L., & Coslett, H. (1984). Comprehension of affective and nonaffective prosody. *Neurology*, *34*, 917–921.

Hobson, R. P., Ouston, J., & Lee, A. (1988). Emotion recognition in autism: Coordinating faces and voices. *Psychological Medicine, 18* (4), 911-923.

Hobson, R. P., & Lee, A. (1989). Emotion-related and abstract concepts in autistic people: Evidence from the British Picture Vocabulary Scale. *Journal of Autism and Developmental Disorders, 19* (4), 601-623.

Homack, S., Lee, D., & Riccio, C. A. (2005). Test review: Delis-Kaplan executive function system. *Journal of Clinical and Experimental Neuropsychology, 27* (5), 599-609.

Horton, W. S., & Keysar, B. (1996). When do speakers take into account common ground? *Cognition, 59* (1), pp. 91-117.

Just, M. A., Cherkassky, V. L., Keller, T. A., Kana, R. K. & Minshew, N. J. (2007). Functional and anatomical cortical underconnectivity in autism: evidence from an fMRI study of executive function task and corpus callosum morphometry. *Cerebral Cortex, 17* (4), 951 – 961.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*, 122–149.

Kana, R. K., Keller, T. A., Cherkassky, V. L., Minshew, N. J., & Just, M. A. (2006). Sentence comprehension in autism: thinking in pictures with decreased functional connectivity. *Brain, 129,* 2484 -2493.

Kanner, L. (1943). Autistic disturbances of affective contact. Nervous Child, 2, 217–250.

Kanner, L. (1971). Follow-up of eleven autistic children, originally reported in 1943. *Journal of Autism and Childhood Schizophrenia, 2*, 119–145.

Kaplan, E., Fein, D., Morris, R., & Delis, D. (1991). *WAIS-R as a neuropsychological instrument.* San Antonio, TX: The Psychological Corporation.

Kjelgaard, M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: implications for genetic subgroups. *Language and Cognitive Processes, 16,* 287–308.

Kleinman, J., Marciano, P. L., & Ault, R. L. (2001). Advanced theory of mind in high functioning adults with autism. *Journal of Autism and Developmental Disorders, 31*, 29–36.

Klin, A. (1992). Listening preferences in regard to speech in four children with developmental disabilities. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 33*, 763 – 769.

Korkman, M., Kirk, U., & Kemp, S. (2007a). NEPSY-II: A developmental neuropsychological assessment. San Antonio, TX: The Psychological Corporation.

Korkman, M., Kirk, U., & Kemp, S. (2007b). NEPSY-II: Clinical and interpretive manual. San Antonio, TX: The Psychological Corporation.

Kuhl, P. K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., Stolyarova, E. I., Sundberg, U., & Lacerda, F. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science, 277*, 684–686.

Kuhl, P., Coffey-Corina, S., Padden, D. & Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: behavioral and electrophysiological measures. *Developmental Science, 8* (1), F1 – F12.

Lim, H. (2008). *The effect of 'developmental speech-language training through music' on speech production in children with autism spectrum disorders.* Cambridge: ProQuest.

Lord, C., & Paul, R. (1997). Language and communication in autism. In D.J. Cohen & F.R. Volkmar (Eds.), *Handbook of autism and pervasive developmental disorders* (2nd ed., pp. 195–225). New York: John Wiley & Sons.

Lord C., Risi S., Lambrecht L., Cook E. H., Leventhal B. L., DiLavore P. C., Pickles A., & Rutter M. (2000). The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*, 205-230.

Lord, C., Rutter, M., & LeCouteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, *23*, 659-685.

Luks, T., Nusbaum, H., & Levy, J. (1998). Hemispheric involvement in the perception of syntactic prosody is dependent on task demands. *Brain and Language*, 65, 313–332.

MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology, 24*, 56–98.

McCann, J., & Peppé, S. (2003). Prosody in autism spectrum disorders: A critical review. *International Journal of Language and Communication Disorders, 38* (4), 325-350.

McCann, J., Peppe´, S., Gibbon, F. E., O'Hare, A., & Rutherford, M. D. (2007). Prosody and its relationship to language in school-aged children with high-functioning autism. *Journal of Language & Communication Disorders, 42*, 682–702.

Mesibov, G. (1992). Treatment issues with high-functioning adolescents and adults with autism. In E. Schopler, & G. Mesibov (Eds.), High functioning individuals with autism (pp. 143–156). New York: Plenum Press.

Miller, G. A., & Chomsky, N. (1963). Finitary models of language users. In R. D. Luce, R. R. Bush, & E. Galanter (Eds.), Handbook of mathematical psychology (Vol. 2, pp. 269–321). New York: Wiley.

Nadig, A. S., & Sedivy, J. C. (2002). Evidence of perspective-taking constraints in children's on-line reference resolution. *Psychological Science*, *13*, 329–336.

Ozonoff, S. (1995). Executive function impairments in autism. In E. Schopler & G. Mesibov (Eds.), *Learning and cognition in autism* (pp. 199-220). New York: Plenum Press.

Ozonoff, S, & Jensen, J. (1999). Brief Report: specific executive function profiles in three neurodevelopmental disorders. *Journal of Autism and Developmental Disorders*, *29*, 171-177.

Paul, R., Augustyn, A., Klin, A., & Volkmar, F. (2005a). Perception and production of prosody by speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 35,* 205-218.

Paul, R., Shriberg, L. D., McSweeny, J., Cicchetti, D., Klin, A., & Volkmar, F. (2005b). Brief report: Relations between prosodic performance and communication and socialization ratings in high functioning speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 35* (6), 861-869.

Paul, R., Bianchi, N., Augustyn, A., Klin, A., & Volkmar, F. R. (2008). Production of syllable stress in speakers with autism spectrum disorders. *Research in Autism Spectrum Disorders, 2* (1), 110-124.

Pearlmutter, N. J., & MacDonald, M. C. (1995). Individual differences and probabilistic constraints in syntactic ambiguity resolution. *Journal of Memory and Language, 34*, 521–542.

Peppé, S. (2009) Why is prosody in speech-language so difficult. *International Journal of Speech-Language Pathology, 11* (4), 258 – 271.

Peppé, S., & McCann, J. (2003). Assessing intonation and prosody in children with atypical language development: the PEPS-C test and the revised version. *Clinical Linguistics and Phonetics, 17,* (4–5), 345–354.

Peppé, S., McCann, J., Gibbon, F., O'Hare, A., & Rutherford, M. (2006). Assessing prosodic and pragmatic ability in children with high-functioning autism. *Journal of Pragmatics, 38*, 1776-1791.

Peppé, S., McCann, J., Gibbon, F., O'Hare, A., & Rutherford, M. (2007). Receptive and expressive prosodic ability in children with high-functioning autism. *Journal of Speech, Language, and Hearing Research, 50*, 1015 – 1028.

Peppé, S., Cleland, J., Gibbon, F., O'Hare, A., Castilla, P. (2011). Expressive prosody in children with autism spectrum conditions. *Journal of Neurolinguistics, 24* (1), pp. 41-53.

Rapin, I., & Dunn, M. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain and Development, 25* (3), pp. 166-172.

Roßnagel, C. (2000). Cognitive load and perspective taking: Applying the automatic-controlled distinction to verbal communication. *European Journal of Social Psychology, 30*, 429–445.

Roid, G. H. (2003) *Stanford-Binet Intelligence Scales: Fifth Edition*. Itasca, IL: Riverside.

Rutherford, M. D., Baron-Cohen, S., & Wheelwright, S. (2002). Reading the mind in the voice: A study with normal adults and adults with Asperger syndrome and high functioning autism. *Journal of Autism and Developmental Disorders, 32*, 189–194.

Rutter, M., Bailey, A., & Lord, C. (2003), *Social Communication Questionnaire (SCQ)*. Los Angeles: Western Psychological Services.

Samuelsson, C., Scocco, C., & Nettelbladt, U. (2003). Towards assessment of prosodic abilities in Swedish children with language impairment. *Logopedics Phoniatrics Vocology, 28*, 156–166.

Samuelsson, C. (2011). Prosody intervention: A single subject study of a Swedish boy with prosodic problems. *Child Language Teaching and Therapy, 27* (1), 56-67.

Semel, E., Wiig, E. H., & Secord, W. A. (2003). *Clinical Evaluation of Language Fundamentals* (4th ed.). San Antonio, TX: Harcourt Assessment, Inc.

Sheslow, D., & Adams, W. (1999). *Wide Range Assessment of Memory and Learning, Second Edition (WRAML2)*. San Antonio, TX: Harcourt Assessment.

Shriberg, L. D., Kwiatkowski, J., & Rasmussen, C. (1990). The Prosody-Voice Screening Profile. Tucson, AZ: Communication Skill Builders.

Shriberg, L. D., Paul, R., McSweeny, J., Klin, A., Cohen, D. J., & Volkmar, F. R. (2001). Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research*, *44*, 1097-1115.

Shriberg, L. D., Paul, R., Black, L. M., & Van Santen, J. P. (2011). The hypothesis of apraxia of speech in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 41* (4), 405-426.

Shriberg, L. D., & Widder, C. J. (1990). Speech and prosody characteristics of adults with mental retardation. *Journal of Speech and Hearing Research*, *33*, 627–653.

Simmons, J., & Baltaxe, C. (1975). Language patterns in adolescent autistics. *Journal of Autism and Childhood Schizophrenia*, *5*, 333–351.

Snedeker, J., & Trueswell, J. (2003). Using prosody to avoid ambiguity: effects of speaker awareness and referential context. *Journal of Memory and Language, 48,* 103-130.

Snedeker, J., & Yuan, S. (2008). Effects of prosodic and lexical constraints on parsing in young children (and adults). *Journal of Memory and Language, 58,* 574 – 608.

Staum, M. (1987). Music notation to improve the speech prosody of hearing impaired children. *Journal of Music Therapy, 24*, 146 – 159.

Swets, B., Desmet, T., Hambrick, D. Z., & Ferreira, F. (2007). The role of working memory in syntactic ambiguity resolution: A psychometric approach. *Journal of Experimental Psychology: General, 136* (1), 64-81.

Tager-Flusberg, H. (1995). Dissociation in form and function in the acquisition of language by autistic children. In H. TagerFlusberg (Ed.), *Constraints on language acquisition: Studies of atypical children* (pp.175 – 194). Hillsdale, NJ: Erlbaum.

Tager-Flusberg, H., Joseph, R., & Folstein, S. (2001). Current directions in research on autism. *Mental Retardation and Developmental Disabilities Research Reviews, 7* (1), 21-29.

Thomas-Stonell, N., McClean, M., & Hunt, E . (1991). Evaluation of the SpeechViewer computer-based speech training system with neurologically impaired individuals. *Journal of Speech Language Pathology and Audiology, 15* (4), 47–56.

Thurber, C. & Tager-Flusberg, H. (1993). Pauses in the narratives produced by autistic, mentally retarded, and normal children as an index of cognitive demand. *Journal of Autism and Developmental Disorders, 23* (2), 309 – 322.

VanBourgondien, M., & Woods, A. (1992). Vocational possibilities for high functioning adults with autism. In E. Schopler, & G. Mesibov (Eds.), High functioning individuals with autism (pp. 227–242). New York: Plenum Press.

Van Santen, J. P. H., Prud'hommeaux, E. T., Black, L. M., & Mitchell, M. (2010). Computational prosodic markers for autism. *Autism, 14*, 215–236.

Wallace, G. L., Silvers, J. E., Martin, A., & Kenworthy, L. E. (2009). Brief Report: further evidence for inner speech deficits in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*, 1735 – 1739.

Wechsler, D. (2003). WISC-IV technical and interpretive manual. San Antonio, TX: Psychological Corporation.

Wiig, E. H. & Secord, W. A. (1989). *Test of Language Competence*. San Antonio, TX: Psychological Corporation.

Williams, K. T. (1997) Expressive Vocabulary Test. Circle Pines, MN: American Guidance Service.