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How Children With Autism Extend New Words

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Abstract

Purpose—How do children with autism spectrum disorders (ASD) extend a noun to the category of objects it labels? Given their tendency to perceive locally, their extensions might be too narrow. Given their social-communicative deficits and a context in which the knowledge of a social-communicative partner promotes narrow extensions, their extensions might be too broad.

Method—We tested these predictions by comparing 25 high-functioning school-aged children with ASD to 29 age-matched peers with typical development (TD) in a task that required extraction of commonalities of object referents and use of social-communicative context to support the category inference.

Results—The children with ASD readily extended a given noun to multiple exemplars, thereby demonstrating tacit knowledge that words label categories and the ability to override local perceptual biases they might have. However, unlike their peers with TD, those who had concomitant weaknesses in semantic and syntactic language ability formed broad categories when their social partner's behavior suggested narrow categories.

Conclusions—Some, but not all, people with ASD fail to use social context to support inferences about word extension. The direction of any causal relationship between failure to use social contextual cues and language deficits awaits determination.

Keywords

vocabulary; learning; autism spectrum disorders

Spoken-word learning is largely an inferential process that occurs in social-communicative contexts. In these contexts, the extraction of word meaning is supported by multiple, probabilistic, linguistic, and nonlinguistic cues (Seidenberg & MacDonald, 1999). In this study, we focused on the ability of children with autism spectrum disorders (ASD) to use contextual cues to infer category extensions for new words.

Much of what we know about word learning among children on the autism spectrum is limited to the fast mapping of object labels, or the initial linkage of a novel noun to an unfamiliar referent. Many children with ASD can fast map successfully when their social partners point to or touch the referent being named (Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007); however, as a group, they are less able than their mental or chronological age-mates to fast map when the link to be inferred is conveyed by more subtle cues such as their partner's eye gaze (Baron-Cohen, Baldwin, & Crowson, 1997; see also Preissler & Carey, 2005) or intentions (Parish-Morris et al., 2007). There are

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exceptions to these group patterns such that some individuals with ASD, especially those with average or higher non-verbal intelligence, do succeed in using social context as a support for fast mapping (Luyster & Lord, 2009).

Fast mapping is only the first step in word learning. Save proper names, words refer to categories, not individual referents; therefore, the child who has successfully mapped a novel noun to a single object must appreciate that the word applies to other objects of the same kind. Moreover, object kinds may be categorized at different levels of specificity. A given poodle may be labeled *animal,* a term that extends to superordinate neighbors like cats; *dog,* a term that extends to basic-level neighbors like collies; or *poodle,* a term that extends to subordinate neighbors, that is, to other poodles. Therefore, the child must also recognize the commonalities of exemplars at each level and use contextual cues to determine the correct level of category extension.

The bulk of the evidence suggests that children with ASD establish appropriate word categories. For example, Tager-Flusberg (1985) found that 10-year-old children with ASD and low verbal mental age (M = 5;2 [years;months]) and their typically developing verbal mental age peers performed comparably when asked to categorize pictures of familiar objects from basic-level categories (e.g., boat) and superordinate categories (e.g., tool). Both groups performed better with prototypical than atypical exemplars, and there was a trend toward better performance at the basic level than the superordinate level. Children with ASD also respond differentially to concrete and abstract words during comprehension (Eskes, Bryson, & McCormick, 1990) and naming (McGregor et al., 2011) in a manner comparable to peers. Also, by adolescence, people with ASD are as quick as typically developing age- and IQ-matched peers at identifying typical and somewhat typical members of familiar object categories (Gastgeb, Strauss, & Minshew, 2006). However, there are exceptions to this positive description. Even as adults, people with ASD are slower than age- and IQ-matched peers at identifying atypical category members (Gastgeb, et al., 2006), and they generate fewer exemplars in semantic fluency tasks (e.g., name all the animals you can think of within 1 min) than unaffected adults with similar levels of language comprehension (Spek, Schatorjé, Scholte, & van Berckelaer-Onnes, 2009).

Even if we accept category extension as a relative strength, we do not know whether learners with ASD derive these extensions via the same processes used by other learners. For example, unlike children with typical development (TD), young children with ASD fail to privilege similarity of shape as a basis for extending nouns to exemplars within an object category (Tek, Jaffery, Fein, & Naigles, 2008). There are multiple routes to language learning; documenting the routes taken by children with ASD is critical to understanding the time course and ultimate attainments we can expect. Therefore, in the current study, we enrolled high-functioning children with ASD and their age-mates with TD in a task that required them to extend novel nouns to the (visually presented) objects they label. As in the real world, cues to the appropriate extension of the nouns were available in the physical and social-communicative context of the task.

Perception of Physical Context

Visual perception is integral to the development of object concepts and the learning of their labels (Goldstone & Barsalou, 1998). To learn a new label for an object present in the physical context, the learner must determine which object is relevant (to accomplish fast mapping) and which other objects are of the same kind (to accomplish extension). In typically developing individuals, perceptual processing of objects at a global level takes precedence over the local level, all things being equal. For example, when people listen to the name of a letter while viewing a large letter made of smaller ones (e.g., a large *h* made of many small *b*s), their auditory perception will suffer when the large letter is inconsistent with what is heard but not when the small letters are inconsistent (Navon, 1977). In the everyday world, this means that people process the global features of objects (e.g., shape) before they process their local features (e.g., parts). This is an advantageous sequence because the whole facilitates analysis of the part and also because, in a fleeting visual world, a rough idea of general structure is typically more useful than detail about a limited number of parts. Moreover, and more pertinent to the current work, the ability to overlook irrelevant details is useful to the process of categorization and, in fact, learners with TD used similarities in shape more often than details such as color or texture as a basis for word category extensions (Landau, Smith, & Jones, 1988). For this reason, reliance upon local processing could adversely affect categorization and extension.

Perceptual processing among many people with ASD is different. For them, especially in the visual modality, local processing takes precedence over global processing (Behrmann, Thomas, & Humphreys, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). With local, detail-oriented perception as a default setting, performance on any task that requires attention to individual pieces of a scene or individual parts of objects might well be enhanced. Indeed, people with ASD are stronger than peers with TD at finding embedded figures, copying impossible figures, and detecting visual and auditory figures against complex ground, to name a few examples (Mottron et al., 2006). However, tasks that require recognition of wholes and the extraction of common characteristics across objects—a task like word mapping and extension, for example—may well suffer. As Plaisted (2001) states, "Specifically, the idea that perception in autism enhances the discriminability of stimuli predicts that category boundaries will be sharper and category content much narrower in autism than in typically developing individuals" (p. 149). The tendency to perceive locally may adversely affect word extension such that overly narrow categories are formed.

Most studies of categorization in individuals with ASD have focused on preexisting knowledge of concepts such as cars and vegetables (Plaisted, 2001). Whereas the categories of children with ASD and their peers with TD appear similar, the basis for such groupings may differ. For example, Johnson and Rakison (2006) found preschoolers with ASD as happy to model walking with a toy table as a toy dog, suggesting that their categories were based on selective parts (i.e., things with legs vs. things without) rather than more abstract relationships among movement, parts, and wholes (i.e., animate vs. inanimate). Moreover, in a looking habituation paradigm in which the stimuli were moving geometric objects, these same children noticed changes in the parts of the objects but not in the bodies of the objects or their movement trajectories (Johnson & Rakison, 2006). In both cases, categorization in children with ASD appeared to be driven by local rather than global processing. This tendency to focus locally, as demonstrated by hyper-attention to parts, may also explain why children with ASD can readily form categories based on rules (e.g., all members of this category have big feet) but not when category formation depends upon extraction of an abstract prototype (Klinger & Dawson, 2001).

Evaluation of Social-Communicative Context

During word learning, children with TD pay attention not only to the objects or events being named but also to the behavior of their social partners (Akhtar & Tomasello, 2000). For example, 3- and 4-year-olds are more likely to learn a new word spoken by an adult who directly expresses his knowledge (e.g., "I know just which one is the blicket") than one spoken by an adult who directly expresses his ignorance (e.g., "I don't know what a blicket is"; Birch, Vauthier, & Bloom, 2008). However, direct verbal expression is not necessary, as children as young as 2 can deduce knowledge states by reading body language (e.g., a confident posture vs. a puzzled facial expression; Birch, Akmal, & Frampton, 2010). Furthermore, preschoolers assume that adults are better informants in word learning situations than are other children, unless adults demonstrate unreliable behavior on known words (e.g., if an adult mistakenly identifies a shoe as a glass; Jaswal & Neely, 2006). These findings reveal the young child's ability to evaluate cues to the mental states of others and to use that information to infer word mappings.

Social-communicative context supports not only fast mapping of words but also word extension. Consider Xu and Tenenbaum (2007), who showed 4-year-olds with TD an array of novel objects that had neighbors at each level of a nested hierarchy. For any given object, there were others that were subordinate (identical), others that were basic (differing in color), and others that were superordinate (differing in shape and color). Children were assigned to one of two social-communicative conditions. In both, the child heard a novel word and saw three subordinate exemplars sampled from the array; the difference was that the examiner selected these subordinates in the teacher-driven condition, but the child helped to select them in the learner-driven condition, with the promise of a prize if he selected correctly. The child's task was to determine whether the novel word could extend to additional exemplars at the subordinate and basic levels.

Given that the social partner's behavior constitutes a relevant cue to extension, the prediction was that the small variation in sampling context—namely, whether the teacher or the learner selected the exemplars—would influence extension inferences. In the teacher-driven condition, children would view the teacher's conservative choices as meaningful: Why would a knowledgeable person sample only subordinates if, in fact, the term extends more broadly? In the learner-driven condition, the conservative sample was not based on knowledge but on the naïve learners' desire to win a prize. Therefore, subordinate extensions would be preferred in the teacher-driven condition, and broader extensions would be preferred in the learner-driven condition. This prediction held. Xu and Tenenbaum (2007) concluded that learners weigh the social-communicative context when inferring extensions; specifically, they evaluate the knowledge state of their social partners and use this evaluation to refine their inference. Of course, in the case of a child learner and an adult teacher, this refinement process will typically favor the knowledge of the adult (Jaswal & Neely, 2006), that is, if the child perceives the adult's expertise and interprets the adult's behavior as meaningful.

Despite huge variability in language and cognitive ability, social-pragmatic deficits are a universal characteristic of ASD. A consistent finding across research studies is that individuals with ASD fail to consider the behaviors of their social partners. For example, affected individuals have difficulty using gaze to coordinate joint attention with others (Lewy & Dawson, 1992; McArthur & Adamson, 1996; Mundy & Crowson, 1997; Mundy, Sigman, Ungerer, & Sherman, 1986), and those who are successful at following gaze remain less sensitive to the social informativeness of that gaze than peers with TD (Norbury, Griffiths, & Nation, 2010). In other words, they fail to use physical behavior to infer the goals and mental states of others, inferences often termed *theory of mind* (Baron-Cohen, Tager-Flusberg, & Cohen, 1994). Language ability and performance on theory-of-mind tasks are correlated (Milligan, Astington, & Dack, 2007); however, these difficulties characterize children with ASD to a much greater extent than children with specific language impairment (Perner, Frith, Leslie, & Leekam, 1989) or Down syndrome (Baron-Cohen, 1989), suggesting that it is not only the language or general cognitive level required by these attributions that is problematic. Such deficits could adversely affect word extension. Specifically, in a task such as Xu and Tenenbaum (2007), failure to correctly interpret the behavior of the teacher could result in overly broad categories.

Current Study

In the current study, we were interested in the processes involved in learning a word category in the moment. We employed the protocol designed by Xu and Tenenbaum (2007) to determine whether children with ASD infer noun category boundaries in the same ways as children with TD. The protocol was ideal in that it requires both extraction of commonalities of physical referents and use of social-communicative context to support the category inference. These processes are commonly involved in day-to-day word learning, and prior evidence suggests that they may be deficient in children with ASD. A critical attribute of the experimental design is that deficits in the perception or use of physical context and deficits in the evaluation or use of the social-communicative context lead to two different predicted patterns of performance.

1. Differences in the perception or use of physical context are predicted to lead to differences between ASD and TD groups in the learner-driven condition. If the children with ASD perceive the potential object referents for the new word locally at the expense of extracting commonalities, they should form narrow categories with more extensions to the subordinate level in the learner-driven condition than demonstrated by the TD group. They should not differ in the teacher-driven condition because there the TD group should also be forming narrow categories (on the basis of the teacher's knowledge state).

2. Deficits in the evaluation or use of the social-communicative context are predicted to yield differences in the teacher-driven condition. If the children with ASD fail to read the nuances of the social-communicative situation, specifically the expertise of the teacher, they should form broad categories with more extension to the basic level in the teacher-driven condition than demonstrated by the TD group. They should not differ in the learner-driven condition because there, the TD group should also be forming broad categories (on the basis of their own knowledge state).

Method

Participants

We began with 26 children with ASD (25 boys, 1 girl) and 29 age-mates with TD (16 boys, 13 girls) who were between 7;7 (years;months) and 13;11. All were recruited and tested according to approved IRB protocols for the treatment of human subjects. All had also taken part in a larger study of syntactic and lexical semantic knowledge reported in McGregor et al. (2011). Each child in the ASD group was included on the basis of an independent diagnosis of and services for ASD via parent report and scores on the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999) and the Social Communication Questionnaire (SCQ; Rutter, Bailey, Berument, Lord, & Pickles, 2003) that met cutoffs for autism spectrum or autism disorders. To be included in the TD group, each child had to achieve a standard score of at least 85 on the core battery of the Clinical Evaluation of Language Fundamentals—4 (CELF–4; Semel, Wiig, & Secord, 2003) and score outside the range of autism spectrum (lower than 11) on the SCQ.

All children passed a pure-tone hearing screening administered according to American Speech-Language-Hearing Association (1990) guidelines and earned a standard score of at least 85 on the Kaufman Brief Intelligence Test—2 (KBIT–2; Kaufman & Kaufman, 2004). Mothers of all children had completed at least a high-school education, and most had completed university, with the ASD group averaging 16.04 years of maternal education (SD = 3.26) and the TD group averaging 15.24 years (SD = 1.92), $t(53) = 1.12$, $p = .27$.

We assigned children from each diagnostic group pseudorandomly to either the teacher- or learner-driven condition. To match the children with ASD assigned to the teacher and learner conditions on the basis of autism severity, we excluded one child with ASD from the learner condition because he had an exceptionally poor ADOS score. The resulting mean ADOS scores (based on the Social + Communication algorithm) were 13.67 (SD = 4.33) for the children in the learner condition and 14.85 for children in the teacher condition (*SD* = 3.29), $t(23) = -0.77$, $p = .45$.

The participants ultimately included in the primary analysis were 25 children in the ASD group (12 in the learner condition and 13 in the teacher condition) and 29 in the TD group (17 in the learner-driven condition and 12 in the teacher-driven condition). The unbalanced size of the TD assignments reflected human error: Two children were assigned to the learner-driven condition who should have been assigned to the teacher-driven condition. A secondary analysis compared only a subset of children in the learner condition to the full cohort in the teacher condition (see the *Extension Performance* subsection below). In Table 1, the age and standardized test data for the full set and subset of children in the learner-driven condition may be compared to those for children in the teacher-driven condition.

The learner- and teacher-driven conditions were group matched for chronological age; this was true when comparing the teacher-driven condition to the full learner-driven sample, $t(52) = -0.34$, $p = .73$, or to its subset, $t(45) = -0.10$, $p = .92$. Also, within each condition, the participants with ASD and TD were group matched for age: teacher-driven, $t(23) = 0.72$, $p = .48$; learner-driven full, $t(27) = 0.67$, $p = .50$; learner-driven subset, $t(20) = 0.26$, $p = .80$.

Children with ASD assigned to the teacher-driven condition and the full sample of the learner-driven condition were group matched for expressive and receptive language ability as measured by the CELF–4 core, $t(23) = 0.47$, $p = .64$, and for receptive vocabulary in particular as measured by the Peabody Picture Vocabulary Test—III (PPVT–III; Dunn & Dunn, 1997), $t(23) = 0.24$, $p = .81$. This was also true when comparing the children with ASD in the teacher-driven condition to those in the subset of the learner-driven condition: CELF–4 core, $t(18) = 0.28$, $p = .79$; PPVT–III, $t(18) = 0.26$, $p = .80$. In Table 1, note that the mean scores earned by the ASD group on the language tests were within normal limits, that is, within 1 standard deviation of the normative mean; however, the variance around these means was large. It is common to find children with excellent language abilities as well as those with semantic and syntactic language impairments within the high-functioning ASD population (Tager-Flusberg & Joseph, 2003). In the current study, of the 12 children with ASD who were assigned to the learner-driven condition (full sample), seven earned scores more than 1 standard deviation below the mean on the CELF–4 core, as did one on the PPVT–III. Of the 13 children with ASD who were assigned to the teacher-driven condition, three earned low scores on the CELF–4 core, as did two on the PPVT–III. The effect of language ability on task performance is explored in the *Extension Performance* subsection below.

Stimuli

The stimuli were two sets of colored shapes printed onto 8-in. × 11.5-in. paper. Set A appears in Appendix A; Set B is excerpted from Xu and Tenenbaum (2007). In each set, there were two basic-level categories of 15 members each. The members of each basic-level category shared a given shape (e.g., rectangular with an arrow protruding) and space (e.g., upper left portion of the page). Within each of the two basic-level categories were three subordinate categories of five members each. The members of each subordinate category shared a given color, pattern, and orientation (e.g., bluish-purple, striped, and tilted 5°).

In both the learner- and teacher-driven conditions, the participants were presented with the two sets of shapes, one at a time in counterbalanced order across participants. Three subordinates (i.e., same shape, space, color, pattern, and orientation) were sampled from each set and labeled with a novel word (*blicket, tupa, wug,* or *fep*) with the assignment of a particular word to a particular set being varied across sets and participants.

Procedure

Teacher-driven condition—We followed the procedure of Xu and Tenenbaum (2007) as summarized in Appendix B. In the sampling phase of the teacher-driven condition, the examiner pointed to three subordinates (e.g., three rectangles with protruding arrows, all of which were aqua and spotted) from the first item set, saying, “See this? It’s a blicket [or tupa/wug/fep]” each time. In the extension phase, she then pointed to two subordinate neighbors (same shape, color, and pattern), two basic-level neighbors (same shape but different color and pattern), and one superordinate neighbor (different shape, color, and pattern), asking for each, “Is this a blicket [or tupa/wug/fep]?”). These neighbors were presented for acceptance or rejection in the order subordinate, superordinate, basic, subordinate, basic. The participants received no feedback about the accuracy of their acceptances or rejections. The procedure was repeated with the second set, yielding four chances to agree or disagree with extensions of the new word to subordinate-level neighbors and four chances to agree or disagree with extensions to basic-level neighbors. Just as in Xu and Tenenbaum (2007), extensions to the superordinate level were not analyzed. The spatial separation between the two basic-level categories in each set (see Appendix A) made it unlikely that the children would agree to extend to the superordinate level and, indeed, they did not.

Learner-driven condition—In the sampling phase of the learner-driven condition, the examiner pointed to one of the items (e.g., one spotted aqua rectangle with a protruding arrow) and said, “See this? It’s a blicket [or tupa/wug/fep]. Point to another blicket [or tupa/wug/fep]. If you get it right, you’ll get an extra prize at the end of the session.” After the participant selected a shape, the examiner again said, “Now point to another blicket [or tupa/wug/fep]. Again, if you get it right, you’ll get an extra prize at the end of the session.” The extension phase was identical to that of the teacher-driven condition.

Results

Sampling in the Learner-Driven Condition

Recall that the child played an active role in the sampling phase of the learner-driven condition. The promise of an extra prize was meant to promote conservative behavior, that is, to elicit subordinate neighbors; however, five of 12 members of the ASD group sampled basic-level neighbors on one or more of the four trials, a rate higher than expected, $\chi^2(1)$ (with Yates correction for cell frequencies < 0) = 4.04, $p = .04$. Basic-level sampling also characterized two of 17 members of the TD group, but this was not significantly different from expectation, $\chi^2(1)$(with Yates correction for cell frequencies < 0) = 0.53, $p = .47$.

Extension Performance

Before analyzing extension performance, we excluded data from the seven children who selected basic-level exemplars during sampling. Remaining in the subsample of the learner-driven condition were seven children with ASD and 15 children with TD. Importantly, by removing these children from the analysis, we equated the samples from which the children inferred their extensions in the learner- and teacher-driven conditions (the samples now consisted of three subordinate exemplars for each child in both conditions).

A mixed model 2 × 2 × 2 analysis of variance (ANOVA) by subject, with group (ASD, TD) and condition (teacher-driven, learner-driven) as between-subjects variables, level (subordinate, basic) as a within-subjects variable, and number of agreements as the dependent variable yielded no main effect of group, $F(1, 43) = 1.67$, $p = .20$, or condition, $F(1, 43) = 0.92$, $p = .34$. There was a main effect of level, $F(1, 43) = 88.75$, $p < .0001$, partial η^2 = .67. The effect of level reflected more agreements to subordinates (*M* = 3.58, *SE* = 0.11) than basics (*M* = 1.29, *SE* = 0.25).

There was a significant interaction between group and condition, $F(1, 43) = 5.08$, $p = .03$, partial η^2 = .10. In the learner-driven condition, the ASD and TD groups behaved similarly ($p = .88$). The ASD and TD groups differed only in the teacher-driven condition ($p = .01$; see Figure 1). There, the broad extension behavior of the participants with ASD was revealed: They were more willing to extend to the basic level than the participants with TD.

Next, we related broad category formation to lexical and semantic-syntactic language ability and the severity of social-communicative deficits among the children with ASD. Specifically, we asked whether the children with ASD who sampled more broadly than expected (i.e., sampled at least one basic-level exemplar) in the learner-driven condition and those who extended more broadly than expected (i.e., extended to at least one basic-level exemplar) in the teacher-driven condition earned poorer CELF–4 core and PPVT–III standard scores and ADOS Social + Communication algorithm scores than those who sampled and extended as expected in these conditions (i.e., extended to the subordinate level only). Children with ASD who formed subordinate-level categories ($n = 12$) scored around the normative mean on the CELF4, whereas those who formed basic-level categories ($n = 13$) scored 1 standard deviation below the normative mean, $t(23) = 2.06$, $p = .05$ (see Figure 2, top). Although both groups' average scores were well within normal limits on the PPVT–III, there was again a trend toward higher performance on the part of those who formed subordinate-level categories, $t(23) = 1.79$, $p = .09$ (see Figure 2, top). In contrast, the children were similar in severity of social-communicative deficits as measured by the ADOS, $t(23) = 0.04$, $p = .97$ (see Figure 2, bottom). Therefore, the tendency to form broad categories was not related to autism severity but was, instead, characteristic of the children affected by ASD and concomitant language problems.

Following Xu and Tenenbaum (2007), we examined the consistency of extension responses among each child. Classification of the children according to their group (ASD or TD), condition (learner-driven or teacher-driven), and consistency (subordinate, basic, or neither) appears in Figure 3. Two children with ASD, both in the teacher-driven condition, were inconsistent, that is, they agreed to extend to subordinates only for one of the novel words but to basic-level exemplars as well for the other, even though both words were presented under identical sampling conditions. Four of the children with TD from the subsample of the learner-driven condition were inconsistent, as were three of the children with TD assigned to the teacher-driven condition.

In the learner-driven condition, the majority of the children, whether in the ASD or TD group, were consistent in extending to subordinates (they agreed to subordinate exemplars only for both words). In the teacher-driven condition, it is again apparent that some members of the ASD group extended more broadly than expected. There, six of 13 children in the ASD group consistently extended to the basic level compared to zero of 12 children in the TD group. This difference between groups was significant, $\chi^2(1)$(with Yates correction for cell frequencies < 0) = 4.98, $p = .03$.

Summary

To summarize, high-functioning children with ASD were more likely than their unaffected age-mates to form broad categories—categories that included basic and subordinate neighbors rather than subordinates alone—in social contexts that warranted narrow categories. The broad sampling and extension behavior of the ASD group was driven by individuals who had concomitant weaknesses in semantic and syntactic aspects of language.

Discussion

In this study, we were interested in the ability of children with ASD to determine the category extensions of novel nouns in the moment. We considered two alternative predictions. The first followed from the hypothesis that perceptual processing at the local level is the default setting for people on the autism spectrum (Plaisted, 2001). This is opposite of the global default that characterizes learners with TD and, if it interferes with the learning of object noun extensions, it should result in the formation of overly narrow categories. However, there was no evidence of overly narrow category extensions in this task.

The second prediction followed from the fact that social-communicative impairment is a universal feature of ASD and the hypothesis that people with ASD have difficulty considering the knowledge states of others (Baron-Cohen, 1989). In this particular study, the critical social-communicative context was one in which the expertise of the teacher sampling the relevant exemplars of the category (and the fact that she sampled only narrowly) were the relevant cues that should lead the learner to extend narrowly. As a group, the children with ASD instead extended broadly.

Below we summarize the evidence of broad category formation and consider the integrity of various processes that the children with ASD brought to bear on the task of word extension. Finally, we offer potential explanations for the association between poorer language ability and broad word extensions.

Broad Category Formation

Three strands of evidence led us to conclude that children with ASD formed broader categories than their unaffected age-mates. First, the learner-driven condition was designed with the expectation that all children would sample only subordinates because only then would they be sure of winning a prize. This expectation held without exception in Xu and Tenenbaum (2007) and in the current study with only two exceptions (out of 17) in the TD group assigned to the learner-driven condition. In contrast, five of 12 children with ASD assigned to the learner-driven condition sampled basic level exemplars. Second, the teacher-driven condition was designed to elicit narrow extensions. Because the teacher herself sampled only subordinates, children making note of her behavior would be apt to form narrow categories that extend only to the subordinate level. This was the inference made by the majority of children in the TD group assigned to the teacher-driven condition; they were roughly 7 times more likely to agree to subordinates than basic-level extensions. In contrast, the children with ASD in the teacher-driven condition were only 1.5 times more likely to agree to subordinates than basic-level extensions. In fact, in the teacher-driven condition, six of the 13 participants with ASD, but none of the participants with TD, consistently extended to the basic level.

Broad category formation was not simply a matter of affected children performing like younger unaffected peers. The children included in Xu and Tenenbaum (2007) averaged 4 years of age, with no child older than 4;10, and these very young children also formed narrower categories in the teacher-driven than learner-driven conditions. Failure to understand the general demands of the task cannot explain the unusual performance of the children with ASD either, as this failure characterized the teacher-driven condition only. Rather than attributing the problem to immaturity or a misunderstanding of the task, we consider instead potential deficits in the processes that support word extension in this experimental context. To be successful here, the learner had to (a) come to the task with relevant prior knowledge about words; (b) perceive the physical context; (c) evaluate the social context; and (d) combine prior knowledge and contextual information to infer the extension of the new word. Below we consider each in turn.

Prior knowledge—Could it be that the children with ASD brought to the social context different prior knowledge than the unaffected children? Importantly, to perform the extension task, children must know that words label categories rather than individual referents and that words that label objects reside in a nested hierarchy. Behavior during the extension phase (in either condition) suggested that the children with ASD had such knowledge. No child refused to extend the novel words; they all treated the words as labels for a category of a given size, not as a label for an individual exemplar. Also, both the ASD and TD groups, whether in the learner- or teacher-driven condition, agreed more often to extend the novel labels to subordinates than to basic-level neighbors. This is logical given that subordinates are a subset of the basic level. Subordinate extensions will always be correct, whereas basic-level extensions will only sometimes be correct. Moreover, those who extended to the basic level also accepted subordinate neighbors. Therefore, their extensions reflected the knowledge that subordinates are nested within basic-level categories. We conclude that the children with ASD had adequate tacit knowledge of two facts: that words label categories and that noun categories are hierarchical. This knowledge should have allowed reasonable inferences about noun extensions in context.

Perception of physical context—Was the perceptual difference that characterizes ASD at play? Certainly not in the way predicted. According to Plaisted (2001), hyper-acute perception of detail should lead to narrow category formation, but we found no evidence of this. This does not mean that the hypothesis of perceptual differences is incorrect—only that these differences did not interfere in this particular task. In fact, whereas earlier accounts of perception in people with ASD posited a local bias together with a global processing deficit (Frith, 1989), more recent accounts have emphasized the presence of a local bias but no global deficit (Mottron, Burack, Iarocci, Belleville, & Ennis, 2003) because people with ASD can process globally when cued to do so (López, Donnelly, Hadwin, & Leekam, 2004). Perhaps adequate prior knowledge of words, such as the understanding that words label categories rather than single exemplars, or perhaps some aspect of the physical context, such as simultaneous presentation of multiple exemplars, promoted global processing in this task. Recalling that, in the current experiment, exemplars within the broader (basic-level) category were the same in shape but different in color, it is interesting to note that younger children with ASD demonstrate a preference for matching by shape rather than color (despite failing to use shape as a word-learning constraint; Tek et al., 2008). Perhaps this preference was at play here as well. We can only speculate, but it is clear that local perception and narrow category formation did not characterize the behavior of the children with ASD.

Evaluation of social context—In the sampling phase of the learner-driven condition, the child had to judge by the teacher's words and enthusiasm that a prize was a worthy goal. In the extension phase of the teacher-driven condition, the child had to recognize that teachers are authority figures and generally knowledgeable (or, to be more exact, that an investigator in a place called the "Word Learning Lab" probably knows the meanings of the words on the tests that she administers). They also had to view it as unlikely that this knowledgeable adult sampling at random from a category would happen to select three subordinates in a row if indeed the correct extension was to the basic or superordinate level. That is, to extend appropriately in the teacher-driven condition, the children had to consider the knowledge of the teacher and the conservative nature of her sample. There is ample evidence that people with ASD have difficulty judging the knowledge of others (Baron-Cohen, 1989; Baron-Cohen, 2001; Perner et al., 1989), and this may be one example. One limitation of the current study is that it included no independent measure of theory of mind. Had we included one, correlations between theory-of-mind performance, especially in the realm of knowledge attribution, and breadth of category extension in the teacher-driven condition would have been telling.

Inference making—The ultimate step in the initial establishment of a category boundary is the inference itself: The child must combine his prior knowledge of how words work with his reading of the immediate physical and social-communicative context and infer that the new word extends to a narrower or broader range of exemplars. Deficits in inference making may interfere with successful extension. In Jolliffe and Baron-Cohen (1999), adults with ASD and unaffected peers were asked to make a series of bridging inferences. For example, they were told, "George left his bath water running. George cleared up the mess in the bathroom." and were meant to infer that the bath overflowed (Jolliffe & Baron-Cohen, 1999, p. 156). Those with ASD were less accurate at inferring the bridge between the two sentences. In a similar task, Norbury and Bishop (2002) found that 70% of a group of high-functioning children with ASD and language impairment were deficient in inference making (defined as significantly poorer scores on inferential than literal language comprehension). Therefore, among children with ASD, a general deficit in inferencing could prevent successful word extension, and this could be one example. Again, independent measures of inference making would be useful in future studies.

Associations Among Language Ability, Theory of Mind, and Inference Making

Individuals with ASD who inferred broad category boundaries as evident in their sampling behavior in the learner-driven condition or their extension behavior in the teacher-driven condition tended to have weaker semantic and syntactic language abilities than those who inferred narrow category boundaries. Could we use this pattern of individual differences to determine whether the breakdown in the social-communicative context was a failure in evaluating the knowledge of the communicative partner or in using it as a basis for inference? Unfortunately not, as there is evidence that links language ability to both theory of mind and inference.

Language ability, as measured by omnibus receptive and expressive oral language tests, bears a moderate-to-large relation to theory-of-mind performance, accounting for an additional 10% of the variance over chronological age (Milligan et al., 2007). In particular, the ability to comprehend sentential complements (e.g., Jon thinks Magnus is hiding) may be critical to understanding the mental states of others (de Villiers & Pyers, 2002; Hale & Tager-Flusberg, 2003; Lohmann & Tomasello, 2003). Furthermore, children with specific language impairment, who have semantic and syntactic language limitations, are delayed in theory-of-mind development (Ziatas, Durkin, & Pratt, 1998). If language development facilitates theory of mind development which, in turn, facilitates word extension in social contexts, it is unsurprising that those children with ASD who had the weakest language abilities were the ones who formed the broad word extensions.

Language ability is related to inference-making success as well, even when the contextual information used as a basis for inference is nonverbal (Ford & Milosky, 2003). Children with specific language impairment perform more poorly than their age-mates when asked to infer emotions from either verbally or visually presented stories. Importantly, they are not poorer at labeling the emotions conveyed by decontextualized faces; the problem is in integrating information from the faces with the story context (Ford & Milosky, 2003). Astington, Pelletier, and Homer (2002) relate both theory of mind and inference making to the ability to attribute second-order beliefs and find that attribution is positively correlated with language ability in 5- to 7-year-olds who are typically developing. Again, if language ability facilitates inference making, and inferences are required to determine word extensions in a social context, then it is unsurprising that those children with ASD who had the weakest language abilities were the ones who formed broad word extensions.

Of course, causal interpretations cannot be tested given the correlational nature of our data. Moreover, the direction of any potential causal relationships among language ability, theory of mind, inference making, and word extension is unclear. Possibly the children with weaker language were developmentally less able to read the relevant cues or draw inferences from them. Possibly they were less able to do so in the moment because the relevant contextual cues were conveyed, in part, verbally. For example, the context that promoted narrow sampling in the learner-driven condition involved complex syntax ("If you get it right, you'll get an extra prize at the end of the session."). On the other hand, it is possible that those children who are weaker at reading and inferring from context are those who form overly broad word categories in the moment and who ultimately build a weaker language system. In the future, including children with language impairment in the absence of ASD would make for an interesting test of these hypotheses.

Conclusions

Children with ASD and TD demonstrate a number of strengths when it comes to word extension. Their behavior reveals a tacit understanding that common nouns label categories of objects and that these categories have a nested, hierarchical structure. They overcome any bias they have toward local processing and perceive common physical features that allow categorization of nonidentical objects. Some of them also read the social context, in particular the knowledge state of their social partner, and use this information to infer the correct category boundary. Others do not, and, in this particular study, this led them to form overly broad categories. These heterogeneous outcomes represent hope for families who support the development of children with ASD and an interesting challenge for researchers who seek to understand the complicated relationships among development in the linguistic, social, and conceptual domains.

In accord with previous reports of positive correlations between language ability and performance on both theory-of-mind and inferencing tasks, those children with ASD who had difficulty using social context to infer category extensions were those who had the weaker semantic and syntactic language ability. Because children with ASD and concomitant language problems are likely to be represented on clinical case-loads, clinicians should be mindful that failure to read social-communicative cues may have consequences beyond the purely pragmatic. Such failures may adversely affect lexical semantic development; conversely, those with deficits in lexical semantics may be more prone to such failures. The direction (or multidirectionality) of the relationships among theory of mind, inference, and language ability is yet to be determined.

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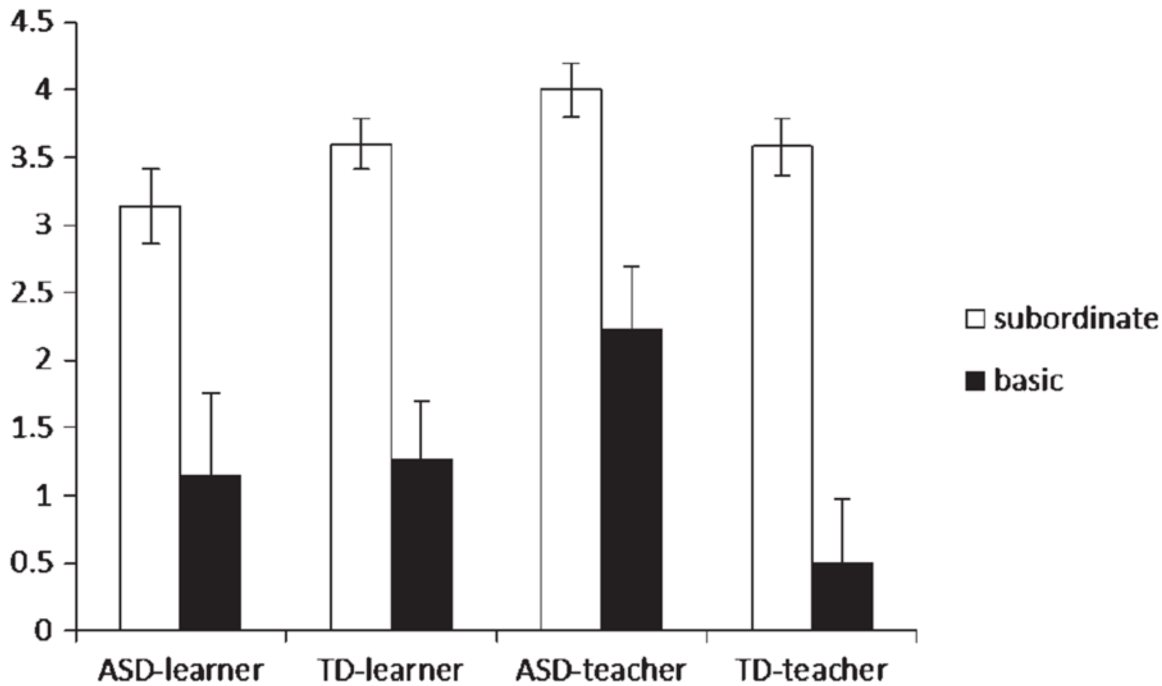

Figure 1.

Mean number of agreements to subordinate- and basic-level extensions by group and condition (subsample of the learner-driven condition included). Error bars indicate standard errors.

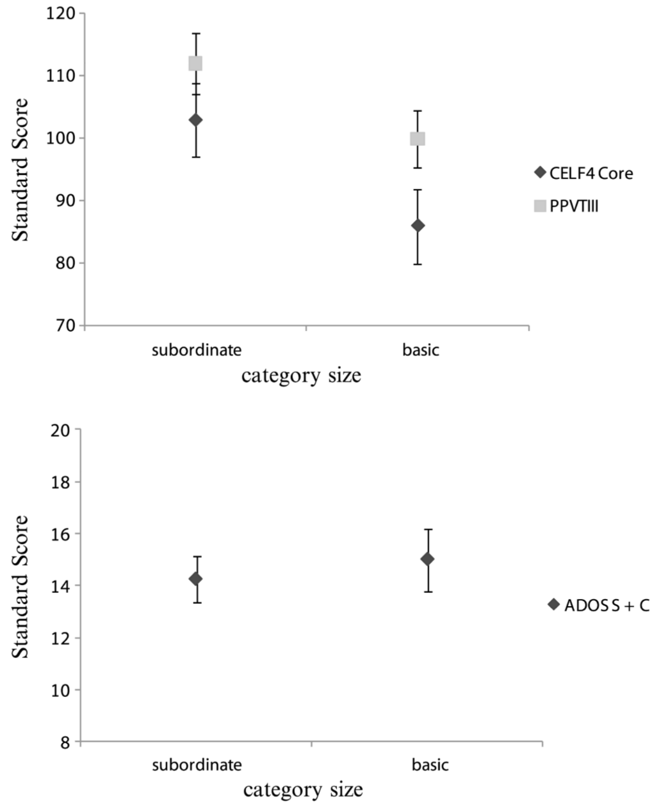

Figure 2.

Standard scores ($M \pm 1$ SE) on the CELF–4 core and the ADOS Social + Communication algorithm earned by children with ASD who formed subordinate-level (narrow) or basic-level (broad) categories. Sampling behavior in the learner-driven condition and extension behavior in the teacher-driven condition are collapsed here.

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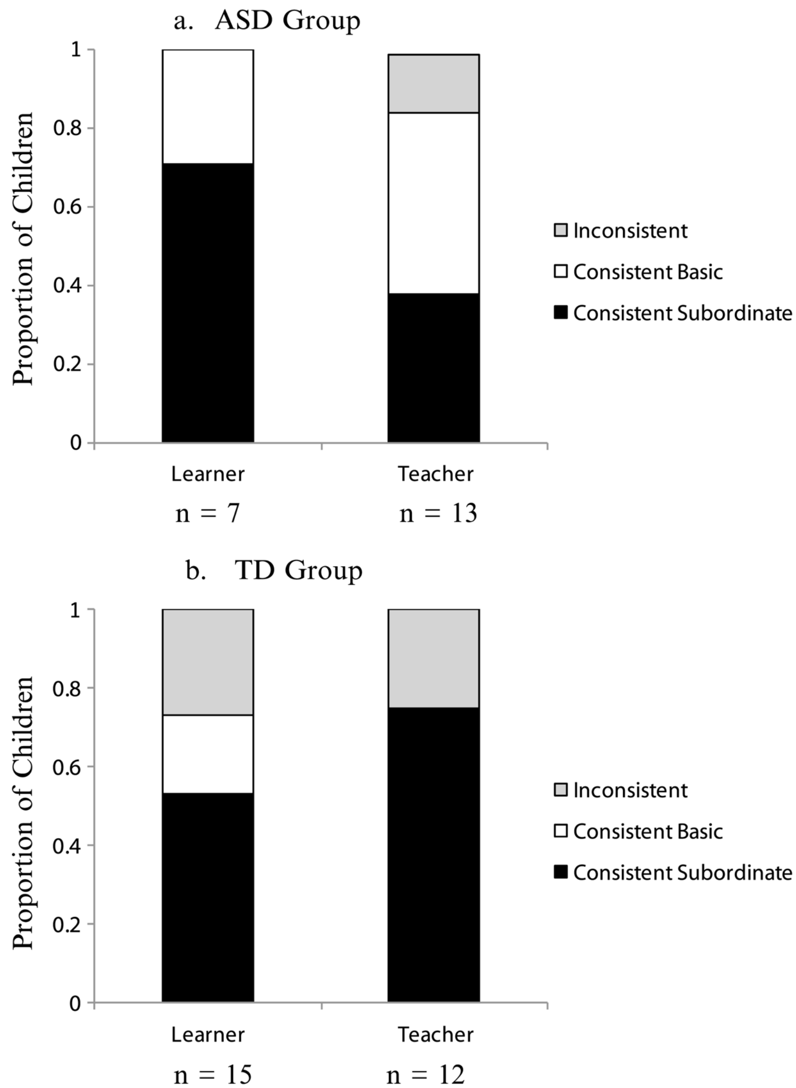


Figure 3.
Proportion of children in the ASD group (a) and the TD group (b) who consistently extended to the subordinate or basic level in the learner- and teacher-driven conditions.

Table 1

Age and test data for participants with autism spectrum disorders (ASD) and typical development (TD) expressed as group means (and standard deviations). The learner-driven condition includes a full sample, germane to the primary analysis, and a subset of the full sample, germane to the secondary analysis.

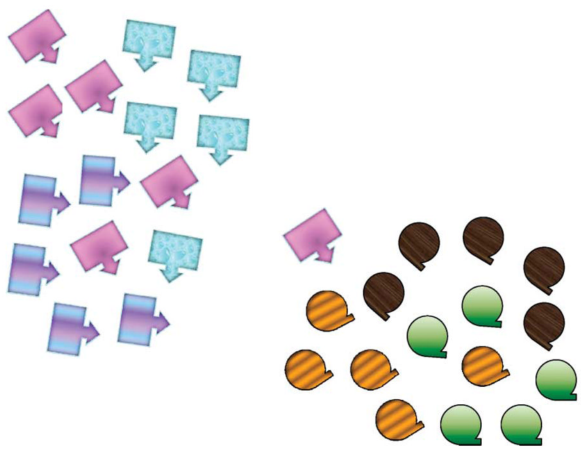
		ASD			TD		
		Learner-driven full	**Learner-driven subset**	**Teacher-driven**	**Learner-driven full**	**Learner-driven subset**	**Teacher-driven**
Construct	**Measure**	**(*n* = 12)**	**(*n* = 7)**	**(*n* = 13)**	**(*n* = 17)**	**(*n* = 15)**	**(*n* = 12)**
Maturation/experience	Age in months	130.83 (27.09)	130.57 (25.24)	132.61 (25.85)	124.12 (25.75)	127.53 (25.44)	125.58 (22.85)
Nonverbal cognition	KBIT2[a] matrices	104.75 (10.91)	107.00 (11.42)	110.46 (12.63)	112.64 (9.47)	112.07 (9.62)	110.67 (12.12)
Language	CELF4 core	91.67 (21.43)	98.86 (20.76)	95.92 (23.64)	116.47 (8.09)	116.13 (8.46)	114.67 (7.52)
Receptive vocabulary	PPVT–III	104.00 (15.29)	108.00 (18.73)	105.69 (19.50)	118.58 (7.37)	119.33 (7.31)	118.83 (8.76)

Note. KBIT2 = Kaufman Brief Intelligence Test—2; CELF4 = Clinical Evaluation of Language Fundamentals—4; PPVT–III = Peabody Picture Vocabulary Test—III.

[a]Expressed as standard scores (M = 100, SD = 15).

Appendix A

Set A: Visual stimuli.



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Appendix B

Sampling and extension procedure following Xu and Tenenbaum (2007).

	Teacher-driven condition	**Learner-driven condition**	**Example object pointed to**
Part I Sampling	Teacher points to a subordinate and says, “See this? It’s a blicket.”	Teacher points to a subordinate and says, “See this? It’s a blicket.”	
	Teacher points to another subordinate and says, “See this? It’s a blicket.”	Teacher says to learner, “Point to another blicket. If you get it right, you’ll get an extra prize at the end of the session.”	
	Teacher points to another subordinate and says, “See this? It’s a blicket.”	Teacher says to learner, “Now point to another blicket. Again, if you get it right, you’ll get an extra prize at the end of the session.”	
	Result: Three subordinates have been sampled by the teacher.	Result: Three subordinates have been sampled, one by the teacher and two by the learner.*	
Part I Extension	Teacher points to a subordinate neighbor and asks, “Is this a blicket?”	Teacher points to a subordinate neighbor and asks, “Is this a blicket?”	
	Teacher points to a superordinate neighbor and asks, “Is this a blicket?”	Teacher points to a superordinate neighbor and asks, “Is this a blicket?”	
	Teacher points to a basic-level neighbor and asks, “Is this a blicket?”	Teacher points to a basic-level neighbor and asks, “Is this a blicket?”	
	Teacher points to another subordinate neighbor and asks, “Is this a blicket?”	Teacher points to another subordinate neighbor and asks, “Is this a blicket?”	
	Teacher points to another basic-level neighbor and asks, “Is this a blicket?”	Teacher points to another basic-level neighbor and asks, “Is this a blicket?”	
	Result: Learner answers yes or no to each question.	Result: Learner answers yes or no to each question.	
Part II	Identical sampling and extension procedure is repeated with set A or B (whichever was not used in Part I) and a new novel word.	Identical sampling and extension procedure is repeated with set A or B (whichever was not used in Part I) and a new novel word.	

* If the learner did not select two subordinates during sampling, his or her data were excluded from the extension analysis.