RESEARCH ARTICLE

Abstractness and Continuity in the Syntactic Development of Young Children With Autism

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Grammar is frequently considered to be a strength in the cognitive profile of individuals with autism spectrum disorders (ASDs); however, few studies have investigated how *abstract* (i.e. distinct from specific lexical items) is the grammatical knowledge of individuals with ASD. In this study, we examine the extent to which children with ASD have abstracted the transitive (SVO) frame in English. Participants in a longitudinal study of language acquisition in children with autism (17 children with ASD averaging 41 months of age, 18 TD children averaging 28 months of age) were taught two novel verbs in transitive sentences and asked (via intermodal preferential looking) whether these verbs mapped onto novel causative vs. noncausative actions. Both groups consistently mapped the verbs onto the causative actions (i.e. they engaged in syntactic bootstrapping). Moreover, the children with ASD's performance on this task was significantly and independently predicted by both vocabulary *and* sentence-processing measures obtained 8 months earlier. We conclude that many children with ASD are able to generalize grammatical patterns, and this ability may derive from earlier lexical and grammatical knowledge. ***Autism Res*** *2011,4:422–437*. © 2011 International Society for Autism Research, Wiley Periodicals, Inc.

Keywords: developmental psychology; preschoolers<pediatrics; language; grammar

Grammar is frequently considered to be a strength in the cognitive profile of individuals with autism spectrum disorders (ASDs): notwithstanding their pervasive difficulties with communication [APA, 2000], high-functioning children with ASD often exhibit good to excellent scores on the grammatical portion of standardized tests, mental age-appropriate mean lengths of utterance (MLUs) in their spontaneous speech, and good performance on psycholinguistic comprehension tasks [Eigsti, Bennetto, & Dadlani, 2007; Fein et al., 1996; Kjelgaard & Tager-Flusberg, 2001; Rapin & Dunn, 2003; Tager-Flusberg et al., 1990; Waterhouse & Fein, 1982]. However, the keynote of grammar in typical populations involves the realization that syntactic constructions are *abstract*; that is, not simply a function of the specific lexical items in which constructions or frames have been heard or learned [Chomsky, 1965; Radford, 1990; Tomasello, 2000; Valian, Solt, & Stewart, 2009]. There is reason to believe that such abstraction may be a challenge for children with ASD; many studies have demonstrated their difficulties with generalizing a rule or concept beyond the specific stimuli with which it was taught [e.g. Minshew, Meyer, & Goldstein, 2002; Shulman, Yirmiya, & Greenbaum, 1995; Tek, Jaffery, Fein, & Naigles, 2008]. The purpose of this study was to investigate whether young children with autism have formulated an abstract transitive (SVO) frame, and to explore the precursors of this abstraction in their early lexical and grammatical abilities.

Studies examining the degree to which grammatical knowledge is abstract in children usually employ one of two methods [McDaniel, McKee, & Cairns, 1998]: Researchers may examine the children's spontaneous speech and analyze the degree to which they use grammatical constructions with a variety of lexical items [e.g. Naigles, Hoff, & Vear, 2009], or they may give the children an experimental task in which they are asked to interpret grammatical constructions, some of whose content words have been replaced with nonsense words [e.g. Gertner, Fisher, & Eisengart, 2006; Naigles, 1990]. The latter method demonstrates abstraction because the only way that children could interpret, say, ''The duck is gorping the bunny'' is to realize that ''gorping'' is a verb in an active transitive frame, whose subject/agent is ''the duck'' and whose object/patient is ''the bunny.'' Recent research has demonstrated that children with autism understand and perform predictably in tasks in which novel nouns are taught and then tested for interpretation [Baron-Cohen, Baldwin, & Crowson, 1997; Franken, Lewis, & Malone, 2009; Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007;

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Received December 15, 2010; accepted for publication July 19, 2011
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Grant sponsor: National Institutes of Health; Grant numbers: R01 DC07428; R01 2DC007428.
Published online 19 October 2011 in Wiley Online Library (wileyonlinelibrary.com)
DOI: 10.1002/aur.223

Preissler & Carey, 2005; Swensen, Kelley, Fein, & Naigles, 2007; Swensen, Naigles, & Fein, 2007; Tek et al., 2008]; therefore, this methodology seems promising as a way to investigate grammatical abstraction in these children. In this study, we gave children with ASD a novel *verb* learning task, in which the verbs were embedded in transitive sentence frames (SVO). If the children had command of the abstract transitive frame, they should interpret the verbs in a constrained (i.e. causative) way—doing what has been called "syntactic bootstrapping" [Gleitman, 1990; Naigles, 1990; Naigles & Swensen, 2007].

Syntactic bootstrapping involves the integration of syntactic and visual/spatial information during word learning. It is the process by which children (and adults) use the sentence frames in which newly encountered words appear to make conjectures about the meanings of those words [Gleitman, 1990; Naigles & Swensen, 2007]. For example, transitive frames, which include direct objects, co-occur with verbs involving causation (e.g. *He dropped the ball*), whereas intransitive frames, which exclude direct objects, appear with verbs not involving causation (e.g. *The ball fell.*). Thus, saying "She is blicking the dolly" when a child is carrying a doll would suggest that *blick* means "carry"; saying "She is blicking" under the same circumstances might instead suggest that *blick* means "walk" or "move." Syntactic bootstrapping is one of the core processes of typically developing children's language development (Joint attention and concept learning are others, not studied here). Syntactic bootstrapping has been demonstrated to apply to children's acquisition of nouns, verbs, and adjectives; however, the procedure has been investigated in the most detail with respect to verb learning, and that will be our focus here [Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Naigles & Swensen, 2007].

To engage in syntactic bootstrapping during verb learning, children need to have abstracted some sentence frames (e.g. transitive (SVO) and intransitive (SV)) and recognized the semantic correlates of those frames in the actions or relations in the available context or situation (e.g. causality or lack thereof). Studies involving typically developing (TD) children indicate that they are able to use syntax to learn about verb meanings by 2 years of age [Bavin & Kidd, 2000; Fisher & Tokura, 1996; Naigles, 1990, 1998; Waxman, Lidz, Braun, & Lavin, 2009]. For example, using the intermodal preferential looking (IPL) paradigm, Naigles [1990] presented 25-month-olds with a multiple-action scene, displaying both a causative and a noncausative/synchronous action. The scene was paired with a novel verb, either in a transitive ("The duck is gorping the bunny") or intransitive ("The duck and the bunny are gorping") frame. After three such presentations, the two actions were separated and the child was asked to "find gorping." The children consistently looked longer at the causative action when they had been taught the verb in the transitive frame, and at the noncausative action when taught the verb in the intransitive frame. In other words, they integrated the information from the visual scene plus that from the sentence frame to discover the referent of the verb. Two-year-olds, then, can exploit the different semantic implications of transitive and intransitive frames to make different conjectures about novel verb meaning. One question we address in this article is, can children with ASD do this, too?

Syntactic Bootstrapping in Children With Autism?

Investigations of children with ASD have tended to conclude that basic syntactic abilities are intact. For example, studies have found that (English-learning) children with ASD adhere to SVO order in their spontaneous language production [Eigsti et al., 2007; Tager-Flusberg et al., 1990], and pay attention to SVO order during language comprehension tasks [Paul, Fischer, & Cohen, 1988; Swensen, Kelley et al., 2007; Tager-Flusberg, 1985]. Swensen, Kelley et al. [2007] even found understanding of SVO order (e.g. *the girl pushes the boy* vs. *the boy pushes the girl*) in children with ASD who were not yet producing such sentences spontaneously. Moreover, Brock, Norbury, Einav, and Nation [2008] tracked the eye movements of adolescents with ASD while they were listening to sentences, and found earlier/faster eye gaze to the target object (e.g. a hamster) for specific (e.g. *stroke*) vs. general (e.g. *choose*) verbs. Thus, these adolescents were clearly interpreting the verbs with their possible direct objects in mind.

However, as mentioned earlier, none of these studies have actually investigated whether the children's knowledge of basic sentence frames was *abstract*; that is, independent of their understanding of the specific verbs used. There are, in fact, several reasons to conjecture that the language of children with ASD is context- and/or item-specific rather than abstract. First, in their spontaneous speech, children with ASD have been reported to rigidly use specific words, phrases, and/or sentence types in specific contexts or situations [Eigsti et al., 2007; Lopez, 2008; Paul, Chawarska, Klin, & Volkmar, 2007]. Some children with ASD show great difficulty with generating the past tense and progressive aspectual forms, even of familiar verbs [Roberts, Rice, & Tager-Flusberg, 2004]. Moreover, individuals with ASD have been shown to have great difficulty in going beyond the immediate stimuli and abstracting general rules when forming new concepts [Minshew, Goldstein, & Siegel, 1997; Minshew et al., 2002; Shulman et al., 1995]. For example, preschoolers with ASD show little evidence of using a shape bias to extend novel words to new instances, even with vocabulary sizes of more than 250 words [Tek et al., 2008]. As all sentence comprehension studies discussed earlier [Brock et al., 2008; Paul et al., 1988; Swensen, Kelley et al., 2007; Tager-Flusberg, 1985] employed verbs that the children are likely to understand, it is possible that their good performance was "merely" a function of their good memories for how each verb has been used [Pine, Lieven, & Rowland, 1998]. They may have enacted or understood "the girl pushes the boy" correctly because they had learned that *push* involves a "pusher" in preverbal position and a "pushee" in post-verbal position, not because they had abstracted a Subject-Verb-Object frame in which the thing referred to by the subject noun—in the active voice—acts as the agent of the action while the thing referred to by the object noun acts as the patient.

Findings such as these have led several researchers to propose that language acquisition by individuals with autism proceeds with a heavier reliance on associative learning (i.e. which verbs are to be used with which nouns) over abstract knowledge (i.e. that *The girl pushes the boy* shares the same sentence frame (SVO) as *The dog eats his food*) [e.g. Tomasello, 2003; Walenski, Tager-Flusberg, & Ullman, 2006]. Very few studies have actually tested this proposal, however, by directly investigating the degree to which the grammar of children with autism *is* abstract (i.e. independent of specific lexical items).

Only one study (that we know of) has directly investigated syntactic bootstrapping in children with autism. In an adaptation of Naigles [1990], Shulman and Guberman [2007] taught 5-year-old Israeli children with ASD a single novel verb in either a transitive or a intransitive frame. Because the language was Hebrew rather than English, the transitive frames included the morphological marker–*et*; moreover, the children were given 12 teaching trials (rather than 3) and were asked to point to the event referent rather than look at it. Shulman and Guberman reported above chance performance by the children with ASD, who did not differ significantly from CELF-matched TD 3-year-olds. These results are very promising, but some issues still remain. First, it is not clear that the children's syntactic (i.e. number and arrangement of nouns) rather than morphological (i.e. inflections) knowledge was responsible for their responses. It is possible that the children had learned that sentences with *–et* involve causality, without ever processing the number and position of the noun phrases (NPs). Second, it would be beneficial to demonstrate this effect with more than one test item. And third, it would be beneficial to elicit this effect with fewer teaching trials; it is not clear whether the additional teaching trials were necessary because of processing difficulties (i.e. the children may need more trials simply to extract the frame and remember the verb) or because of less well-formed syntactic knowledge (i.e. the children may need more trials to "remember" the syntax-semantics links). In this study, we adhere more closely to Naigles' [1990] original task.

An additional concern with Shulman and Guberman's study involves their selection of participants with ASD, who were chosen because their CELF scores matched those of the (younger) TD children. The children with ASD were clearly delayed in their language development, but the matching procedures resulted in a much narrower range than is typical for this population. In this article, we investigate whether children with ASD with a wider range of language scores might demonstrate syntactic bootstrapping. Maintaining continuity with Shulman and Guberman, as well as with earlier work on syntactic bootstrapping with TD children [e.g. Fisher, 2002; Naigles, 1990], we focus on the ability of children with ASD to map verbs in transitive frames onto causative meanings. This also allows us to examine our second question about syntactic bootstrapping; namely, what are its linguistic precursors?

Precursors of Syntactic Bootstrapping?

The concurrent use of syntactic bootstrapping necessarily involves both syntactic (i.e. using the abstract sentence frame) and lexical (i.e. mapping a novel word onto a referent in the world) components; however, from a developmental perspective, the *precursors* to syntactic bootstrapping might be different. That is, some researchers have proposed that children's grammatical knowledge "emerges" from their lexical knowledge, based largely on their ability to extract phrasal and sentential patterns from hearing combinations of words already known [e.g. Bates & Goodman, 1998; Tomasello, 2000]. Indeed, Bates and her colleagues have found, in several studies of both typical and atypical children, that "the single best estimate of grammatical status at 28 months … is total vocabulary size at 20 months" [Bates & Goodman, 1998, p 42]. Moreover, children's early production of word combinations seems to progress in a lexically specific way, with "full" flexibility of words in varied grammatical frames and frames with varied words not evident until 30–36 months [Clark, 2009; Tomasello, 1992, 2000; but see also Naigles et al., 2009]. These perspectives would suggest that only early lexical knowledge should be a significant predictor of later syntactic—in this case, syntactic bootstrapping—abilities [see also Marchman & Bates, 1988].

However, all the above studies have relied on children's production—either spontaneous or reported—as an indicator of their early grammatical knowledge, and it is a truism that children cannot demonstrate their production of grammar without using words as well. Recent research with preverbal infants and toddlers performing perception and comprehension tasks has revealed well-established abilities to extract grammatical and grammar-like patterns from auditory input [e.g. Gervain, Nespor, Mazuka, Horie, & Mehler, 2008; see Gerken, 2007, Höhle, 2009, and Naigles, 2002 for summaries]. Thus, it is possible that previous studies did not find independent contributions of early grammatical knowledge in children's later use of grammar because they did not tap their early grammatical *comprehension*. Indeed, Newman, Ratner, Jusczyk, Jusczyk, and Dow [2006] have found significant correlations between infants' early speech segmentation abilities and later grammar; however, this study did not directly compare early lexical and grammatical abilities to see if these components each accounted for independent sources of variance in children's later grammar. Moreover, no studies have investigated detailed precursors to syntactic knowledge in children with autism. Investigating the degree to which lexical and/or syntactic abilities are precursors to syntactic bootstrapping in both TD and ASD children is the second purpose of the current research.

This study has a longitudinal design: when we first visited the ASD and TD participants, we assessed their syntactic knowledge via a SVO word order comprehension task, and their lexical knowledge via a novel noun-learning task and a vocabulary checklist. Eight months later, we visited the children again and assessed their performance on Naigles' [1990] syntactic bootstrapping task. This task at Visit 2, then, addressed our first question, which was whether children with autism could engage in syntactic bootstrapping. The Visit 1 tasks provided the tools to examine our second question, which was whether early lexical and/or grammatical knowledge predicted later syntactic bootstrapping. We expected that the IPL noun learning task and the Communicative Development Inventory (CDI) vocabulary assessment would correlate with each other; however, we nonetheless included the IPL-based measure of noun learning as a control for any effects seen from the IPL-based measure of SVO comprehension (i.e. maybe all IPL-based tasks correlate with each other). Several longitudinal studies have found correlations between early and later language in children with ASD; however, none have thus far distinguished either precursor or outcome language at this level of detail [Charman et al., 2003; Gabriels, Hill, Pierce, Rogers, & Wehner, 2001; Paul, Chawarska, Cicchetti, & Volkmar, 2008]. Moreover, those studies that have reported distinct scores for grammatical vs. lexical skills [e.g. Kjelgaard & Tager-Flusberg, 2001; Tager-Flusberg & Joseph, 2003] have often found poorer grammatical skills coupled with (normatively) better lexical knowledge. Thus, grammar and lexicon may be differentially impaired in at least some members of this population. Such differential impairment could lead to the prediction that early grammatical and lexical abilities should contribute independently to later syntactic bootstrapping performance in children with autism.

Method

Participants

The final participant pool included 17 children with ASD and 18 TD children. The ASD group (16 males, 1 female) was recruited through treatment facilities and schools in Connecticut, Massachusetts, New York, and New Jersey. This sample size is within the usual range of language outcome and experimental studies [e.g. Brock et al., 2008; Charman et al., 2003; Eigsti et al., 2007; Swensen, Kelley, et al., 2007]. The children ranged in age from 27 to 37 months at the onset of the study ($M = 32.86$ months, $SD = 3.45$). All the children were diagnosed with Autistic Disorder or Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) by clinicians before the beginning of the study. Due to the difficulty in distinguishing between the two disorders before the age of 3 years, either diagnosis was accepted. We confirmed this diagnosis with the ADOS [Autism Diagnostic Observation Schedule; Lord, Rutter, DiLavore, & Risis, 1989] and Childhood Autism Rating Scale [CARS; Schopler, Reichler, & Renner, 1988] before start of the study (Table I). These measures generate good agreement between themselves, and with other diagnostic tools [Chlebowski, Green, Barton, & Fein, 2010; Ventola et al., 2006]. All the children were within 8 months of the start of an ABA program (either inside or outside of the home) and were receiving between 5 and 30 hr of ABA therapy per week ($M = 21.07$ hr; $SD = 10.13$) at the onset of the study.

The TD group consisted of 16 males and 2 females with a mean age of 20.59 months ($SD = 1.73$). Their average CDI production vocabulary did not differ significantly from the ASD group (Table II). The typical children were also given the ADOS and CARS evaluations; as summarized in Table I, none of these children (in contrast to all of the children with ASD) showed elevated scores. All were considered to be normally developing by their parents; none had been referred for any special services by their pediatricians.

To further explore the differences and similarities between our two groups, Tables I and II present the children's scores from the Vineland Adaptive Behavior Scale and the Mullen Scales of Early Learning. As the tables show, the TD children yielded significantly higher standard scores than the children with ASD on all four subscales of the Vineland (Communication: $t(33) = 5.35$, $P < 0.001$; Socialization: $t(33) = 11.21$, $P < 0.001$; Daily Living: $t(33) = 8.08$, $P < 0.001$; Motor: $t(33) = 7.22$, $P < 0.001$). Thus, as expected, the TD children were significantly more advanced in adaptive behavior than the children with ASD and were functioning at cognitive levels appropriate for their chronological age. By design, the groups were matched on language level consistent with average 20-month-old TD children; as Table II shows, the groups did not differ in their age-equivalent scores on the Mullen Visual Reception and

Table I. Standardized Test Scores, Visit 1

Group	ADOS	CARS	Vineland standard scores[a]			
			Communication	Daily living	Socialization	Motor
ASD (n = 17 for all tests)						
Mean	13.82	34.41	78.52	75.58	74.47	81.29
SD	4.41	7.01	18.23	13.61	6.72	10.82
Range	7–20	27–41.5				
Cutoff for ASD[b]	7	25				
TD (n = 18 for all tests)						
Mean	0.11	15.38	103.83	105.61	100.5	102.44
SD	0.3	0.76	8.16	7.75	6.99	5.91
Range	0–1	15–18				

ASD, Autism spectrum disorder; TD, typically developing; ADOS, Autism Diagnostic Observation Schedule; CARS, Childhood Autism Rating Scale.
[a]Standard scores are calculated with the assumption that average TD children have scores of 100.
[b]Children with scores greater than these numbers are considered to be on the autistic spectrum.

Table II. Mullen Scores and CDI Production Scores (Mean, SD), Visit 1

Group	Visual reception	Fine motor	Receptive lang	Expressive lang	CDI
ASD					
Mean	24.7[a]	23.23[a]	24.17[a]	19.17[a]	94.11[c]
SD	6.97	5.23	10.79	9.77	111.33
Range					(0–328)
Mean	36.64[b]	31.17[b]	37.47[b]	33.00[b]	
TD					
Mean	23.94[a]	20.66[a]	26.0[a]	20.05[c]	118.77[c]
SD	3.78	2.0	4.07	5.35	114.35
Range					(11–317)
Mean	57.35[b]	47.55[b]	58.88[b]	47.66[b]	

ASD, Autism spectrum disorder; TD, typically developing; CDI, Communicative Development Inventory.
[a]Age-equivalent scores, calculated separately for each subscale, and are based on the average scores from the norming sample at each age (in months).
[b]Standard scores, calculated separately for each subscale.
[c]Raw scores, from the infant version (CDI-I).

Motor subscales, as well. This sample of ASD children was somewhat higher functioning than the much larger ASD sample ($n = 142$) described by Chlebowski et al. [2010].

Apparatus

The method used to assess language comprehension was IPL. The video stimuli were initially filmed with a Sony Digital Video Recorder and a Canon Digital Video Recorder and were then edited on an Apple G4 Powerbook into the side-by-side configurations described below. They were played from an Apple G3 Powerbook and projected onto a screen via an LCD projector. The linguistic stimulus was shunted from the Powerbook to a speaker centered below the screen. Lights centered between the event videos attracted the children's attention to the center between trials. The children were seated approximately 3 ft in front of the screen either on a small chair or on a parent's lap. Some children needed to sit in the parent's lap to ensure cooperation; however, parents were instructed not to direct the child in any way (and none did in any overt way). Children's faces were filmed while they watched the videos. This film was subsequently digitized into a format where the children's eye movements were coded on a frame by frame basis. Because this film was silent, the coders were blind to the experimental condition.

Stimuli

IPL videos. Three videos were shown to the children. All were constructed along a similar pattern: Trials were 4 or 6 sec long, preceded by a 3-sec intertrial interval when only the red centering light was visible. Two or three introductory trials were presented first, followed by one baseline trial and one test trial, both with side-by-side videos. Within each video, a given scene was always presented on the same side (see Tables III–IV). The audios were presented first during the intertrial interval to enable children to anticipate the side of the match before it appeared; audios were then repeated when the videos actually appeared. All audios were presented in American English Child-Directed Speech. Novel words conformed to English phonology.

Word order [Hirsh-Pasek & Golinkoff, 1996]. The layout for the word order video is presented in Table III. The pretest trials (labeled "P" in the Table) introduced the characters and their labels. Trials 1–2 presented a familiar action (e.g. tickling) with agent A and patient B on one side, and then with agent B and patient A on the other side. During these trials, the action was labeled in a neutral frame (e.g. "Tickling!"). In Trial 3, both renditions of the action were presented simultaneously but the audio was the same as in Trials 1 and 2; this provided a baseline measure of stimulus salience. Trial 4 was the test trial, in which the verb was placed in a

Table III. Sample Layouts of Visit 1 Videos

Video 1	Audio	Video 2
Word order		
P[a] Girl waves	Look!	Blank
P Blank	Look!	Boy waves
P Girl waves	Look!	Boy waves
P Girl waves	Where is the girl?	Boy waves
P Girl waves	Where is the boy?	Boy waves
1 Girl tickles Boy	Look, tickling!	Blank
2 Blank	See, tickling!	Boy tickles Girl
3 Girl tickles Boy	Hey, tickling!	Boy tickles Girl
4 Girl tickles Boy	Look, the girl is tickling the boy!	Boy tickles Girl
Noun Bias		
1 Possum puppet digs with nose	Here's TOOPEN!	Black
2 Black	See, TOOPEN!	Possum digs with nose
3 Possum puppet digs with nose	Look, TOOPEN!	Possum digs with nose
4 Possum sways side to side	They are different now!	Beetle digs with nose
5 Possum sways side to side	Where's TOOPEN?	Beetle digs with nose

[a]*P* indicates the pretest trials.

Table IV. Sample Layout of Syntactic Bootstrapping Video

Video 1	Audio	Video 2
P Duck waves	Look!	Blank
P Blank	Look!	Bunny waves
P Duck waves	Look!	Bunny waves
P Duck waves	Where is the duck?	Bunny waves
P Duck waves	Where is the bunny?	Bunny waves
1 Duck pushes bunny over, duck & bunny flex arms	The duck is gorping the bunny!	Blank
2 Blank	The duck is gorping the bunny!	Duck pushes bunny over, duck and bunny flex arms
3 Duck pushes bunny over, duck & bunny flex arms	The duck is gorping the bunny!	Duck pushes bunny over, duck & bunny flex arms
4 Duck pushes bunny over	They are different now!	Duck & bunny flex arms
5 Duck pushes bunny over	Where is gorping now?	Duck & bunny flex arms
6 Duck pushes bunny over	Find gorping!	Duck & bunny flex arms

sentence such that only one of the two renditions matched. This trial thus examined whether the child understood the difference between "A verbs B" and "B verbs A." A total of six familiar verbs and actions were introduced and then tested for word order understanding. These were *ride, kiss, hug, push, tickle,* and *wash*. The same characters were used for each action; the girl was the agent for half of the matching actions and the boy was the agent for the others.

Noun bias [Swensen, Kelley et al., 2007]. As shown in Table III, the first three trials introduced the novel puppet (e.g. a possum), the novel action (e.g. nose digging), and the novel word (e.g. TOOPEN); these were the teaching trials. Each novel word was heard a total of six times. Although there is little evidence that even TD children under 2.5 years use the presence of "ing" at the end of a word to deduce that it is a verb [e.g. Hirsh-Pasek & Golinkoff, 1996; but see also Echols & Marti, 2004], the novel words for this study all ended in "en" to provide a morphological shape that is appropriate to both nouns (e.g. *kitten*) and verbs (e.g. *jumpin'*). The baseline trial (trial 4) presented two new visual stimuli; one showed the old puppet performing a new novel action, whereas the other showed a new unfamiliar puppet performing the old action. Lacking a directing audio, this trial revealed the relative salience of the two stimuli. The test trial presented the same visual stimuli as the baseline trial, but was accompanied by the test audio, "Where's TOOPEN?" This tested whether the child attached the novel word to the original object or the original action. Given that we expected the TD children, at least, to display a noun bias, the scene with the original puppet performing the new action was considered to be the matching scene. A total of six novel words, puppets, and actions were introduced and then tested.

Syntactic bootstrapping [Naigles, 1990]. The layout for the syntactic bootstrapping video is shown in Table IV. The pretest trials (labeled "P" in the Table) introduced the characters and their labels. The next three trials (teaching trials) presented two novel actions carried out simultaneously by the two characters; one action was causative (e.g. the duck pushes the sitting bunny over into a stretching position) and the other was noncausative and synchronous (e.g. the duck and bunny each flex one arm in unison). The audio for these trials presented a novel word in a transitive frame (e.g., "The duck is gorping the bunny"); each novel word was heard a total of six times. Trial 4 was the baseline trial, in which the two actions were presented separately on different screens; because its audio was nondirecting ("Look, they are different now!"), this trial reveals the relative salience of the two events. Trials 5 and 6 were the test trials, in which the separate actions were again presented, with the test audio "Find gorping." Children who understood that verbs in transitive frames canonically refer to causative meanings should prefer the causative action during the test trials. Two novel verbs were introduced and tested in this way.

Standardized Test Measures

Autism Diagnostic Observation Schedule [ADOS; Lord et al., 1989]. The ADOS is a structured play session that yields scores in Communication, Social Interaction, Play and Atypical Behaviors, which permits diagnosis of Autistic Disorder and PDD-NOS by DSM-IV [APA, 2000] criteria.

The Childhood Autism Rating Scale [CARS; Schopler et al., 1988]. The CARS is a widely used autism diagnostic tool, which includes a rating scale with 15 items rating autistic behaviors on a half-point scale from 0 to 3, with 3 being the most autistic. A cut-off of 30 is the generally used threshold for autism, and scores between 25 and 30 are indicative of PDD-NOS [Chlebowski et al., 2010].

Vineland adaptive behavior scales, second edition [Sparrow, Balla, & Cicchetti, 1984]. This is a widely used parent interview that yields standard scores for the areas of communication, socialization, daily living skills, and motor skills. It has been found to be very helpful in accurately assessing the adaptive skill development of children with autism [Loveland & Kelley, 1991; VanMeter, Fein, Morris, Waterhouse, & Allen, 1997; Volkmar et al., 1987].

Bates-MacArthur CDI [Fenson et al., 1994]. This is a parent report instrument that includes a vocabulary checklist of words derived from naturalistic and diary studies of words understood and produced by young children. The infant version of the CDI was designed for TD children 8–16 months of age and is composed of two major parts. Part I contains a series of questions followed by a comprehensive vocabulary checklist, including nouns, verbs, adjectives, pronouns, prepositions, and quantifiers, totaling 396 words. Part II focuses on the child's use of actions and gestures in order to provide a more comprehensive evaluation of early communication skills. This version was only given at Visit 1. The toddler version of the CDI was designed for TD children 16–30 months of age and also contains two parts. Part I is a vocabulary production checklist, totaling 608 words, and Part II assesses morphological and syntactic development. This version was only given at Visit 2; to promote comparisons between visits, only the vocabulary production sections in both tests were tabulated and analyzed here.

Mullen scales of early learning [Mullen, 1994]. The Mullen is a widely used, well-standardized test that evaluates both mental and psychomotor development. It gives scores for visual perception, fine motor skills, receptive language, and expressive language (we did not assess gross motor skills) and is normed for children aged 0–68 months. Participants were assigned age equivalent scores for each domain of the test.

Procedure

All visits took place at the children's homes, usually in the living or family room. At the introductory visit, children were administered the ADOS. As in standard ADOS administration for young children, a parent was present in the room while the experimenter was giving the test.

Primary data collection for Visit 1 took place 1–7 days later. At this visit, the children were evaluated using four standardized testing measures: the Vineland Adaptive Behavioral Scales (VLAND), CDI, the Mullen Early Learning Scales and the CARS. The CDI checklist had been sent to the family before the visit, and it was usually reviewed with the research assistants during the visit; the other three measures were collected during the visit. Children were also shown the Word Order and Noun Bias videos. The IPL videos were usually presented before the standardized measures.

Visit 2 occurred 8 months after Visit 1. At this visit, the children viewed the Syntactic Bootstrapping video, the CDI Toddler form was collected, and the parents were administered the VLAND. A summary of the children's standardized test scores from Visit 2 is given in Table V.

Coding

IPL paradigm. The films of the children's eye movements were coded after each visit was completed. The videos were captured onto a nonlinear editing computer and coded via a custom program. A trained coder who could not hear the stimulus audio rated the direction and duration of the child's fixation to the left or right videos, to the center, or entirely away from the screen. The eye movements were coded frame by frame for the duration of each video. The children's visual fixations were then tabulated and analyzed. On each trial, visual fixations were registered after the child had looked at the center lights during the intertrial interval for more than 0.3 sec. Trials preceding those with which the child did not look at the center light for a minimum of 0.3 sec were excluded. Furthermore, trials where the child did not look at either scene (once the pictures appeared) for a minimum of 0.3 sec were excluded. For the ASD group, the percent of excluded trials for the Word Order, Noun Bias, and Syntactic Bootstrapping videos was, respectively, 9.52, 11.1, and 0%; for the TD group these percentages were 13.4, 19.4, and 2.7. The percentages from the Word Order and Noun Bias videos (both viewed at Visit 1) are somewhat higher than is typical for IPL studies [usually less than 10%; Naigles, Bavin, & Smith, 2005], but comparable to those of Swensen, Kelley, et al., 2007; such higher percentages may be attributed to the different population (children with ASD) and/or the fact that these children were tested

Table V. Standardized Test Scores, Visit 2

			Vineland standard scores			
Group	Age	CDI (Toddler)	VComm	VDL	VSoc	VFM
ASD						
Mean	41.27	283.6	82.00	74.63	76.49	83.4
SD	3.74	238.01	20.73	13.34	10.35	11.42
Range		0–580	59–112	60–100	61-100	70–107
TD						
Mean	28.82	503.61	108.55	103.33	102.33	101.89
SD	1.93	153.2	8.25	5.84	7.05	7.65
Range		138–665	97–119	93–113	91–112	88–111

at home instead of in a featureless lab room. Clearly, by Visit 2 both groups had adjusted to the testing situation and were able to watch practically all the trials; of course, both groups were also 8 months older and more mature. Ten participants (six TD, four with ASD) were coded by a second coder to test for reliability. The correlation between coders averaged 0.98 (SD = 0.02); Cohen's κ calculations yielded 0.57 agreement for the Word Order video, 0.58 for the Noun Bias video, and 0.84 for the Syntactic Bootstrapping video.

Four dependent variables were calculated from these data. Three are the most typical measures for IPL with dynamic scenes; they capture the child's preference for the matching scene during the test trials compared with his/her preference during the baseline trials. One measure compares the entire baseline trial to the entire test trial, the second includes just the first half of the test trial, and the third includes just the second half of the test trial. These test–baseline comparisons demonstrate the degree to which the test audio guided the children's looking at the matching scene, relative to their initial preference for that scene based solely on stimulus salience. That is, while we made every effort to "match" the side-by-side stimuli on visual properties such as size of action, number of actors, etc., it is always possible that a given child finds one scene more interesting than the other. The test–baseline comparison allows us to take this initial preference into account. Moreover, by considering the first and second halves of the trials separately, we can ascertain whether children select the matching scene early or late. Early selection, during the first half of the trial, may indicate processing facility because the test audio has only been once, during the ITI. Later selection, during the second half of the trial, may indicate that processing that takes more time or needs an additional hearing of the test audio; it may also indicate selection that is more persistent or long-lasting. One additional measure captures how quickly the children look at the matching scene, starting at the onset of the trials. Comparing latency with the match during the test trials vs. latency to the "match" during the baseline trials, the prediction is children who understand the audio will look *less quickly* (i.e. longer latency) during test because these trials require active processing of the visual scenes plus test audio to determine which scene best matches the audio, whereas the baseline trials only involve processing of the visual scenes.

Results

Analyses were organized according to the two research questions: (1) Do children with ASD, as well as language-matched TD children, use transitive syntax to direct attention to novel causative actions over novel noncausative ones (i.e. syntactic bootstrapping)? (2) Do aspects of their early performance on the tasks of word order comprehension and mapping a novel word onto a novel object predict their later ability to do syntactic bootstrapping?

To address the first question, two-way ANOVAs, with group as the between-subjects factor and trial (baseline vs. test) as the within-subjects factor, were performed for each measure; moreover, because we were especially interested in whether the ASD group manifested the same effects as the TD group at a given visit, follow-up *t*-tests (one-tailed, because the prediction was always unidirectional) were performed for each group separately.

Do Children With ASD Use Syntactic Bootstrapping?

Table VI presents the data for each measure for the ASD and TD groups at Visit 2. Clearly, the overall pattern was that both groups of children looked *longer* at the match during the test trials compared with the baseline trials, especially during the second half of the trials, and had longer latencies to the match during the test trials compared with the baseline trials. With the *total* percent looking to match measure, the ANOVA yielded no significant effects, although the *t*-test with the ASD group alone yielded a marginally significant, medium-sized effect, $t(14) = 1.5$, $P = 0.078$, Cohen's $d = 0.52$. Eleven of the 15 children with ASD who contributed data followed the matching pattern (the other four looked less at the match during test relative to baseline). With the firsts *half* percent-looking-to-match measure, neither the ANOVA nor the follow-up *t*-tests yielded any significant effects; however, with the second *half* percent-looking-to-match measure, the ANOVA yielded a significant effect of trial, $F(1,30) = 6.835$, $P = 0.014$, and no other significant effects or interactions. The follow-up *t*-tests indicated that both the TD group ($t(17) = 1.72$, $P = 0.05$, Cohen's $d = 0.41$, 13 of 18 children) and the ASD group ($t(14) = 2.51$, $P = 0.01$, Cohen's $d = 0.82$, 13 of

Table VI. IPL Measures for Syntactic Bootstrapping Video, Visit 2

Measure	TD	ASD
Total trial percent looking to match		
Baseline trials	48.59 (15.52)	40.01 (10.85)
Test trials	49.44 (10.40)	47.66 (17.90)+
First half percent looking to match		
Test trials	42.93 (16.32)	40.21 (15.67)
Second half percent looking to match		
Test trials	55.85 (19.51)*	57.03 (27.14)**
Latency to match (sec)		
Baseline trials	1.43 (0.781)	1.62 (1.145)
Test trials	2.10 (0.87)*	2.03 (0.97)

Note: $^{+}P<0.10$; $^{*}P<0.05$, $^{**}P<0.01$.

15 children) looked longer at the matching scene during the test trials than the baseline trials (Fig. 1).

With the *latency to match* measure, the ANOVA yielded a significant main effect of trial, $F(1, 30) = 6.72$, $P = 0.015$, and no other significant effects or interactions; however, the followup *t*-tests were significant only for the TD group, $t(17) = 2.84$, $P = 0.005$, Cohen's $d = 0.81$. Thus, both groups took numerically more time to look to the matching scene during the test trials than during the baseline trials; however, this only reached statistical significance for the TD group.

Taken together, these findings indicate that our children with ASD, averaging 41 months of age, demonstrated reliable use of the transitive frame to focus their attention on the causative action over the noncausative one, even though the noncausative/synchronous one was clearly the more interesting action overall. They had numerically longer latencies to the causative action during the test vs. baseline trials, indicating that they were indeed processing the test audio. They then looked significantly longer at the causative action during the test trials than during the baseline trials, especially during the latter half of each trial, indicating that they considered the causative action a better match for the novel verb. They did not differ in this use of the transitive frame from the 28-month-old TD children, although our sample is rather underpowered for detecting group differences [$d = 0.35$, power = 0.27; Cohen, 1988].

There is, however, a possible alternative interpretation of these data. It is possible that the children's preference for the noncausative action during the baseline trials eventually leads to habituation, such that their shift in preference to the causative action during the test trials, especially the latter half, is actually a novelty response, rather than being guided by the transitive syntax of the teaching trials. For the TD children, this explanation is highly unlikely because of the numerous baseline conditions (with different teaching audios) which have been performed, demonstrating that TD children of this age show a causative preference only when they hear a teaching audio with transitive syntax [Naigles, 1990, 1998; Naigles & Kako, 1993; see also Fisher, 2002]. These conditions have not (yet) been performed for children with ASD; therefore, it is important to consider this alternative interpretation more closely.

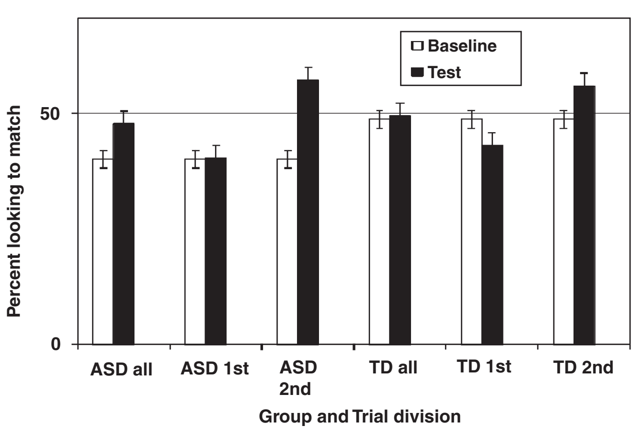

Figure 1. Percent looking to the matching (causative) scene during the first half, second half, and entire test and baseline trials for the syntactic bootstrapping video for both groups of children.

The alternative interpretation rests on the assumption that the ASD children may be habituating to the noncausative action during the baseline trials, so that their shift in looking to the causative action during the test trials, especially the latter half, may be a novelty response. While the relevant research on habituation in ASD children is not completely consistent, most studies have found *enhanced* ability in this population to focus on the details of visual stimuli, and difficulties with *disengaging* attention from such stimuli [Courchesne et al., 1994; Jones & Klin, 2008; Landry & Bryson, 2004; Travers, Klinger, & Klinger, 2010]. Thus, children with ASD tend to habituate to visual stimuli less quickly than typical children, making it is unlikely that the 6-sec baseline trials are enough to elicit a habituation response.

More detailed scrutiny of the ASD children's timecourse of looking during the baseline and test trials of the Syntactic Bootstrapping videos further buttresses this claim. That is, if the children were habituating to the noncausative action progressively more and more across the baseline and two test trials, then the amount of looking at the noncausative should be decreasing across this span. However, as shown in Table VII, the children's amount of looking at the noncausative action actually remains quite stable across the baseline trials and the first half of each test trial. It is only during the second half of each test trial, when the children are asked to "find gorping" that they shift their attention to the causative action (53% in test Trial 1, 64% in test Trial 2).

This is also illustrated in Figure 2, which shows the ASD children's aggregate timecourse of looking (across children and verbs) during the interstimulus intervals (labeled "blank": 3 sec each) and through the baseline and test trials (6 sec each). The pink line shows percent of time looking at the center and the red line shows percent

Table VII. Percent Looking to the Noncausative Action by the Children With ASD

Trial	Percent looking to noncausative action: First half	Second half
Baseline ("they are different now")	61	58
Test trial 1 ("where is gorping now")	60	47
Test trial 2 ("look at gorping")	60	36

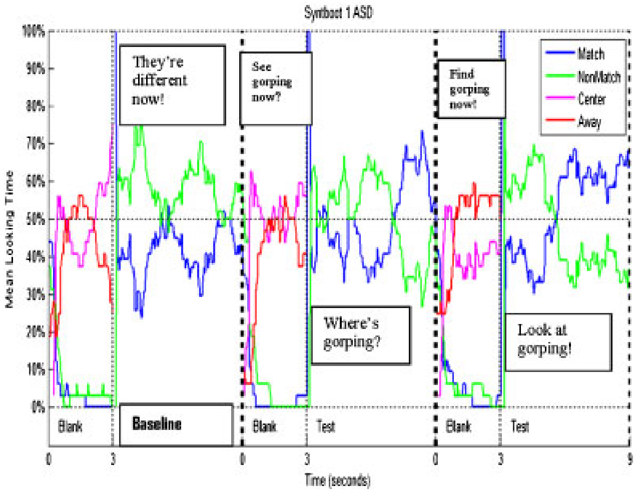

Figure 2. Timecourse of looking to the matching and non-matching scenes for the syntactic bootstrapping video for the children with ASD.

of time looking away from the screens entirely; the green line shows percent of time looking to the noncausative action, and the blue line shows percent of time looking to the causative action. As the figure shows, during the baseline trials, the children clearly look more at the noncausative action, and this preference is still strong during the first half of each test trial. During the second half of each test trial, happening a bit more quickly during the second trial than the first, there is a definite shift in looking to the causative action.

In summary, there is little evidence of habituation to the noncausative action by the children during the baseline trials; moreover, they prefer this action at the same amount during the first half of each test trial. Therefore, it is unlikely that their shift in preference to the causative action during the second half of each test trial is the result of a simple novelty preference. Instead, what we see is that at the beginning of the test trials, the children may be processing the audio ("find gorping"), but they are initially drawn (again) to the noncausative action. Once they hear the audio again ("where's gorping"), they definitively switch their attention to the matching causative scene.[1]

What are the Predictors of Syntactic Bootstrapping?

To address the question of predictors of syntactic bootstrapping, we conducted two hierarchical regressions within each diagnostic group. Each regression investigated whether vocabulary size alone (i.e. performance on the CDI), vocabulary plus noun learning abilities (i.e. performance on the Noun Bias video) and vocabulary plus noun learning plus syntactic abilities (i.e. performance on the Word Order video) predicted syntactic bootstrapping performance at Visit 2 (recall that performance on the Noun Bias video was included to control for the possibility that all IPL tasks correlate with each other). Each regression for each group used the children's degree of matching on syntactic bootstrapping (mean percent looking to the test minus the baseline across the entire trial) as the outcome measure; within each group, one regression used the word order and noun bias *degree of matching* as predictors, whereas the other regression used the word order and noun bias *latency to match* as predictors. Across all four regressions, then, we investigated the degree to which the children's amount and speed of matching during the sentence comprehension (WO) and NB tasks predicted their performance on syntactic bootstrapping, first controlling for vocabulary size. For each regression, the CDI score was always entered first, followed by the Noun Bias score and then the Word Order score. Only those models that accounted for significant amounts of variance are reported here.[2]

As Table VIII shows, the children's CDI scores were consistent positive predictors of later syntactic bootstrapping performance—children who had larger vocabularies at the onset of the study were the ones who showed greater shifts toward the matching (causative) scene at Visit 2. CDI scores accounted for about 31% of the ASD children's variance in syntactic bootstrapping performance. However, both analyses in the table demonstrate that word order performance was also a significant predictor, even after CDI scores were controlled. The first analysis displays the latency

[1]Although not central to the focus of this article, we did compute the correlations between the children with ASD's CARS scores and their CDI and IPL scores. As expected, CARS and CDI scores at Visit 1 were significantly correlated, $r(15) = -0.889$, $P < 0.01$; however, the CARS scores did not correlate significantly with the relevant measures for either the WO or Syntactic Bootstrapping tasks, $r\text{s} < 0.36$, $P\text{s} > 0.20$.

[2]The children's performance on the Word Order and Noun Bias videos was as follows: For Word Order, the ASD group looked at the matching scene significantly longer during the test ($M = 54.39\%$, SD = 6.26) than baseline ($M = 50.0\%$, SD = 9.04) trials, $t(15) = 1.81$, $P = 0.045$; the TD group showed no significant difference, $M(\text{test}) = 52.16\%$, SD = 12.68; $M(\text{baseline}) = 54.35\%$, SD = 11.06. Moreover, the ASD group's latency to the matching scene ($M = 1.65$ sec, SD = 0.72) during the test trials was significantly shorter than their latency to the nonmatching scene ($M = 2.10$ seconds, SD = 0.88); $t((15) = 2.09$, $P = 0.026$); the TD group again showed no significance difference, $M(\text{match}) = 1.97$ sec, SD = 0.83 and $M(\text{nonmatch}) = 1.83$ sec, SD = 0.66. The Word Order video was presented to the TD group 4 months later (when they averaged 24 months of age); they now looked significantly longer at the matching scene during the test trials ($M = 55\%$, SD = 12.71) relative to the baseline trials ($M = 48.77\%$, SD = 8.91), especially during the first half of the trial, $t(17) = 2.29$, $P = 0.034$. For the Noun Bias video, both groups tended to look longer at the match (the object) during the entirety of the test ($M(\text{ASD}) = 57.32\%$, SD = 11.52; $M(\text{TD}) = 51.38\%$, SD = 10.94) relative to the baseline trials ($M(\text{ASD}) = 53.99\%$, SD = 12.98; $M(\text{TD}) = 48.24\%$, SD = 10.79); however, neither the ANOVA nor the follow-up t-tests yielded significant effects of trial. There was a main effect of group, $F(1, 31) = 4.00$, $P = 0.05$, as the ASD group looked longer at the object overall. Both groups also showed longer latencies to the match during the test trials ($M(\text{ASD}) = 1.88$ seconds, SD = 1.14; $M(\text{TD}) = 2.13$ seconds, SD = 0.75) relative to the baseline trials ($M(\text{ASD}) = 1.51$ seconds, SD = 0.75; $M(\text{TD}) = 1.64$ seconds, SD = 0.89), yielding a significant main effect of trial in the ANOVA, $F(1,31) = 5.45$, $P = 0.026$, and significant or marginally significant follow-up t-tests for each group–ASD: $t(14) = 1.51$, $P = 0.07$; TD: $t(17) = 1.83$, $P = 0.04$.

Table VIII. Summary of Hierarchical Regression Analysis for Variables Predicting Syntactic Bootstrapping, ASD group ($N = 17$)

Model	Variable	B	SE	β	ΔR^2
Analysis 1: Predicting SB looking[a]					
1	V1CDI	0.001	0.000	0.61*	0.313*
2	V1CDI	0.001	0.000	0.66*	
	V1NBlatency[b]	028	0.048	0.15	0.00+
3	V1CDI	0.001	0.000	0.74*	
	V1NBlatency[b]	070	0.041	0.39	
	V1WOlatency[c]	−0.164	0.061	−0.56*	0.24*
Analysis 2: Predicting SB looking[a]					
1	V1CDI	0.001	0.000	0.61*	0.313*
2	V1CDI	0.001	0.000	0.61*	
	V1NBlooking[d]	0.04	0.403	0.064	0.00+
3	V1CDI	0.001	0.000	0.51*	
	V1NBlooking[d]	0.440	0.323	0.27	
	V1WOlooking[e]	−1.731	0.583	−0.61*	0.266*

$^{+}P<0.10$, $^{*}P<0.05$. CDI, Communicative Development Inventory; NB, noun bias; WO, word order.

[a]Percent looking to the match for test trials minus baseline trials, entire trial, syntactic bootstrapping.

[b]Latency to the match for the test trials, noun bias.

[c]Latency to the match for the test trials, word order.

[d]Percent looking to the match for test trials minus baseline trials, entire trial, noun bias.

[e]Percent looking to the match for test trials minus baseline trials, entire trial, word order.

predictors of the Syntactic Bootstrapping looking preference; the model was significant when it included both the CDI and Word Order measures, $F(3,\ 12) = 5.86$, $P = 0.017$. Once CDI scores were controlled, children's latency to the object in the NB video contributed little additional variance, but their latency to the matching scene in the Word Order video did. Notice that the predictor is negative—children who look more quickly to the match in the Word Order video (i.e. have a shorter latency), look *longer* at the match in the Syntactic Bootstrapping video at Visit 2. The addition of the word order scores, then, explains an additional 24% of the variance. A negative prediction was also observed in the next analysis, which displays the degree of looking predictors of the Syntactic Bootstrapping looking preference, $F(3,\ 12) = 6.49$, $P = 0.012$. Here, once CDI scores are controlled, the children's degree of looking at the match during the Word Order video is a significant and negative predictor of their subsequent degree of looking at the match during the Syntactic Bootstrapping video, accounting for an additional 26% of the variance. The regressions performed with the TD children's data did not reach significance.

Discussion

This study investigated whether children with ASD could use syntactic bootstrapping, via the transitive sentence frame, to constrain the meaning of a novel verb. We also examined which aspects of their earlier linguistic knowledge were significant predictors of their syntactic bootstrapping performance. We gave the children two comprehension tasks (SVO word order, noun bias) at their initial visit, when they were matched on language and cognitive level with a group of TD children. Eight months later, we taught both groups two novel verbs in transitive frames and then asked whether they mapped those verbs onto novel causative or noncausative actions. Both groups significantly preferred the causative actions, thus demonstrating syntactic bootstrapping. Moreover, hierarchical regressions indicated that CDI scores and word order performance contributed significant and independent amounts of variance; hence, for the ASD group, both lexical and syntactic abilities at Visit 1 predicted syntactic bootstrapping performance at Visit 2. No significant Visit 1–Visit 2 correlations were found for the TD group.

Our findings demonstrate syntactic bootstrapping because the children looked longer at the causative scene during the test trials, when they were asked for "gorping" or "blicking," than during the baseline trials, when they saw the same event pairs but were only told "they are different now" (Table VI). Thus, we know that the children's preferences were not just based on the relative visual salience of the stimuli. Moreover, we know that the transitive frame heard during the teaching trials exerted an influence because the children consistently preferred the causative action during the test trials. Previous research has demonstrated that when TD 2-year-olds see these videos and are taught novel verbs in isolation (i.e. without a frame), they show a nonsignificant preference for the noncausative actions; moreover, when they are taught novel verbs in intransitive frames, they significantly preferred the noncausative actions [Naigles, 1990; Naigles & Kako, 1993]. A preference for the causative actions was only observed when they were taught the verbs in the transitive frame. We see these findings in a microcosm in this study: As Tables VI and VII show, the children, especially those in the ASD group, looked longer at the *noncausative* actions during the baseline trials (40% causative = 60% noncausative), and still showed this preference during the first 3 sec of the test trials (i.e. there was little or no habituation, see Fig. 2). However, by the latter 3 sec of the test trials, after they had heard "find gorping/blicking" twice, they shifted their attention decisively to the causative action.

These findings corroborate and extend those of Shulman and Guberman [2007] in several ways. We have demonstrated syntactic bootstrapping in children with ASD who are younger (3 years, 7 months rather than 5 years, 7 months) using a paradigm that included more verbs (2 rather than 1) and fewer teaching trials (3 rather than 12). Thus, syntactic bootstrapping seems to be a robust phenomenon, at least with children with autism who are somewhat verbal. It remains to be seen, of course, whether this finding generalizes to a truly representative sample of children with ASD, including those receiving all types of interventions. The extent to which syntactic bootstrapping is dependent on concurrent language ability is not entirely straightforward: the children with ASD with larger vocabularies overall at Visit 2 also performed better on the Syntactic Bootstrapping task at the same visit. That is, the correlation between CDI scores at Visit 2 and children's degree of matching on Syntactic Bootstrapping was significant ($r = 0.484$, $P < 0.05$); however, note that the children with ASD's overall vocabulary scores were much lower than those of the TD children at the same visit (Table V), and their overall language level much lower than that of the children with ASD tested by Shulman and Guberman [2007]. It could be interesting to compare these correlations with those including an assessment of vocabulary *comprehension*; however, the current findings suggest that if there is a threshold level of language ability that children require in order to abstract the transitive sentence frame, this level is fairly low.

Taken together, these two demonstrations of syntactic bootstrapping suggest that children with ASD have command of at least one or two abstract sentence frames. Because the verbs heard in the frames were novel, the only way the children could have understood the sentences—so as to map them onto the correct actions—was to realize that "the duck is gorping the bunny" is the same type of sentence as "the girl is pushing the boy." Thus, their documented difficulty with generalizing patterns to new instances [Minshew et al., 2002; Tek et al., 2008] is not without exception. In fact, these findings may suggest that generalizing basic grammatical patterns is easier for individuals with ASD than generalizing conceptual patterns. Possibly, the sheer ubiquity/higher frequency of grammatical patterns across contexts makes them more accessible to children with ASD (i.e. the same sentence frames are used over and over; one analysis of caregiver speech finds that SVO utterances comprise 37.6% of the total [Naigles & Hoff-Ginsberg, 1995; see also Tager-Flusberg, 1994, 2001]). It is also possible that grammatical patterns are inherently more transparent than conceptual patterns, just because grammatical patterns are not directly associated with meanings-in-the-world and so may not require understanding of these meanings to be acquired [see Naigles, 2002, for more discussion]. In any case, these findings suggest that some children with ASD are able to abstract grammatical frames, and thus may not need to rely solely on associative/declarative learning for language acquisition [cf. Tomasello, 2003; Walenski et al., 2006].

Of course, some children performed better than others on the syntactic bootstrapping task, and this performance was found to be predicted by two aspects of their performance at Visit 1, conducted 8 months earlier. That is, children with higher vocabularies on the CDI at Visit 1 were better syntactic bootstrappers. Not surprisingly, then, the ability to accrue words near the beginning of language development appears to exert an influence on the ability to learn new verbs later on. Furthermore, children who were more efficient or faster processors of SVO word order at Visit 1 were also better syntactic bootstrappers at Visit 2, even after the variance attributed to their CDI scores was partialled out. Again, this predictor makes sense: children who are able to process SVO sentences quickly and correctly (i.e. finding the match efficiently) early on have the highest likelihood of subsequently being able to use SVO sentences—the transitive frames of our study—to learn new verbs. It is important to emphasize, though, that the effect of word order latency cannot simply be a general effect of IPL performance, because any general effect of IPL performance would be shared by the noun bias task, and the effect of word order latency held even when variance from the noun bias task was partialled out. Moreover, the regression findings demonstrate that the CDI and word order latency contribute independently; neither word order processing efficiency nor vocabulary knowledge can be subsumed by the other in explaining the variance in the syntactic bootstrapping task. Thus, these findings support our earlier hypothesis about predictors of syntactic ability: possibly because we included measures of grammatical comprehension rather than production, we are able to demonstrate that *both* early lexical *and* grammatical abilities are predictive of later syntax.

Somewhat puzzlingly, the regressions also found that children who looked *longer* at the matching screen during the Word Order task at Visit 1 performed *more poorly* on the Syntactic Bootstrapping task at Visit 2. This effect seems to be at odds with the Word Order latency effect: Why would syntactic bootstrapping be *positively* predicted by children who look faster to the match with word order, but *negatively* predicted by children who look longer to the match with word order? It is possible that the latter effect is attributable to the perseveration of some children with ASD on the match in the Word Order task. That is, while longer looking to the match in an IPL task is generally an indicator of more advanced understanding of the audio, it is possible that in this case it was an indication that the children were no longer attending to the task; i.e. they were watching the video but not trying to link video and audio together. And children who are less facile with audio-visual matching early on *would* be expected to be less good at a more advanced task like syntactic bootstrapping, later in development. This explanation is speculative at the moment, but gains support from other studies showing disengagement difficulties in young ASD children with language delay [Bebko, Weiss, Demark, & Gomez, 2006; Landry & Bryson, 2004; Newell, Bahrick, Vaillant-Molina, Shuman, & Castellanos, 2007; Takarae, Luna, Minshew, & Sweeney, 2008].

These are the first correlational findings to be reported with the ASD population that pertain to specific aspects of language learning. The finding that speed or efficiency of processing SVO sentences (with familiar verbs) at Visit 1 is predictive of children with ASD's later ability to use SVO frames to make conjectures about novel verb meaning is similar to findings reported for TD infants and toddlers, that speed of processing running speech is predictive of their later vocabulary size [Fernald, Perfors, & Marchman, 2006; Newman et al., 2006]. However, it is puzzling that these correlations in this study only reached significance for the ASD group, not the TD group. We believe that the lack of significance found within the TD correlations may be attributed to three possible factors, acting separately or in combination. First, significant correlations occur when there is substantial variance in the outcome measure, and the TD group consistently showed less variance in their syntactic bootstrapping performance than the ASD group (Table VI). With more of the TD children demonstrating robust syntactic bootstrapping, there was less variance for their Visit 1 CDI and IPL scores to explain. Moreover, our sample size ($n = 17$ for the correlations) was smaller than that reported by the studies finding significant correlations between early sound and word processing and later language e.g. 20–30 children were included in Kuhl, Conboy, Padden, Nelson, and Pruitt [2005] and Newman et al. [2006]; 50+children were included in Fernald et al. [2006]. It is likely that if this study had had similar power to these other studies, significant correlations would have been observed (i.e. power analyses indicate that an N of 53 would reach significance [Cohen, 1988]). We are currently replicating these findings with a new cohort of ASD and TD children; when the two cohorts are combined, we will be able to see if the absence of significant predictive correlations for syntactic bootstrapping in the TD group was indeed attributable to low power. Finally, Swensen and colleagues [Swensen, Fein, & Naigles, 2008; Swensen, Naigles, & Fein, 2007] investigated the relationships between maternal speech and subsequent child speech in TD and ASD children and observed similar relationships in both groups but differences in the timing of some of the relationships. For example, relationships seen over a 4- or 8-month span in the TD group only emerged over an 8- or 12-month span in the ASD group; children with ASD took longer to show these relationships than TD children did. It is possible, then, that correlations between early word order processing and vocabulary, and later syntactic bootstrapping, might be seen in the TD group over shorter intervals, as well. Our ongoing replication may be able to address this issue.

Limitations to this study include the relatively small sample size, as discussed above. Moreover, thus far we have only used standardized test and IPL scores as predictors of subsequent syntactic ability; we are currently coding and analyzing the children's spontaneous speech and naturalistic interaction data, and plan to include these as predictor variables when they become available. Richer data may also enable us to paint a more detailed picture of those children who did not succeed in the syntactic bootstrapping task; for now, we observed that neither CARS, Vineland, nor Mullen scores at Visit 1 seem to be predictive of such performance. Finally, future versions of the syntactic bootstrapping task will include a larger number of items.

In conclusion, these findings demonstrate that these young children with autism have generalized at least one grammatical frame in English. Because their choice of action followed the transitive frame (SVO) in which the verb was presented (i.e. the causative action), they demonstrated that this frame carried its own meaning, independently of the verb. This conclusion allows us to speculate that the well-attested generalization difficulties of individuals with autism may be domain-specific rather than domain-general. Perhaps, for these individuals [see also Naigles, 2002], generalizing *grammatical* patterns is easier than generalizing conceptual ones.

Acknowledgments

Letitia R. Naigles, Emma Kelty, Rose Jaffery, and Deborah Fein, Department of Psychology, University of Connecticut.

We thank the National Institutes of Health (R01 DC07428 and R01 2DC007428) for supporting this research, and the Crossroads Center for Children, Douglass Developmental Disabilities Center, Eden Institute, River Street School, Minuteman Intervention Center, May Institute, Sterling Nursery School and Lynn Brennan for their extensive assistance in participant recruitment. We are grateful to all the parents and children for their cheerful participation. Thanks go to Christie Roche, Jonela Karaja, and the undergraduates of the UConn Child Language Lab for help in the data collection and coding process. Portions of these findings have been reported at the 2008 International Meetings for Autism Research, the 2009 Bienniel Meeting of the Society for Research in Child Development, the 2010 Conference on Human Development, and to the UConn Psycholinguistics Group. We gratefully acknowledge the helpful commentaries at these venues, especially from Bernard Grela, Virginia Marchman, William Snyder, and Michael Tomasello.

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