Published in final edited form as:
Autism Res. 2012 April ; 5(2): 109–123. doi:10.1002/aur.1220.

Comprehension of wh-questions precedes their production in typical development and autism spectrum disorders

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Abstract

Lay Abstract—Children with autism produce few wh-questions, compared to their typically developing peers. It is unclear if this is because of social-pragmatic difficulties, or if they have not yet learned the grammar for asking wh-questions. If children do not know how to use grammatical rules to produce questions, they might simply repeat sentences that they have heard without completely understanding them first. We visited the homes of 15 children with autism and 18 typically developing children with similar language abilities, across a three-year period. At each visit, children watched a video that depicted an apple hitting a flower and keys hitting a book. The children were then shown the items side-by-side on the screen and the audio asked “what hit the flower?” and “what did the keys hit?” We filmed the children’s eye movements and analyzed how long they looked at the named item, compared to when they heard “where is the flower/keys?” At each visit, we also filmed a 30-minute mother-child play session and analyzed the types of questions that the children asked. Children with autism showed comprehension of wh-questions at a later age than typically developing children, but at a similar level of overall language development. Neither group produced wh-questions before they had demonstrated that they understood the underlying grammatical rules. Therefore, children with autism seem to process wh-questions in the same way as their typically developing peers, just at a later age. This paper discusses the implications of our findings for the language development of children with autism.

Scientific Abstract—Children with autism (ASD) rarely produce wh-questions (e.g., “What hit the book?”) in naturalistic speech. It is unclear if this is due to social-pragmatic difficulties, or if grammatical deficits are also involved. If grammar is impaired, production of wh-questions by rote memorization might precede comprehension of similar forms. In a longitudinal study, 15 children with ASD and 18 initially-language-matched typically developing toddlers were visited in their homes at four-month intervals across a three-year period. The wh-question task was presented via intermodal preferential looking. Silent ‘hitting’ events (e.g., an apple hitting a flower) were followed by test trials in which the apple and flower were juxtaposed on the screen. During test trials, subject-wh and object-wh-question audios were sequentially presented (e.g., “What hit the flower?”/”What did the apple hit?”). Control audios were also presented (e.g., “Where’s the apple/flower?”). Children’s eye movements were coded off-line, frame-by-frame. To show reliable comprehension, children should look longer to the named item (i.e., apple or flower) during the “where” questions, but less at the named item during the subject-wh and object-wh-questions. To compare comprehension to production, we coded 30-minute spontaneous speech samples drawn from mother-child interactions at each visit. Results indicated that comprehension of subject and object-wh-questions was delayed in children with ASD compared to age-matched TD children, but not when matched on overall language levels. Additionally, both groups comprehended wh-questions before producing similar forms, indicating that development occurred in a similar manner. This paper discusses the implications of our findings for language acquisition in ASD.

Keywords

wh-questions; language; grammar; production; comprehension

Introduction

In recent decades, researchers have begun to investigate the language acquisition of children with autism spectrum disorders (ASD) in considerable detail. Most of this research has documented which aspects of language remain seemingly intact (e.g., ability to acquire a lexicon; Eigsti, Bennetto & Dadlani, 2007; Fein et al., 1996; Tager-Flusberg et al., 1990) and which domains (e.g., pragmatics; Tager-Flusberg, 1994, 2004) pose a problem for children with ASD. Few studies have investigated the *processes* by which children with ASD achieve these linguistic outcomes. For example, typically developing (TD) children almost always demonstrate understanding of words and grammatical constructions prior to their production of these forms (Fenson et al., 1994; Hirsh-Pasek & Golinkoff, 1996; Huttenlocher, 1974; Maratsos, 1998; Naigles, 2002; Snyder, 2007). This indicates that they are analyzing the language of their input prior to using it in conversation. It is still an open question whether children with ASD do this as well, because many assessments have reported higher production than comprehension scores, suggesting a process where children with ASD only analyze what they can first produce (e.g., Ellis Weismer, Lord & Esler, 2010; Fein et al., 1996). However, Swensen, Kelley, Fein and Naigles (2007) have reported that a sample of children with ASD understood sentences in Subject-Verb-Object (SVO) word order before producing connected speech, using a new method of comprehension assessment, namely, Intermodal Preferential Looking (IPL). The current study expands on this line of research with a more complex grammatical construction, investigating when children with ASD first understand specific types of wh-questions relative to their production of similar forms, compared to their typically developing peers.

Syntactically, an English wh-question is an interrogative sentence that begins with a "wh" word (e.g., *who, what, where, why, when*), which represents missing information. Wh-questions can ask for a missing argument (e.g., "*What did he eat*?") or an adjunct (e.g., "*Why did he eat that*?").[1] Furthermore, an argument wh-question can ask for the subject of a sentence (usually the actor of the action; e.g., "*Who likes Mary*?") or the object of a sentence (usually the patient of the action/relation; e.g., "*Who does Mary like*?"). Because the wh-word is (almost) always produced at the beginning of the sentence, wh-questions deviate from the standard SVO word order that English-learning children acquire before 24 months of age (Gertner, Fisher & Eisengart, 2006; Swensen et al., 2007).[2] Pragmatically, wh-questions typically ask for information which is desired, but not known by the speaker, and which the speaker assumes to be known by the addressee (Searle, 1969).

Young TD children begin producing 'where' and 'what' wh-questions by 27–29 months of age (e.g., Bloom, Merkin & Wooten, 1982; Malzone & Parker, 1979; Smith, 1933; Stromswold, 1995; Tyack & Ingram, 1977). Children's earliest wh-questions may be tied to social routines (e.g., "What is that?" "Where is the X?"); however, spontaneous subject and object wh-questions, which indicate specific knowledge of the thematic role of the wh-word (e.g., actor, patient), are nonetheless attested in appropriate contexts before 30 months of age (Stromswold, 1995).[3] In contrast, wh-question production is both delayed and sparse in

[1]Arguments are noun phrases (i.e., a subject or object), which are required by the verb in order for the sentence to be grammatical. An adjunct is any portion of the sentence (e.g., an adverb or adjective), which adds supplemental information, but is not required for grammaticality.

[2]The relations between standard word order and wh-question word order vary across languages. The wh-word moves to the front of the sentence in some languages (e.g., English), but not others (e.g., Mandarin).

children with ASD. For example, 3- to 7-year-olds produced many fewer wh-questions in spontaneous speech than language-matched peers (Tager-Flusberg, 1994), and even those children who are verbal frequently fail to request information during naturalistic interactions (Wetherby & Prutting, 1984; Wetherby, Prizant & Schuler, 2000). Moreover, Eigsti et al. (2007) reported that 5-year-olds with ASD were more 'scattered' with respect to number and complexity of wh-questions than TD controls.

These contrasting presentations lead to two questions about wh-question acquisition in children with ASD. First, to what extent is their paucity of wh-question production grammatically versus pragmatically based? The non-SVO word order of some types of wh-questions (e.g., "What did the apple hit?" is OSV) may present a grammatical challenge to children with ASD, who are frequently reported to use less varied sentence structures than language-matched peers (Eigsti et al., 2007; Fein et al., 1996; Scarborough et al., 1991; Tager-Flusberg et al., 1990). Moreover, understanding that the wh-word stands for information not present in the spoken sentence may also be challenging for individuals who do not have a detailed grasp of abstract syntactic structures (Botwinik-Rotem & Friedmann, 2009; Eigsti & Bennetto, 2009; Hawkins, 1999). On the other hand, the desire to communicate with others is impaired in autism, leading to pragmatic challenges in knowing when to ask questions appropriately (Rutter, 1978). Pragmatically-based deficits in theory of mind—such as understanding that others have the answers to one's questions—are also likely to result in fewer questions being asked (Baron-Cohen, Leslie & Frith, 1985; Tager-Flusberg, 1994).

Tager-Flusberg (1994) has argued that ASD children's difficulties with wh-questions are more related to pragmatics because their wh-questions were generally grammatically well-formed, especially with respect to subject-auxiliary inversion (see footnote 3), while their range of usage of these questions was much more restricted. Another way to address this question, particularly with respect to our focus on the thematic roles of wh-words, is to investigate how well children with ASD can *understand* wh-questions. This is because comprehension tasks can minimize social/pragmatic constraints on wh-question use: Children need neither assume knowledge on the part of another person, nor produce a question at a specific time or context. Thus, if children with ASD perform poorly on wh-question comprehension tasks, *both* pragmatic and grammatical impairments are likely to be implicated in their production deficits with this construction.

Experimental studies suggest that TD children's comprehension of such wh-question properties as the thematic role of the wh-word, and the non-SVO order of the sentence, emerges earlier than their production (e.g., de Villiers, 1995; de Villiers, Roeper & Vainikka, 1990; Seidl, Hollich & Jusczyk, 2003). For example, Seidl, et al. (2003) used an IPL task to investigate toddlers' comprehension of object-questions (e.g., "what did the keys hit?"), subject-questions (e.g., "what hit the book?") and where-questions (e.g., "where is the book?"). As revealed by their eye movement patterns, typically developing children demonstrated reliable understanding of all three types of questions at 20 months of age, which is considerably earlier than most reports of their first productions of these same forms (Stromswold, 1995). No one has yet examined when children with ASD first *comprehend* specific types of wh-questions (e.g., subject- and object-wh-questions). However, because the IPL methodology makes minimal social, cognitive, and motor demands on child

[3]In contrast, another feature of wh-questions, subject-auxiliary inversion, does not seem to be *consistently* available to (or utilized by) children until later in development (Ambridge, Rowland, Theakston & Tomasello, 2006; Rowland & Pine, 2000). While auxiliary verbs are important for wh-question production, the focus of the current investigation is on children's understanding of the thematic roles of the wh-words, themselves.

participants (i.e., all they need to do is look at visual stimuli), it provides a feasible way to assess what these children know about these questions.

Investigation of children with ASD's understanding of wh-questions also addresses our second question about their acquisition of these questions; namely, to what extent do they, like TD children, demonstrate comprehension of language before producing it? The phenomenon of comprehension preceding production is pervasive in the language development of TD children, as they have been shown to understand more words than they produce (Dapretto & Bjork, 2000; Fenson et al., 1994; Huttenlocher, 1974), simple sentences before they put words together in speech (Hirsh-Pasek & Golinkoff, 1996; Swensen et al., 2007), and grammatical morphemes (e.g., "the" before nouns) that are months away as far as production goes (Gerken & MacIntosh, 1993; Gerken & Shady, 1996). With standardized assessments, too, TD children generally score higher on receptive language than expressive language (e.g., Allen & Rapin, 1992; Fein et al., 1996). The comprehension-preceding-production phenomenon gives a picture of the typical toddler using language at one level to engage in the social/cognitive interactions that dominate their waking lives while also analyzing language at more sophisticated levels for no immediate social/interactional purpose, and it highlights that TD children's acquisition of linguistic forms does not depend on their ability to produce them. And to the extent that comprehension requires only that the child access a stored representation (i.e. a pattern abstracted from specific lexical items) based on perceived sounds whereas production requires as well a successful generation of that representation based on the desire to express a more-or-less well-formed meaning (Huttenlocher, 1974), comprehension, of course, seems easier.

However, research with children with autism has often yielded the opposite finding, that higher scores have been reported for expressive measures than receptive ones (Allen & Rapin, 1992; Charman, Drew, Baird, & Baird, 2003; Ellis Weismer et al., 2010; Fein et al., 1996; Kjelgaard & Tager-Flusberg, 1999; Muller et al., 1999). Moreover, Eigsti et al.'s (2007) finding that 5-year-old children with ASD show a different developmental progression with their question forms (e.g., they may say the more complex "what does it do?" rather than the simpler "what's that?") may also indicate that these children did not always understand the more advanced forms that they produced. That is, they might have learned them as holistic strings rather than as sentences including wh-words that stand for specific thematic roles. These findings suggest that children with autism may follow a different process during language acquisition, possibly one in which they need to produce some aspects of language in order to fully acquire them (e.g., Mitchell et al., 2006; Wynn & Smith, 2003).

However, it is also possible that some of the difficulties that children with ASD demonstrate with standardized tests of receptive (as opposed to expressive) language stem from methodological challenges, such as difficulties with pointing and/or deliberating selecting among numerous alternatives (Ellis Weismer et al., 2010; Kjelgaard & Tager-Flusberg, 2001; Luyster, Lopez, & Lord, 2007). That is, the well-documented motor and executive function difficulties of children with autism (for a review, see Pennington & Ozonoff, 1996) may be impacting their ability to carry out explicit language comprehension tasks (e.g., Chapman & Miller, 1975; Hirsh-Pasek & Golinkoff, 1996). Moreover, failure to demonstrate comprehension via parental checklists may index challenges with social responsiveness rather than true language comprehension, (e.g., Mitchell et al., 2006). Finally, standardized receptive language tests may include fewer items than either expressive language counterparts, such that missing one item on the receptive part leads to a relatively larger decrement in scoring (see also Ellis Weismer et al., 2010; Luyster, Lopez & Lord, 2007 for more discussion). The IPL paradigm may provide a more precise indication

of language comprehension in children with ASD just because it places fewer social, motor, and cognitive demands on the child participants. That is, IPL simply measures the extent to which children's changes in eye gaze to two side-by-side events are guided by the accompanying language; there is little to no social interaction, and the videos generally last less than five minutes. For these and other reasons, over the past 15 years, this method has revealed quite refined levels of language comprehension at both the word and sentence levels in 1- and 2-year-old TD children (e.g., Arias-Trejo & Plunkett, 2010; Chan, Meints, Lieven, & Tomasello, 2010; Gertner et al., 2006; Hirsh-Pasek & Golinkoff, 1996; Naigles, 2002; for summaries, see Brandone et al., 2007; Piotroski & Naigles, 2011; Swingley, 2011).

Recently, researchers have begun to use IPL to investigate what children with ASD know about the words and grammar of English. For example, Swensen et al. (2007) used IPL to assess the comprehension of transitive (i.e., SVO) word order in ASD and language-matched TD children. Two videos were juxtaposed on the screen: a boy tickling a girl, and the girl tickling the boy. The audio ("look, the girl is tickling the boy!") matched only one of the videos. Children in both groups looked reliably longer at the video that matched the utterance, indicating that they understood SVO word order, even if they were not yet producing it (i.e., 90% of children in each group only produced one- or two-word utterances). Additional IPL tasks have suggested that children with ASD use a 'noun bias' in word learning (i.e., they prefer to map novel words onto novel objects over novel actions; Swensen et al., 2007; Tek, Jaffery, Fein & Naigles, 2008); however, IPL tasks have also found that children with ASD have difficulty with the more complex 'shape bias'; that is, they do not consistently extend novel words to objects of similar shapes (Tek et al., 2008). In sum, IPL tasks have been used to provide reliable indications of comprehension (or not) of words and sentences in children with ASD (see also Edelson, Fine & Tager-Flusberg, 2008; Naigles, Kelty, Piotroski, & Fein, in press; Venker, Eernisse, Bean, Saffran & Ellis Weismer, 2011).

Thus, the current study attempts to answer two sets of questions about the development of wh-questions in children with ASD. First, can we obtain evidence that children with ASD *comprehend* subject and object wh-questions? Moreover, do they show a delay in comprehension relative to their (initially) language-matched TD peers? Secondly, does comprehension precede production of wh-questions in children with ASD, showing evidence of a similar developmental process as TD children, or will these children show earlier production than comprehension, indicating that they need to produce these forms in order to learn them?

Method

Participants

Fifteen children with an ASD and eighteen typically developing children (TD) participated in a longitudinal study of language development, of which this study was one part. All were monolingual English learners. Two additional children began the study in the ASD group, but were not included in the final analyses of this study because they each missed visits and/or failed to provide sufficient data during the wh-question IPL task (see below). We recruited participants in the ASD group by contacting facilities that offer Applied Behavior Analysis (ABA; Lovaas, 1987); we restricted the sample to children receiving ABA so as to ensure some consistency in the interventions being received. Moreover, ABA is the most common intervention offered in our geographic area (northeastern U.S.). These service providers distributed information about the study to parents of children who had been diagnosed within the last six months and were within one month of beginning ABA training. Interested parents then contacted us and were interviewed via telephone to verify their

child's diagnosis and eligibility for the study. All parents signed consent forms prior to participating.

Participants in the ASD group included 13 White males, one White/Hispanic male, and one White/Asian male. One female participant with ASD began the study but did not complete enough visits to be included in the final analyses. This sample of children somewhat reflects the prevalence of ASD in the general population. All children were from middle-class or upper-middle-class families living in the Northeast United States. At the first visit, the children with ASD ranged in age from 26.17 months to 37.87 months (M = 32.86, SD = 3.6). To be included in the study, the children with ASD had to be receiving at least 20 hours of ABA intervention per week. Because it is difficult to distinguish between Autism Spectrum Disorder and Pervasive Developmental Disorder-NOS, we accepted participants with either diagnosis, which was then verified by the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore & Risi, 1999). Their ADOS and other test scores are provided in Table 1.

The TD group was recruited via birth announcements from local newspapers. The TD group included 16 White males and 2 White females from middle-class or upper-middle-class families living in Connecticut. These demographics closely resembled those of the ASD group. Rather than matching the TD group to the ASD group on age, we chose to match them on language development. Therefore, we began testing TD children at approximately 20 months of age (M = 20.63, SD = 1.8), when their language abilities were most similar to those of the ASD group at visit 1 (see Table 1).

Materials

IPL Setup—The IPL paradigm (Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987) consists of showing children two videos side by side, while playing child-directed speech that corresponds to only one of the videos. The child's direction and duration of gaze are recorded and used as indications of his/her understanding. An Apple Powerbook was used to project the stimuli onto a portable 63" x 84" screen, via an LCD projector. The computer was connected to an external speaker, which was placed out of sight behind the screen. A digital camcorder for filming the child's face was placed on a small tripod in front of the screen, just below the center.

The wh-question video included *familiarization trials*, which introduced the video stimuli sequentially on each side of the screen; *control trials*, during which the two videos were played simultaneously without any directing audio, to obtain baseline looking times for comparison to the test trials; and *test trials*, during which the two stimuli were displayed side by side and the audio directed the child to look at one of them.

We employed a modified version of the video used by Seidl, Hollich and Jusczyk (2003). Familiar items (an apple, flower, keys and a book) appeared in hitting events (i.e., an apple hitting a flower, keys landing on a book), then were shown separately while the child heard one of three wh-questions (see Table 2). The first two blocks (Table 2; trials 1–16) asked object-what-questions (i.e., "what did the apple/keys hit?"). The second two blocks (trials 17–32) asked subject-what-questions (i.e., "what hit the flower/book?"). The final block (trials 33–40) asked where-questions (i.e."where is the apple/flower/keys/book?"). In sum, each child was asked two object-wh-questions, two subject-wh-questions, and four where-questions.

Each what-block consisted of a baseline trial (trial 2 in Table 2), two familiarization trials (trials 4 & 6 in Table 2) and a test trial (trial 8 in Table 2). During the baseline trial, one item appeared on each side of the screen and the audio prompted the child to look, without

designating which side to look at. In the familiarization trials, the hitting event was seen sequentially on each side of the screen. Then, in the test trial, a what-question was heard while each item was displayed simultaneously, side by side. The final block showed each pair of items juxtaposed while the audio asked the 'where' questions. Unlike the other blocks, the audio in the where-trials (trials 34, 36, 38 & 40 in Table 2) directed the child to look at the *named* item.

Standardized Tests—The Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1999) was administered to assess ASD status. We also administered the Vineland Adaptive Behavior Scales, 2nd Edition (Vineland II; Sparrow, Cicchetti, & Balla, 2005) to evaluate children's communication, socialization, daily living skills, and motor skills, which yielded standard scores based on mothers' reports. The Mullen Scales of Early Learning (Mullen, 1995) were administered to measure development in the areas of visual perception, fine motor skills, receptive language, expressive language, and gross motor skills. Finally, the MacArthur Communicative Development Inventory (CDI; Fenson et al., 1994) provided a measure of the child's language-production abilities, via parental report. The infant version of the CDI was used at visit 1, followed by the toddler version at visits 2 and 3, and (for those children reported to produce more than 300 words on the toddler version) version III at visits 4 through 6.

Procedure

Children were visited in their homes, at four-month intervals for a total of six visits. Ages at each visit are displayed in Table 3. The visits began with one experimenter administering standardized tests, while another experimenter prepared the IPL setup. Next, the child sat approximately three feet in front of the screen and camcorder and watched a series (n = 3 or 4) of IPL videos. The Wh-Question video was shown on visits 3 through 6, and was always the 2nd or 3rd video in the series. Breaks were allowed as needed between videos.

Following the IPL videos, the mother and child engaged in a 30-minute play session. After this, the mother was asked if this amount of speech was typical for her and her child. Finally, the mother completed any remaining surveys or forms.

Mother-Child Play Session—At each visit, mother and child engaged in a 30-minute play session, half of which was semi-structured (based on the Screening Test of Autism in Two-year-olds (STAT) protocol; Stone, Coonrod, & Ousley, 2000). For the first portion, mothers were periodically handed cards that prompted them to play with particular items that had been provided by the researcher. For example, cups were used to build a tower, the child was asked to choose between an empty container and one with a snack in it, and the mother and child looked in a pillowcase filled with toys. The prompts facilitated discussion of a variety of topics, while allowing the mother to produce the same quality of speech that she normally would in that situation. The prompts also facilitated the production of wh-questions by the children, who asked about the contents of the pillowcase. As described in more detail below (see also Naigles, Goodwin, Dixon & Fein, 2011), the proportion of wh-questions produced by the children with ASD in this study was higher than had been previously reported for this population (Tager-Flusberg, 1994). The final portion of the session was free play. The play session was recorded and later transcribed.

Coding

Wh-Question Comprehension—The film of the child's gaze during the IPL task was captured and digitized in the lab. Looking times were coded offline by watching these films frame-by-frame, using a custom coding program. The voice audio was removed, so the coders did not know which direction of looking was correct. Looking during each frame was

coded as to the left, right, center or away. To test for the reliability of the coding, two children with ASD and two TD children were coded a second time at each of the four visits (i.e., 11% of the data, as is common for the IPL (Arias-Trejo & Plunkett, 2010; Hirsh-Pasek & Golinkoff, 1996; Wagner, Swensen & Naigles, 2009)). The coder pairs achieved a mean *r* of .99. If a child did not look at either screen for more than 0.3 seconds of a given trial, his/her data was not included for that trial; instead, it was replaced by the group mean. This occurred in 4.3% of test and control trials in the TD group and 4.2% of test and control trials in the ASD group. One child in the ASD group was omitted from the IPL analyses at visit 3, because he looked away from both screens for more than half of the time during the baseline and test trials.[4]

The dependent variable was the proportion of time that the child looked at the named item during each trial type (i.e., subject-, object- and where-questions). To demonstrate what-question comprehension, we used the metric employed by Seidl et al. (2003); namely, the child needed to look at the named item significantly less when a subject- or object- wh-question was asked than when the where-question was asked. For example, to assess comprehension of "What hit the book?", we compared their looking time to the book for this trial vs. the "Where is the book?" trial. During the 'where' trial they should look consistently at the book whereas during the 'what' trial they should look consistently away from the book. Similarly, comprehension of "What did the apple hit?" was assessed by comparing their looking at the apple during this trial versus the "Where is the apple?" trial. Such within-subjects comparisons are common with the IPL paradigm, as children's eye movements during baseline trials serve as their own controls for performance during test trials (Brandone et al., 2007; Piotroski & Naigles, 2011; Swingley, 2011). To succeed at this task, then, children need not demonstrate a completely adult-like understanding of the grammar; they need only to allow the what-questions to pull their attention away from the named item, indicating that they are aware that grammatical movement has occurred (and that SVO is no longer the correct word order). There is evidence that adults, too, initially look at the named item before switching to the correct referent, during on-line processing of what-questions (Kukona & Tabor, 2011; Sussman & Sedivy, 2003).

Wh-Question Production—All wh-questions produced by the children were extracted from the transcripts of the mother-child play sessions. Because we were interested in the thematic roles of wh-questions, only the phrases that were wh-questions with verbs were included in the analyses (e.g., questions such as "Why?" and "What?" were excluded). The question type was determined for each utterance (see Table 4), and then totals and percentages were calculated for each type.

Initially, the question types of interest were those for which comprehension was assessed: subject-, object-, and where-questions. Additional questions (e.g., "why", "when" and "how" questions; adjuncts) were classified as "other". Examination of the transcripts revealed that another type of question was well represented in the children's speech; we called these Predicate Nominative questions (Quirk, Greenbaum, Leech & Svartvik, 1985). These questions resembled subject wh-questions, but the verb was always a copula (i.e., a form of "be"), followed by a pronoun (e.g., "who is that?"). In each case, the wh-word and the pronoun referred to the same physical object in the environment. Predicate adjectives were included in this category as well (e.g., "what is big?"). Example questions are shown in Table 4.

[4]As stated previously, 2 children in the ASD group and 1 child in the TD group did not complete all visits. Because they did not provide comprehension *or* production data for multiple visits, they were omitted from all analyses (and our final *n*).

Results

When Did Children Comprehend Wh-Questions?

Our first analyses used children's percent of time looking to the named item, averaged separately across object-wh-test trials (trials 8 and 16 in Table 2), subject-wh-test trials (trials 24 an 32 in Table 2), and the four where-questions (trials 34, 36, 38, 40 in Table 2). These scores were then averaged by group for each visit.

A mixed analysis of variance was conducted, with Group (ASD or TD) as a between-subjects variable, and Visit (3, 4, 5 or 6), Type (Subject or Object) and Trial (Where vs. What) as within-subjects variables. The results showed a main effect of Visit ($F(3, 90) = 2.686$, $p = 0.051$, partial eta squared = .082) and Trial ($F(1, 30) = 40.905$, $p < 0.001$, partial eta squared = .577). There was no main effect of Type, indicating that there was no difference between subject and object questions in our sample ($F(1, 30) = 2.829$, $p = .103$, partial eta squared = .086).[5] There was, however, a Group x Visit interaction ($F(3, 90) = 3.330$, $p = 0.023$, partial eta squared = .100). There was also a Group x Trial interaction ($F(1, 30) = 4.585$, $p = 0.040$, partial eta squared = .133), indicating that the two groups showed different patterns of looking to the where- vs. what-trials. Because of this interaction, we next analyzed the groups' looking patterns separately.

Figures 1a and 1b show the TD group's percentage of looking to the named item for the where-trials compared to object-what-trials and subject-what-trials, respectively, at each visit. For the TD group, the diminution of looking to the named item during the what-trials was significant for all visits for the object questions (visit 3: $t(17) = -2.37$, $p = 0.015$, $d = -0.75$; visit 4: $t(17) = -2.0$, $p = 0.03$, $d = -0.8$; visit 5: $t(17) = -4.28$, $p < 0.001$, $d = -1.47$; visit 6: $t(17) = -3.17$, $p = 0.003$, $d = -0.96$). For subject questions, performance varied across visits (visit 3: $t(17) = -1.64$, $p = 0.06$, $d = -0.51$; visit 4: $t(17) = -3.92$, $p < 0.001$, $d = -1.24$; visit 5: $t(17) = -1.52$, $p = 0.07$, $d = -0.51$; visit 6: $t(17) = -5.72$, $p < 0.001$, $d = -1.39$). The ASD group's performance during object wh-questions (Figure 2a) showed no significant difference in looking from visits 3 through 5 (ts ≤ 1.23, ps ≥ 0.12, ds < −0.18). However, at visit 6, they looked significantly less at the named item during object-what-questions than where-questions ($t(14) = -1.89$, $p = 0.04$, $d = -0.55$). For subject wh-questions (Figure 2b), the ASD group looked significantly less during what-trials than where-trials for visit 3 ($t(13) = -2.30$, $p = .02$, $d = -0.87$), but not at the remaining visits (visit 4–5, $p > 0.15$; visit 6: $t(14) = -1.60$, $p = 0.07$).

In sum, the TD children displayed stable evidence of wh-question comprehension by 32 months of age (visit 3) whereas the ASD group did not demonstrate this level of consistent comprehension until 54 months (visit 6). It is important to place these latter findings in the context of the ASD group's overall language level, though. Although the groups were matched on language production at visit 1, the TD group subsequently developed language more quickly than the ASD group. Thus, the TD group's general language measures at visit 3 included a CDI vocabulary production score of 74% (i.e., of all the words on the toddler form), an overall MLU in spontaneous speech of 2.28 (SD = 0.68), and mean noun and verb type productions during spontaneous speech of 36.78 (SD = 20.68) and 24.89 (SD = 8.49), respectively. The ASD group's general language measures at visit 6 were quite similar: they produced 66% of the words on the CDI toddler form, had MLUs of 2.01 (SD = 1.09), and mean noun and verb type productions of 26.76 (SD = 23.23) and 21.82 (22.17), respectively. To compare the ASD group at visit 6 to the TD group at visit 3, we conducted a MANOVA with group (TD or ASD) as the between-subjects variable and the IPL comprehension scores

[5]We continue to discuss Subject and Object questions separately, though, for the purpose of comparing these different question types to the wh-questions produced by the children.

and the spontaneous speech measures (MLU, Nouns and Verbs) as within-subjects variables. There was no effect of group on any of the measures (*F*s <1). Thus, it appears that the TD and ASD groups achieved stable comprehension of wh-questions at similar language levels.

It is also important to ascertain the number of children who contributed to these effects. We adopted Naigles' (1996) criterion that children who showed a difference of 0.65 seconds or more between the where- and what-trials (in the correct direction) would be designated 'strong' comprehenders, while those who showed a difference of between 0.64 and 0.01 seconds were designated 'weak' comprehenders. All children who showed a difference in the wrong direction (i.e., less than zero) were designated 'non-comprehenders'. These results are shown in Table 5, which indicates that both groups consist of more comprehenders than non-comprehenders at each visit, and in all cases except one (i.e., the ASD group at visit 3), strong comprehenders outnumber weak comprehenders. A series of chi-square tests comparing strong- vs. weak- vs. non-comprehenders, as well as strong- vs. weak- and non-comprehenders, revealed no significant relationship between group and type of comprehension. Finally, it is important to note that several individual children in the ASD group did demonstrate comprehension at each visit; however, these children did not perform consistently across all visits, and the ASD group, as a whole, did not show statistically significant comprehension before visit 6. In fact, only 5 children in the ASD group showed consistent comprehension of subject-questions across visits, as did 3 for object-questions, compared to 9 TD children who showed consistent comprehension of subject-questions across visits, and 7 who did so for object-questions.

Further individual differences were revealed by correlating the ASD children's overall wh-question comprehension scores (looking during 'where' questions minus looking during 'what' questions) at a given visit with their concurrent CDI, Vineland, and spontaneous speech measures. Children with higher wh-question comprehension scores at visit 3 also had higher Vineland Social scores ($r = .584$, $p < .028$). Children with higher wh-question comprehension scores at visit 5 had larger vocabularies according to a number of measures (Percent of words produced on the CDI, number of noun and verb types produced during spontaneous speech, *r*s > .515, *p*s < .049). Moreover, higher wh-question comprehension scores at visit 5 also correlated with concurrent higher Vineland Social and Motor scores (*r*s > .560, *p*s < .03), and lower autism severity scores (ADOS: $r = -.659$, $p = .008$; CARS: $r = -.665$, $p = .007$). Performance on the Mullen, which was only administered at visits 1, 4, and 6, did not yield any significant concurrent relationships with wh-question comprehension scores.

Does Comprehension Precede Production?

What types of wh-questions did children produce?—Wh-questions comprised a minority of the total utterances in both groups (2–6%, depending on the visit). These percentages are consistent with those reported for TD children by Stromswold (1995; i.e., 5.2%), and higher than has been reported for children with ASD (1%; Tager-Flusberg, 1994). More specifically, at visit 1, only 2 out of 18 TD children and 5 out of 15 children with ASD produced any wh-questions at all. For the TD group, this increased to 14–15 children at visits 2 and 3, and 18 children at visits 4–6. For the ASD group, between 8 and 10 children produced wh-questions at any given visit. The number of wh-questions that had verbs, for each wh-question type and visit, are given in Table 6.

For both groups, the majority of wh-question tokens (37% for TD and 40% for ASD) were where-questions, followed by predicate nominative (PN) questions (34% and 18%, respectively; see Table 4 for examples). Together, then, these types of wh-questions comprised 70% (TD) and 58% (ASD) of children's wh-questions. However, a small number

of subject- and object-wh-questions was produced by both groups. Proportions of question types across visits are shown in Figure 3.

How does comprehension compare to production?

Comprehension of wh-questions was first assessed at visit 3, so it is not possible to determine what children understood about these structures at visits 1 and 2. However, we know that many of the TD children, as well as some children with ASD, demonstrated understanding of the wh-questions overall when they were first tested. We also know that some of the questions that they produced are of a similar quality to the questions in the IPL task. Therefore, for each child, we determined the visit (and so age) at which he or she first produced each question type, as well as the visit (and so age) at which s/he first comprehended each question type. Table 7 shows that most TD children produced and comprehended 'where' questions at the same visit, with the remainder of the children comprehending 'where' questions before producing them. For subject- and object-questions, the majority of children in the TD group comprehended these questions at an earlier visit than they first produced them. No children in the TD group produced questions at an earlier visit than they comprehended them. Paired-sample one-tailed *t*-tests found that the children's age of first production was significantly higher than their age of first comprehension for the where, subject, and object questions ($t(16) = 2.07$, $p = .027$; $t(10) = 2.54$, $p = .014$; $t(7) = 2.94$, $p = .01$, respectively; the degrees of freedom vary because not all children produced all question types). See Table 8 for the means and standard deviations.

The ASD group also showed a pattern of comprehension developmentally preceding production, as shown in Table 7. At any given visit, no more than 10 children in the ASD group showed comprehension of what-questions; however, each child did show comprehension during at least one of the visits. Likewise, several children did not produce each question type at every visit. Nevertheless, when first comprehension was compared to first production of each question type, all but one child in the ASD group showed some comprehension prior to, or concurrent with producing similar questions. The majority showed comprehension *earlier* than production for each question type. Paired-sample one-tailed *t*-tests found that the children's age of first production was significantly higher than their age of first comprehension for the subject, and object questions ($t(7) = 1.51$, $p = .03$ and $t(4) = 4.17$, $p = .007$, respectively; again, the degrees of freedom vary because not all children produced all question types).[6] See Table 8 for the means and standard deviations.

Discussion

In this study, we addressed two main questions: (1) when do children with ASD, and their TD peers, first comprehend subject- and object-wh-questions (e.g., "What hit the book?"/"What did the keys hit?"), and (2) does this comprehension precede their production of similar forms? Replicating Seidl et al. (2003), we found that TD children demonstrated comprehension of both subject- and object-questions by 28 months of age (i.e., at Visit 3). That is, these TD children knew that 'where' questions referred to the item that is named whereas subject- and object 'what' questions did not. Most children with ASD (but not all, see Table 5, Figures 2a and 2b) showed stable comprehension of wh-questions by 54 months (i.e., at visit 6), likewise demonstrating a consistent strategy for interpreting 'where' questions and subject and object 'what' questions. Furthermore, we found such subject and object wh-questions to be rare in children's spontaneous speech—and in all cases, the

[6]We performed an additional analysis on the age-of-first-use data, whereby the children with ASD's age at visit 6 was inserted into every empty cell (i.e., every wh-question type which they had not produced and/or comprehended). This enabled us to include every child who showed evidence of comprehension or production at at least one visit. These t-tests yielded significant effects, with first production significantly later than first comprehension, for all three wh-question types (*t*s(14) >2.55, *p*s <.01).

children showed evidence of comprehending these questions at the same or *earlier* visits than when they first produced them.

The ASD group seemed to be delayed in developing wh-question comprehension; however, this delay was strongly linked with their overall language level. That is, their MLU and word production at visit 6, when they first showed better-than-chance comprehension, was actually quite similar to those of the TD children at visit 3, the earliest visit when these children showed stable comprehension. Moreover, the ASD children with higher language levels at visit 5 were the ones who showed better wh-question comprehension (see also Howlin, 2003). Not surprisingly, their parents also rated them higher in social functioning, possibly reflecting the children's ability to use these questions in real life. These findings, then, provide evidence that children with ASD are able to surmount at least some of the grammatical challenges of wh-question acquisition, such as learning a sentence form that deviates from SVO order, and learning that a wh-word can stand for a missing noun phrase (e.g., actor or patient). Our findings are thus similar to those of de Villiers, Roeper, Bland-Stewart and Pearson (2008), who showed sensitivity to similar structures in older children with language impairments. These findings are also consistent with those of Tager-Flusberg (1994), who showed that another property of wh-questions, subject-auxiliary inversion, was acquired by children with ASD even though the pragmatics of wh-question use remained impaired. Taken together, these studies (and see also Oi, 2010) suggest that the difficulties that children with ASD show vis-à-vis wh-questions are primarily pragmatically based. That is, the relative paucity of wh-question *production* observed for the ASD group in the current study (i.e., only 3–5 children produced these wh-questions whereas up to 10 children demonstrated comprehension), as well as in other studies, may be attributable to difficulties with pragmatic knowledge involving, e.g., the deliberate seeking of new information, the assumption that such information is known by one's addressee, and the knowledge of when and how such questions fit into discourse (Searle, 1969). In sum, investigating wh-question comprehension in children with ASD via the minimally social context of an IPL task thus seems to have provided a way to distinguish the syntactic challenges of this construction from the pragmatic ones.

Nonetheless, a couple of caveats are in order. First, the current study has only investigated a subset of wh-questions (i.e., 'where' and 'what'); children with ASD are also reported to have difficulty with 'when', 'why', and 'how' questions (Clark & Rutter, 1981; Hewitt, 1998; Oi, 2010). Clearly, these types of questions need to be investigated in more detail, in terms of both production and comprehension. Moreover, whereas the children in the ASD group in the current study showed better-than-chance comprehension of 'what' and 'where' questions at visit 6, they did not show quite as good performance as the TD children at visit 6 (i.e., 88% of TD children demonstrated comprehension at visit 6, compared with 67% of children with ASD). Thus, continued development, even of 'what' and 'where' questions, might be expected for the ASD group beyond visit 6. The ability to demonstrate comprehension in the minimally social context of IPL may not immediately transfer to real-world situations.

Our second major finding was that the children with ASD clearly showed an overall pattern of their comprehension preceding their production: for those children who did produce wh-questions, these typically appeared *after* comprehension had been demonstrated (i.e., for the ten children who showed comprehension before visit 6). These results provide evidence that at least one basic process of language acquisition seen in TD children is likely also present in children with ASD; namely, that they process their linguistic input to some extent, and arrive at some kinds of interpretations of that input, before they produce certain constructions (i.e., SVO statements and wh-questions; see also Maratsos, 1998; Snyder, 2007; Swensen et al., 2007). This finding appears to be at odds with studies that have found

better production than comprehension performance from children with ASD on standardized tests; however, as discussed in the Introduction, this discrepancy could be due to methodological differences between the IPL paradigm and many standardized test formats. The IPL paradigm used here provides an *implicit* measure of comprehension, making fewer demands on working memory, and requiring coordination only of movements of the eyes, rather than the hands. Therefore, it is not unreasonable to find stable comprehension demonstrated via IPL before this might be observed in a 'standard' assessment of receptive language. It is also important to point out, though, that findings of better or earlier production than comprehension lead to a theory of language development in which children produce constructions they don't yet understand. While children with ASD are attested in producing rote or echolalic speech, there is no evidence that such productions were precursors to linguistically more advanced speech (Tager-Flusberg & Calkins, 1990).

One limitation of this study is the relatively small sample of spontaneous speech; with only 30 minutes of mother-child interaction filmed at six visits, we likely missed some wh-question use that might have occurred outside of our filming sessions. By comparison, Stromswold (1995) analyzed a much larger sample of speech; the corpora that she analyzed consisted of 12 children who were recorded approximately once a month for several years. Larger speech samples, of course, allow for more opportunities to observe wh-question use. However, our sample size was typical for a study of language development in a developmentally delayed population (e.g., Eigsti et al., 2007; Tager-Flusberg et al., 1990). Therefore, our results can be compared to those from previous studies without much concern about similarity of samples. However, our restriction of the participants to children receiving ABA as their primary intervention does limit the generalizability of these findings to the ASD population as a whole.

Other limitations of our study may have arisen from one or more aspects of the IPL video. First, it is possible that the 'blocked' presentation of the subject-wh and object-wh trials (see Table 2) may have made the study more challenging for the ASD group because their known difficulties in executive function (e.g., Pennington & Ozonoff, 1996) may have hindered their ability to switch sentence frames. If this were the case, then we would expect lower performance on the subject-wh questions because they always appeared second in the video. There is some indication (Figures 2a and 2b) of poorer subject-wh question comprehension; however, no significant differences were found in children's performance on the subject-wh and object-wh trials (for either group), and the number of children who demonstrated comprehension during these trials were comparable (i.e., at visit 6, 13 comprehended the 'where' questions, 10 the subject-wh questions, and 10 the object–wh questions). Therefore, the changing audios within the IPL task do not seem to have been especially problematic. A second issue might arise, though, from the verb choice. It is possible that 'hit' was not the best verb for investigating the beginnings of wh-question comprehension, because scrutiny of the children's CDIs revealed that only 40% of the children with ASD were reported to understand or produce the verb "hit" by the first time they saw the wh-question video at visit 3, and only 53% by visit 6. All TD children were reported to either understand or produce the verb "hit" by visit 3. Moreover, the use of this verb to refer to the action of an inanimate agent on an inanimate patient may also have been non-prototypical, leading to some confusion on the children's part. We are currently replicating this study with a new sample of children, using videos with two animate characters and with verbs that are understood by 2.5 years of age (Swensen et al., 2007). It is possible that we will discover earlier comprehension of wh-questions with these new materials. However, our findings in the current study remain: the majority of the children with ASD eventually seemed (by visit 6) to be able to understand the wh-questions being asked, and demonstrated this comprehension prior to production of similar forms.

In conclusion, using the IPL paradigm can demonstrate early comprehension of wh-questions in TD children (i.e., by 28 months). Moreover, consistent comprehension of wh-questions by children with ASD was observed by, on average, 54 months of age, when they had achieved similar general language levels to the 28-month-old TD children. Wh-questions, then, do not seem to be a specific difficulty in the *grammatical* development of young children with ASD. Furthermore, comprehension preceded production of wh-questions in both TD children and those with ASD. Therefore, it seems that at least some of the same processes are recruited for language acquisition in both groups.

Acknowledgments

This research was funded by a grant from the National Institute on Deafness and Other Communication Disorders (PI: Letitia Naigles; Grant number: R01 DC07428). We are grateful to Rose Jaffery and Janina Piotroski for assistance in stimulus creation and data collection, and to the undergraduates of the UConn Child Language Lab for coding and transcribing. We thank George Hollich for sharing the wh-question video with us, and Wendy Stone for making the STAT available to us. We appreciate the helpful commentary received from Jeff Lidz, Lisa Edelson, and attendants at IMFAR, BUCLD and the SRCD biennial meetings. Finally, many thanks are due to the children and families who participated in our study.

Grant sponsor: National Institute on Deafness and Other Communication Disorders; Grant number: R01 DC07428.

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Figure 1a.

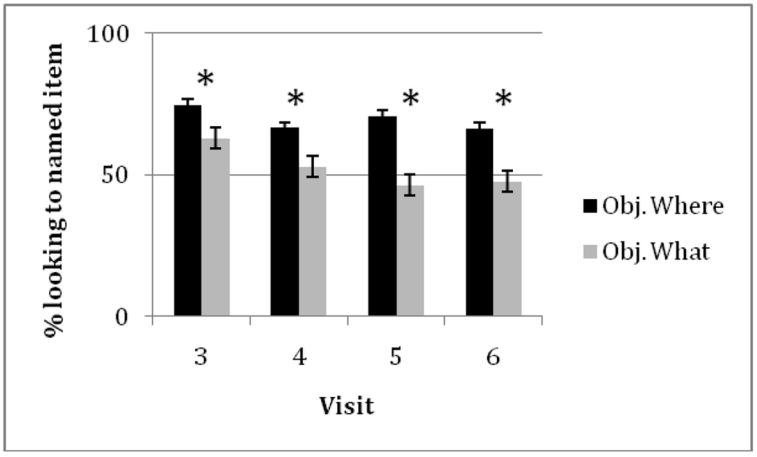


Figure 1b.

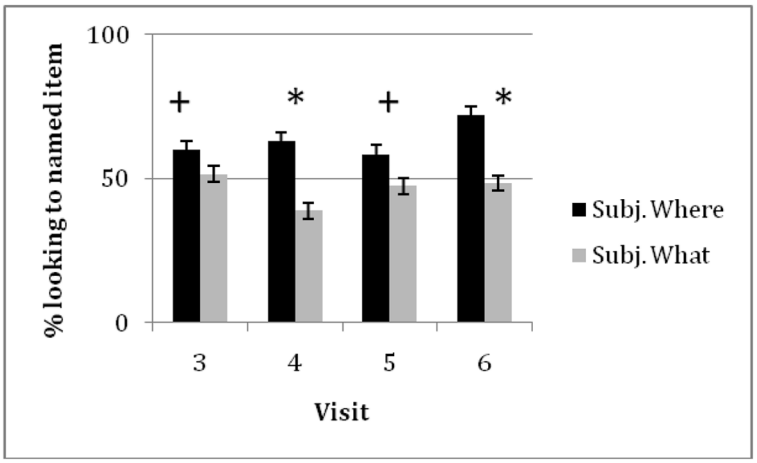
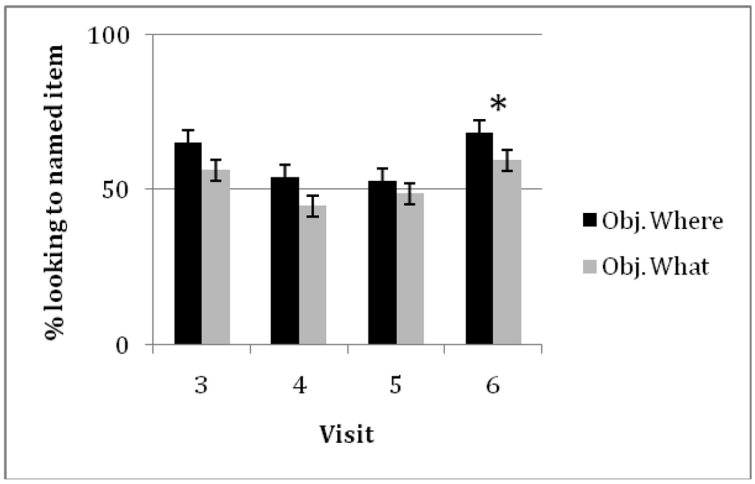


Figure 1.

Figure 1a. Comparison of Object Where vs. What trials for TD children across visits.
* $p < 0.05$

Figure 1b. Comparison of Subject Where vs. What trials for TD children across visits.
* $p < 0.05$
+ $p < 0.10$

Figure 2a.



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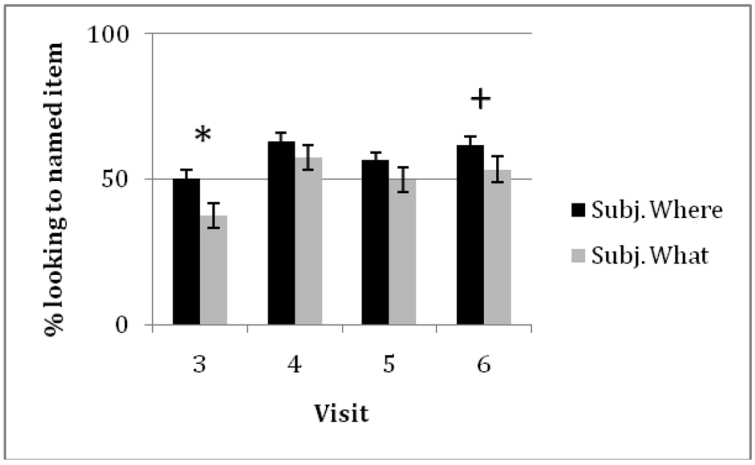

Figure 2.

Figure 2a. Comparison of Object Where vs. What trials for children with ASD across visits.
* $p < 0.05$

Figure 2b. Comparison of Subject Where vs. What trials for children with ASD across visits.
* $p < 0.05$
+ $p < 0.10$

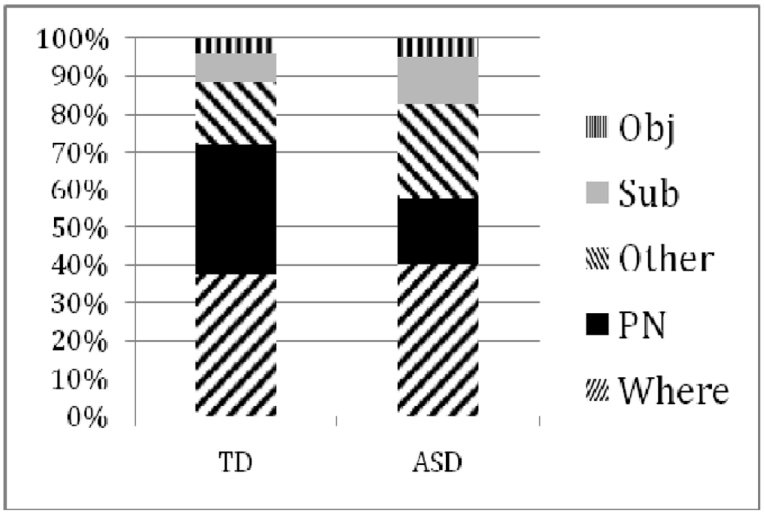

Figure 3.
Proportion of question types produced by all children in the TD and ASD groups.

Table 1

Comparison of TD and ASD Groups at First and Final Visits

	TD	ASD	*t*	*d*
Visit 1				
Gender	16 boys, 2 girls	15 boys		
ADOS	0.11 (0.32)	13.6 (4.63)	−11.27*	−4.46
Range[a]	0–1	7–21		
CARS	15.4 (0.76)	33.5 (7.01)	−9.98*	−3.94
Range[b]	15–18	19.5–45		
CDI (Infant Version)[c]				
Word Production	118.8 (114.4)	106.7 (112.89)	0.31	.11
Percent of Words	30	27		
Mullen Raw Scores				
Receptive Language	25.33 (2.93)	23.80 (8.44)	0.72	.26
Expressive Language	19.44 (4.46)	19.60 (8.07)	−0.07	−.03
Visual Reception	26.11 (3.23)	26.33 (6.37)	−0.13	−.05
Fine Motor	21.83 (1.54)	23.93 (4.42)	−1.89	−.68
Mullen Age Equivalents (Months)				
Receptive Language	26.0 (4.07)	25.0 (11.17)		
Expressive Language	20.1 (5.35)	20.5 (9.69)		
Visual Reception	23.9 (3.78)	24.6 (7.44)		
Fine Motor	20.7 (2.00)	23.3 (5.55)		
Vineland Standard Scores				
Communication	103.83 (8.16)	80.67 (18.38)	4.52*	1.74
Daily Living	105.61 (7.75)	77.07 (13.82)	7.48*	2.70
Socialization	100.50 (7.00)	74.93 (6.95)	10.48*	3.78
Motor	102.44 (5.91)	81.53 (11.53)	6.36*	2.42
Visit 6				
CDI (Level III)[d]	81.94 (14.78)	48.21 (35.5)	3.29*	1.33
Mullen Raw Scores				
Visual Reception	44.5 (2.57)	37.7 (9.17)	2.77*	1.09
Fine Motor	35.5 (2.64)	32.9 (8.74)	1.13	.043
Receptive Language	39.0 (3.97)	31.1 (11.26)	2.58*	1.00
Expressive Language	39.7 (5.49)	28.1 (13.84)	3.05*	1.18
Mullen Age Equivalents (Months)				
Visual Reception	51.7 (6.02)	41.4 (15.57)		
Fine Motor	39.1 (4.58)	35.9 (14.50)		
Receptive Language	47.7 (7.23)	36.5 (18.17)		
Expressive Language	48.6 (9.74)	33.0 (19.46)		

$^{*}p < 0.05$

[a] Autism Spectrum = 7+; Autism = 12+

[b] CARS range = 15–60; Autism Spectrum = 30+; Autism = 36+

[c] Number of words produced out of a possible 396.

[d] Number of words produced out of a possible 100.

Table 2

Sample Layout of the Wh-Question Video

Trial Type	Audio	Video 1	Center	Video 2
1	Oh, look!	Black	✓	Black
2 Control	They're on both screens!	Apple		Flower
3	Oh, wow!	Black	✓	Black
4 Familiarization	Look at this!	Apple hits Flower		Black
5	Look here!	Black	✓	Black
6 Familiarization	See this?	Black		Apple hits flower
7	What did the apple hit__?	Black	✓	Black
8 Test[a]	What did the apple hit__?	Apple		Flower
9–16	(Block repeats with Keys/Book)			
17	Look here!	Black	✓	Black
18 Control	They're on both screens!	Apple		Flower
19	Oh, wow!	Black	✓	Black
20 Familiarization	See this?	Apple hits Flower		Black
21	Oh, look!	Black	✓	Black
22 Familiarization	Look at this!	Black		Apple hits Flower
23	What __hit the flower?	Black	✓	Black
24 Test[b]	What __hit the flower?	Apple		Flower
25–32	(Block repeats with Keys/Book)			
33	Oh, look!	Black	‡	Black
34 Where	Where is the flower?	Apple		Flower
35–40	(Block repeats with Flower/Keys/Book)[c]			

✓ = Red dot flashing to draw the child's attention back to the center before the next trial begins

‡ = Fish swimming across screen to maintain children's interest

[a] Object wh-questions = What did the apple hit?; What did the keys hit?

[b] Subject wh-questions = What hit the flower?; What hit the book?

[c] Where is the apple?; Where is the flower?; Where are the keys?; Where is the book?

Table 3

Children's Ages at Each Visit (In Months)

	TD	ASD
Visit	**M (SD)**	**M (SD)**
1	20.63 (1.84)	32.86 (3.60)
2	24.75 (1.87)	37.15 (3.59)
3	28.82 (1.93)	41.06 (3.77)
4	32.85 (1.87)	45.29 (4.10)
5	36.93 (1.70)	49.59 (4.33)
6	41.20 (2.12)	53.89 (4.68)

Note: All *p*s < 0.05

Table 4

Wh-Question Types Produced by Children

Question type	Example
Subject question	Who_____has that? Who_____wrote it?
Object question	Which one do you want_____? What is he eating_____?
Where question	Where'd it go? Where's the baby doll?
Predicate Nominative [a]	What's that? What is it? Who is that?
Other wh-question	How can you do that? Why won't it work?

[a] Also includes predicate adjective questions, such as "what's blue?" or "who is big?"

Table 5

Number of Children Showing Strong, Weak, or No Comprehension of Wh-Questions (Subject and Object Questions Averaged)

Visit	Comprehension Type	TD	ASD
3	Strong	8	5
	Weak	6	6
	None	4	3
4	Strong	11	5
	Weak	3	5
	None	4	5
5	Strong	11	4
	Weak	4	5
	None	3	6
6	Strong	12	5
	Weak	4	5
	None	2	5

Table 6

Number of Times Each Wh-Question Type Was Produced by Children

		TD		ASD	
Visit	**Question Type**	**# Children**	**# Tokens**	**# Children**	**# Tokens**
1	Where	1	3	3	4
	Object	0	0	0	0
	Subject	0	0	0	0
	Other	0	0	1	1
2	Where	5	11	4	14
	Object	1	1	1	1
	Subject	2	3	0	0
	Other	6	27	5	10
3	Where	12	56	6	16
	Object	1	5	1	3
	Subject	5	12	2	12
	Other	12	50	5	19
4	Where	14	67	7	25
	Object	4	5	3	3
	Subject	8	23	3	5
	Other	17	87	6	13
5	Where	16	56	5	13
	Object	5	7	4	16
	Subject	6	10	2	7
	Other	17	91	5	49
6	Where	12	41	5	27
	Object	6	7	5	12
	Subject	7	9	3	5
	Other	17	73	7	31

Table 7

First Comprehension Relative to First Production by Child

	# of children who comprehend at an earlier visit than they first produce	# of children who produce at an earlier visit than they first comprehend	# of children who first produce and comprehend at the same visit	# of children who neither comprehend nor produce
TD GROUP				
Where	7 (39%)	0 (0%)	11 (61%)	0 (0%)
Subject	11 (61%)	0 (0%)	7 (39%)	0 (0%)
Object	15 (83%)	0 (0%)	3 (17%)	0 (0%)
ASD GROUP				
Where	9 (60%)	1 (7%)	5 (33%)	0 (0%)
Subject	12 (80%)	0 (0%)	3 (20%)	0 (0%)
Object	11 (73%)	0 (0%)	3 (20%)	1 (7%)

Table 8

Ages of first production and first comprehension (Mean, SD) for each wh-question form

	Where questions		Subject questions		Object questions	
	First P*	First C	First P	First C	First P	First C
ASD	39.99 (3.64)	38.88 (3.16)	43.88 (4.57)	40.57 (4.38)	47.03 (6.41)	40.56 (3.31)
TD	30.06 (2.66)	28.83 (1.99)	32.67 (5.19)	30.22 (3.76)	35.04 (4.35)	29.38 (3.12)

*P = production, C = comprehension