Published in final edited form as:
Autism Res. 2008 October 1; 1(4): 208–222. doi:10.1002/aur.38.

Do Children with Autism Spectrum Disorders Show a Shape Bias in Word Learning?

Saime Tek, **Gul Jaffery**, **Deborah Fein**, and **Letitia R. Naigles**
University of Connecticut, Department of Psychology, 406 Babbidge Road, Unit 1020, Storrs, CT, 06269-1020, USA

Abstract

Many children with autism spectrum disorders (ASD) acquire a sizeable lexicon. However, these children also seem to understand and/or store the meanings of words differently from typically developing children. One of the mechanisms that helps typically developing children learn novel words is the shape bias, in which the referent of a noun is mapped onto the shape of an object, rather than onto its color, texture, or size. We hypothesized that children with Autistic Disorder would show reduced or absent shape bias. Using the Intermodal Preferential Looking Paradigm (IPL), we compared the performance of young children with ASD and typically developing children (TYP), across four time points, in their use of shape bias. Neither group showed a shape bias at Visit 1, when half of the children in both groups produced fewer than 50 count nouns. Only the TYP group showed a shape bias at Visits 2, 3, and 4. According to growth curve analyses, the rate of increase in the shape bias scores over time was significant for the TYP children. The fact that the TYP group showed a shape bias at 24 months of age, whereas children with ASD did not demonstrate a shape bias despite a sizeable vocabulary, supports a dissociation between vocabulary size and principles governing acquisition in ASD children from early in language development.

Keywords

Autism; shape bias; word learning

INTRODUCTION

There has been extensive research on the language abilities of children with autism spectrum disorders (ASD); however, the processes by which they acquire language are not yet well understood. We do not yet know how similar or different children with autism are from typically developing children in utilizing the constraints or biases characteristic of typical language acquisition. In this study we investigate the *shape bias*, which emerges when children map the referent of a noun onto the shape of an object rather than its texture, color, or size (Smith, 2000). The shape bias is a word learning mechanism that facilitates rapid word learning in young children. Moreover, the shape bias underlies a link between semantic and conceptual development, in that it indicates category membership by organizing different perceptually similar objects around the shape category (Gelman, 2003). Thus, the presence or absence of a shape bias in the early language of children with ASD may be an indicator of later facility or impairment in semantics and/or categorization.

Correspondence should be addressed to the first author: Saime Tek, University of Connecticut, Department of Psychology, 406 Babbidge Road, Unit 1020, Storrs, Connecticut, 06269-1020, U.S.A. Phone: 860-942-0435, fax: 860-486-2760, email: saime.tek@uconn.edu.

Lexical semantic language in children with autism

Impairments in communication are one of the defining characteristics of autism, ranging from a total lack of spoken language to difficulty in initiating or maintaining conversations with others (DSM IV-TR, APA, 2000). Impairments or difficulties in language are present in varying degrees in individuals with autism across the developmental life span; however, exactly which aspects of language are impaired is still a topic of debate. Deficits in pragmatic skills, such as understanding the gist of a story, responding to questions, understanding figurative language, and engaging in conversation, have been consistently reported to be impaired in children with autism (Tager-Flusberg, 2004). However, deficits in lexical and semantic development have been a source of controversy among researchers. Many studies have shown intact lexical/semantic skills, whereas others have demonstrated that lexical/semantic skills as well as conceptual skills can be delayed or impaired in individuals with autism.

In one of the earliest studies that investigated conceptual and semantic development in ASD, Tager-Flusberg (1985) demonstrated that children with ASD could correctly map a label—at both the basic and superordinate levels—onto line drawings of animals, food, and artifacts. Similarly, Ungerer & Sigman (1987) found no significant differences between mental age-matched typically developing children and children with ASD in their ability to sort objects into categories according to their function, physical form, or color. Finally, similar to typical children, those with ASD have early vocabularies dominated by nouns (Fein et al., 1996; Tager-Flusberg, Calkins, Nolin, Baumberger, Anderson & Chadwick-Dias, 1990), and many who are higher functioning understand and produce as many words as their typically developing counterparts (Eigsti, Bennetto & Dadlani, 2007). Moreover, when a novel word is taught, both children with ASD and their typically developing language age-mates prefer to map that word onto an object rather than the accompanying action (Swensen, Kelley, Fein, & Naigles, 2007). Thus, ASD children (at least, those exposed to English) seem to expect their first words to preferentially refer to objects or nouns, the so-called noun bias (Gentner, 1982).

Whereas the above studies show considerable mental-age appropriate lexical semantic knowledge in children with ASD, other studies find evidence of impairment. For example, Dunn, Gomes and Sebastian (1996) found that children with ASD produced fewer prototypical responses on a word fluency task than typical children matched for mental age. More recently, Kelley, Paul, Fein, and Naigles (2006) tested grade-school-aged children, who had been diagnosed with an ASD in toddlerhood but at the time of the study no longer carried the diagnosis, on a categorical induction task (Gelman & Markman, 1986). These children were significantly more reluctant to extend the properties associated with one instance of a category (e.g., that a rabbit eats grass) to other instances with the same label. Similarly, Gastgeb, Strauss, and Minshew (2006) compared the categorization efficiency of high functioning children and adolescents with autism with age- and IQ-matched typically developing individuals. Participants were asked to judge, as quickly and accurately as possible, whether a picture depicted a member of a named basic level category. Participants in both groups responded more slowly to the somewhat typical and the atypical exemplars of a category than the typical exemplars across all ages; however, the ASD group performed at a significantly slower rate than the controls when judging the atypical members of a category.

These disparate sets of studies highlight an often-discussed dichotomy in the abilities of many children with ASD, between their lexical/semantic representation or identification, which appears to be unimpaired, and the use or active organization of their lexical semantic knowledge (Dunn et al., 1996; Schulman, Yirmiya & Greenbaum, 1995; Minshew, Meyer & Goldstein, 2002). What is still unknown is the process by which older children and adults with ASD arrive at this dichotomy. That is, early language development data, albeit sparse, suggests that at least some processes of word learning function typically, in that lexical development proceeds apace and the children demonstrate a noun bias (Tager-Flusberg et al., 1990; Swensen et al., 2007). However, the semantic use or active organization tasks have only been given to older children (grade school and beyond) who have already achieved a high level of language. The question arises: are these difficulties with semantic use and higher level lexical organization a product of the atypical nature of language development in ASD, or could they be evident in ASD learners much earlier in development? Put another way, is there some process of early lexical development that seems to require active organization on the part of the child, which might foreshadow later difficulties or impairments? In the next section, we discuss one such candidate process.

Lexical Biases

Starting at a very young age, children can learn many thousands of words at a rapid rate (Markman, 1989). Moreover, they successfully map words onto objects and entities even though the possible meanings of a label can be vast and indeterminate based only on the visuo-spatial information given to the child in the environment (Quine, 1960). To solve the puzzle of object-word mapping when learning novel words, children seem to rely on some constraints or biases. One of the biases used to explain rapid word acquisition in children is the *Shape Bias*, according to which children selectively attend to perceptual cues such as shape to extend a newly-learned word to new objects (Smith, 2000). For example, when children are presented with a new object that is named with a novel noun (i.e., “This is a *dax*”) and asked which of the newly introduced test objects can be called by the same name (i.e., “Where is the *dax*?”), children tend to choose test objects which are similar to the exemplar in shape, and ignore objects that are of the same color or texture as the exemplar but different in shape (Landau, Smith & Jones, 1988). The shape bias seems to develop around two years of age, and after children have acquired at least 50 count nouns in their production vocabularies (Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002; Samuelson & Smith, 1999).

The shape bias involves generalizing a novel name to different instances of a particular object by shape. This kind of generalization requires categorization, or finding the right similarities among a set of different object properties and forming a prototype (i.e., average), exemplar or dimension by ignoring uninformative information (Son, Smith & Goldstone, 2006). Many recent studies have suggested that it is these kinds of abstraction abilities that can be impaired in individuals with autism (Gastgeb et al., 2006; Minshew et al., 2002), possibly in tandem with their enhanced attention to details (Happe & Frith, 2006). If the abstracting ability is either delayed or impaired in autism, then we expect that individuals with autism will show difficulties with the shape bias when exposed to new words, and ultimately will show slower vocabulary growth.

To date, there has been limited research studying lexical biases in children with autism, nor, indeed, has their lexical development been studied over an extended period of time. In this study, we investigate the shape bias (and for comparison purposes, the noun bias) across four time points, which comprise a year of development, using the Intermodal Preferential Looking paradigm (IPL) (Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987). IPL is a method that has been widely employed to tap the language comprehension abilities of very young typically developing children. In the IPL paradigm, children are seated in front of a screen on which the linguistic stimuli are presented. Children see two videos, one of which is constructed as the “match” whereas the other video serves as the foil stimulus. The stimulus audio is presented via a hidden speaker located behind the screen. The logic of this paradigm is that children will look longer at the video that matches the audio relative to the nonmatching video. Children's eye movements are recorded by a camera, and the dependent variable is the child's visual fixation to the matching visual stimulus.

By using IPL, we have been able to assess children with autism and typical children who were in their initial stages of language learning, because the method makes minimal demands on their compliance (Edelson, Fine & Tager-Flusberg, 2008; Kjelgaard & Tager-Flusberg, 2001; Naigles, Jaffery, Tek & Fein, 2008; Swensen et al., 2007). Because IPL is an implicit measure of language comprehension (i.e., children's changes in eye gaze, while guided by their concurrent language comprehension, are not necessarily deliberate), we decided to include a second shape bias task that used an explicit measure. Therefore, we also asked the children to point to the 3-dimensional objects that they thought matched the linguistic stimuli. A pointing task may be considered easier for children with ASD because it is similar to some of the procedures they follow in therapy (Jensen & Sinclair, 2002); however, this task may also be considered more challenging for these children, because it asks them to deliberately choose one item over another when each has potentially matching features. In this vein, the IPL task may be considered easier for children with ASD, because they are 'permitted' to look at both videos; it is their *relative* preference for one video over the other, an implicit measure which indicates their level of language comprehension.

Method

Participants

Fifteen typically developing children and 14 children with ASD participated in this study. The ASD group was recruited through treatment facilities and schools in Connecticut, Massachusetts, Rhode Island, New York, and New Jersey; they ranged in age from 26 to 37 months (M = 33.2, SD = 3.5) at the beginning of the study. All children in the ASD group were boys, and they had been diagnosed by professionals prior to the beginning of the study. Their diagnosis was confirmed with the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, Goode, Heemsbergen, Jordan, Mawhood & Schopler, 1989) and Childhood Autism Rating Scale (CARS; Schopler, Reichler, & Renner, 1988) before the start of the study; eight qualified for a diagnosis of Autistic Disorder (see Table 2). Furthermore, because the type of treatment for children with ASD can vary tremendously, and this can lead to variations in linguistic performance across time, we partially homogenized our ASD group by including only children committed to receiving at least 15 hours per week of Applied Behavior Analysis (ABA). ABA is a systematic process of modifying behavior with specific teaching, which has been shown to be an effective intervention for children with ASD (Lovaas, 1987; Cohen, Amerine-Dickens & Smith, 2006). The number of ABA hours is presented in Table 1, and standardized test scores are summarized in Table 2.

The TYP group included two girls and 13 boys, ranging in age from 18 to 23 months (M = 20.5, SD = 1.7) at the beginning of the study; they were recruited from a database of children at the University of Connecticut Child Language Lab.[1] Children in the TYP group were administered the ADOS and the CARS, and none had elevated scores (see Table 1). The groups were matched on language at Visit 1, which was measured by the Expressive (t (27) = .33, $p > .70$) and Receptive (t (27) = .97, $p > .30$) Language Scales of Mullen Scales of Early Learning, and the "Total Understands and Says" part of MacArthur Communicative Development Inventory (t (27) = 1.02, $p > .30$) (see Tables 2 and 3). In more detail, at Visit 1, six ASD children and five TYP children produced 0-50 words on the CDI, four ASD children and four TYP children produced 51-100 words, one ASD child and one TYP child

[1]The ASD group originally consisted of two girls and 14 boys. However, at Visit 2, both girls in the ASD group dropped out of the study. The girls in the TYP group, initially, were included in the study to match them with the girls in the ASD group.

produced 101-200 words, and three ASD children and five TYP children produced more than 200 words.

Materials

IPL Videos

Noun Bias Video: The same noun bias video was used as in Swensen et al. (2007). This video consisted of 6 blocks of five trials each. Within each block, the first three trials were teaching trials in which children saw a novel puppet performing a novel action, paired with a novel word "Look, (novel word)!" whose pronunciation could be construed either as a verb or a noun (e.g, *toopen*, similar to *kitten* or *jumpin'*). In the fourth trial, the puppet and the action were separated, such that one video showed the first puppet performing a new action and the other showed a new puppet performing the first action; the audio was "They're different now!" Because the fourth trial lacked a directing audio, it served as the baseline trial (i.e. control trial). The fifth trial was the test trial, in which the same videos as in the fourth trial were presented, now with the test audio "Where's (novel word)?"[2] This trial tested whether children had mapped the novel word onto the novel object or the novel action (A partial layout is shown in Table 4).

A total of six novel words were used (*toopen, piffen, gippen, blicken, zellen, kradden*). Each video was presented for approximately 6 seconds with 3 seconds of inter-stimulus interval when a centering red light was presented, for a total of 36 seconds per block and 3.5 minutes for the entire video.

Shape Bias Video: Five novel target objects and 10 novel test objects were presented; these had been constructed from simple toys such as wooden blocks and Lego pieces (approximately 3-5 inches wide and 3-8 inches long). One of the test objects matched the target exactly in shape (same-shape object), but not in color, whereas the other matched the target only in color and decorations (same-color object) but not in shape. Figure 1 shows one of the targets with its same-shape and same-color test objects.

The stimuli were presented in two consecutive blocks of trials. The first block presented the NoName condition, in which the objects were introduced without labels, and the second block presented the Name condition, in which each target object was presented with a novel name. Each block was composed of five sets of 4 trials each. In the NoName block, each target object was presented alone, once on the left side of the screen (Trial 1) and once on the right side of the screen (Trial 2) for familiarization, and accompanied by the audio "Look at this!" (see Table 5). In the third trial, the same-shape and the same-color objects were presented side by side, paired with the audio "They are different now!" The NoName test trial (Trial 4) included the same objects as trial 4, with the test audio "Which one looks the same?" This trial served as the baseline or control trial, indicating the relative salience of the test pairs. The layout of the Name trials was identical to the NoName trials except for the auditory stimuli. In the first and second trials, the audio that matched with visual stimuli was "Here is the (novel word)!" In the third trial the audio was "They are different now!" In the Name test trial, the audio asked "Where is the (novel word)?" This trial tested whether the children mapped the label onto the same-shape or same-color object. The order of objects was varied between the NoName and Name conditions.

---

[2]This test audio might seem to bias children to a noun interpretation, because the carrying phrase "Where's X?" is more commonly used in English with nouns ("Where's Daddy?") than with verbs ("Where's jumping?"). However, the "where's X?" carrying phrase is used in ABA therapy to refer to all types of words ("where's doggy/running/pretty"). Moreover, both TYP and ASD children have demonstrated in other IPL studies that they can respond to the "where's verb-ing?" test audio with significant looking to an action referent (Naigles, 1990; Naigles et al., 2008).

A total of five novel words were used (*zup, tiz, dax, pilk, pim*). Each video was presented for approximately 4 seconds with 3 seconds of inter-stimulus interval when a centering red light was presented, for a total of 21 seconds per block and 4.5 minutes for the entire video. The videos were constructed to have the identical structure, presented in perfect synchrony on both screens, and the auditory stimuli were presented in Child Directed Speech (i.e., speech that is slower, with more exaggerated pitch (Fernald & Simon, 1984)). The side of the matching screen was counterbalanced within subjects, and alternated in a Right/Left - Left/Right pattern.

Pointing Task: The same objects that appeared in the IPL video were employed in this task (see Figure 1).

Standardized Test Measures

The Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1989) is a structured play and interview session for the diagnosis of autism spectrum disorders.

The Childhood Autism Rating Scale (CARS; Schopler et al., 1988) is another measure used for the diagnosis of autism spectrum disorders, consisting of 15 subscales. The child is rated on each subscale based on the clinician's observation of how the child responds to structured activities.

MacArthur Communicative Development Inventory (CDI; Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick & Reilly, 1991). The CDI is a standardized parent reporting instrument used to assess the early language development of children. The CDI consists of three separate versions. The infant version is designed for typically developing children 8 to 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. The toddler version is designed for typically developing children 16 to 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. Finally, Level III is used for assessing language skills in typically developing children between 30 and 37 months. The CDI Level III is a questionnaire that includes a 100-item vocabulary checklist, 12 sentence pairs for assessing grammatical complexity, and 12 yes/no questions concerning semantics, pragmatics, and comprehension. Only the vocabulary checklist parts in all three tests were tabulated and analyzed here.

The Vineland Adaptive Behavior Scales, Second Edition (Sparrow, Cicchetti, & Balla, 2005) is a parent report interview that evaluates adaptive functioning across the domains of communication, daily living skills, socialization, and motor skills. The Vineland Adaptive Behavior Scales has been widely used by professionals as a measure of personal and social skills needed for everyday living to identify individuals who have developmental delays, autism spectrum disorders, or other impairments.

Mullen Scales of Early Learning (Mullen, 1995). The Mullen Scales provide a measure of intellectual development, including subsections that measure cognitive, expressive and receptive language, and motor development for children ages birth to 5 years, 8 months. The Mullen gives both standard scores and age equivalent scores for each domain of the test.

Procedure

Children were visited individually in their homes. Two sessions were conducted at Visit 1. In the first session, the ADOS, Mullen, Vineland, and CARS were administered. One week later, in the second session, the IPL videos were shown. Both the noun bias and the shape bias videos were shown at this time. The CDI Infant Form had been mailed to parents ahead of time, and was collected at the end of the first session. Only the “Total Understands and Says” part in the CDI Infant Form is tabulated and analyzed in the current study (see Table 3). Visits 2, 3, and 4 occurred four, eight, and 12 months later, respectively. At these visits, the shape bias video was presented, followed by the administration of Vineland. The CDI Toddler Form at Visits 2 and 3 was collected from the parents at the end of each session. For Visit 4, the Toddler Form was used for children with ASD who had produced fewer than 250 words at Visit 3 ($n = 5$), and the Level III was used for children with ASD whose vocabularies had included more than 250 words at Visit 3 ($n = 9$). The Level III form was used for all of the TYP children at Visit 4. For the CDI Toddler Form and the Level III form, only the “Total Words Produced” part is tabulated and analyzed in this study (see Table 3).

IPL videos—The videos were projected from a laptop onto a wide screen via an LCD projector. Children were seated either on the floor or on their parents’ lap approximately three feet in front of the screen. Some of the mothers who held their children on their laps wore headphones and listened to classical music while the videos were playing. Some mothers did not wear headphones, because their children became distracted by the headphones, or moved around so much they pulled the headphones off. The audio stimuli were presented via a centrally-placed speaker that was located behind the screen, outside the view of the children. A digital camera located in front of the screen recorded the children’s eye movements, which were coded later in the laboratory.

Pointing Task—The pointing task used the original three-dimensional objects filmed for the IPL videos. The experimenter sat down in front of the child, and introduced the target object in one of her hands. After the target object was introduced and set down in front of the child, the same-shape and the same-color objects were presented simultaneously, one in each of the experimenter’s hands. The task included two consecutive blocks of trials: NoName trials, which served as control trials, and Name trials, which served as test trials. In the NoName trials, children were directed towards the target object by saying “Look at this!” Then the children were presented with the same-shape and the same-color objects; after they had looked at each one, they were asked “Point to the same!” The same procedure was repeated for the Name trials, but the target was labeled with a novel word (i.e., “This is a (novel word)”). The children were asked to “Point to the one that is also (novel word).” The number of responses that matched by shape for the NoName and Name trials was recorded manually.

IPL Coding

Research assistants who were unaware of the stimulus audio coded the children’s eye movements frame-by-frame after each visit, recording fixations to the right or left screens, to the center, or away from the screens. Then, the children’s visual fixations were tabulated and analyzed by the computer according to percent of looking to each screen for each trial. On each trial, visual fixations were registered after the child looked at the centering light for more than 0.3 seconds. Trials where a child did not look at the centering light for at least 0.3 seconds were excluded; moreover, trials were excluded if the child did not look at either screen once the videos had been presented. Excluded trials comprised 13% of the total for the TYP group, and 8% of the total for the ASD group (11 % overall). This level of exclusion is comparable to other studies using IPL in home settings (Swensen et al., 2007). The excluded trials were replaced with the group mean for each trial.

To assess inter-rater reliability, ten percent of the videos from both groups were recoded by a second person; the correlation between coders was .975 ($p < .001$).

Results

IPL Videos

The Noun Bias—To determine whether the children with ASD would map a novel word onto an action vs. an object, we conducted a mixed-design ANOVA where the variable Trial (Control and Test, Trial 4 and 5, respectively) served as the within-subjects factor, and the variable Group served as the between-subjects factor. The analysis revealed only a significant effect of Trial (F (1, 30) = 4.77, $p < .05$, η^2 =.137). Children, overall, preferred to map the novel words onto novel objects as opposed to novel actions (see Figure 2).

The Shape Bias—The shape bias video tested whether the children generalized novel names by shape or by other visual properties of objects such as color. The dependent variable was the percent of time the child looked to the same-shape object during the NoName trial (Trial 4 in Table 5), as compared to the Name trial (Trial 8 in Table 5); children were considered to show a shape bias if they looked significantly longer at the same-shape match during the Name trials compared with the NoName trials. In the following analyses, we conducted mixed-design ANOVAs to investigate whether the ASD group differed from the TYP group in their shape bias performance. If a significant Trial effect or Trial and Group interaction emerged, we conducted planned *t* tests to determine whether the separate groups demonstrated a shape bias. Correlations were also performed between the children's shape bias performance (% shape match to the Name minus NoName trials) and their number of count nouns, CDI scores, Vineland and Mullen scores, and (for the ASD group only) ADOS scores and number of hours in ABA therapy.

<u>Visit 1:</u> A mixed-design ANOVA was run where Trial (NoName and Name) was entered as the within-subjects variable, and Group (ASD and TYP) was entered as the between-subjects variable. The analysis revealed no significant main effects or interactions. As can be seen in Figures 3a and 3b, neither the ASD group nor the TYP group showed an increased preference for the shape match during the Name trials as compared to the NoName trials. Note from Table 3 that substantial numbers of TYP (53%) and ASD (50%) children produced fewer than 50 count nouns at this visit, so perhaps the absence of a shape bias is not surprising (Smith et al., 2002).

Correlations were conducted to investigate whether the shape bias performance (% of looking to the shape match during the Name trials minus % of looking to the shape match during the NoName trials) of the children was related to the degree of autism (i.e., ADOS), language (i.e. CDI), adaptive functioning (i.e. Vineland), general cognitive ability (i.e. Mullen), and the number of ABA hours (for the ASD group) at Visit 1. The shape bias significantly correlated with the Expressive Language Subscale of Vineland for the TYP group (r = .56, p < .05). For the ASD group, there were significant correlations between the shape bias and ADOS (r = -.57, p < .05), Vineland Receptive Language Subscale (r = .58, p < .05), Vineland Expressive Language Subscale (r = .59, p < .05), Vineland Daily Living Subscale (r = .81, p < .01), Mullen Visual Reception Subscale (r = .61, p < .05), Mullen Receptive Language Subscale (r = .63, p < .05), and Mullen Expressive Language Subscale (r = .70, p < .01).

To determine if the groups preferred the shape match above a 50% chance level, two mixed-design ANOVAs were run (for the NoName and the Name trials separately), where Group was entered as the between-subjects variable and Performance (i.e., % looking to shape match versus 50%) was entered as the within-subjects variable. The analysis revealed that children in neither group preferred the shape match above chance levels in either trial (ps > .10).

Visit 2: Figures 3a and 3b show the mean percent of looking to the shape match for the NoName and Name trials for the TYP and ASD groups at Visit 2. A mixed-design ANOVA was conducted where Trial (NoName and Name) was entered as the within-subjects variables, and Group (ASD and TYP) was entered as the between-subjects variable. The analysis revealed only a significant main effect of trial (F (1, 27) = 7.07, $p < .05$, $\eta^2 = .207$). Planned *t*-tests were conducted to ascertain if the effect held for both groups; however, only the *t*-test for the TYP group was found to be significant (t (14) = 2.49, $p = .02$; for the ASD group, $p > .10$). Thus, the TYP children showed a shape bias, preferring the shape match more for the Name than the NoName trials. As shown in Table 3, all of the children in the TYP group produced more than 100 count nouns whereas only eight of the 14 ASD children produced more than 100 count nouns. A separate analysis including only these eight children in the ASD group revealed no significant effects ($p > .20$). In other words, the children in the ASD group whose count-noun vocabularies exceeded 100 words did not look longer at the shape match during the Name compared with the NoName trials.

At this visit, none of the correlations between the shape bias and the standardized tests as well as the ABA hours for the ASD group were significant for either group (ps > .10).

To determine if the groups preferred the shape match above a 50% chance level, two mixed-design ANOVA were run (for the NoName and the Name trials separately), where Group was entered as the between-subjects variable and Performance (% looking to shape match versus 50%) was entered as the within-subjects variable. Children in neither group preferred the shape match above chance levels in the NoName trial. However, there was a significant effect of performance in the Name trial: the children's shape preferences were significantly above 50% chance levels (F (1, 27) = 9.35, $p < .01$, $\eta^2 = .26$). Planned *t*-tests for each group separately revealed that the TYP group's shape preferences were significantly above 50% chance levels (t (14) = 2.6, $p < .05$), whereas the ASD group's shape preferences did not differ from chance ($p > .20$). These ANOVAs were repeated including only the children whose count noun vocabularies exceeded 100 count nouns in both ASD and the TYP groups, with very similar results.

Visit 3: Figures 3a and 3b show the percent looking to the shape match for the NoName and Name trials for the TYP and ASD groups at Visit 3. The mixed-design ANOVA revealed a significant main effect of trial (F (1, 27) = 5.43, $p < .05$, $\eta^2 = .167$) and a significant interaction between trial and group (F (1, 27) = 15.22, $p < .001$, $\eta^2 = .36$). *T*-tests revealed that, as at Visit 2, only the TYP group showed a significant preference for the shape match during the Name trial relative to the NoName trial (t (14) = 3.922, $p = .002$; ASD group *p*-value > .20). Again, at Visit 3, only eight children in the ASD group had more than 100 count nouns in their production vocabularies. When the *t*-test was conducted including only the children in the ASD group whose count-noun vocabularies exceeded 100 words, no significant trial effect (shape preference during the Name compared with NoName trial) was found ($p > .20$).

Significant positive correlations emerged for the ASD group between their degree of shape bias and the Vineland Receptive Language Subscale ($r = .56$, $p < .05$), the Vineland Expressive Language Subscale ($r = .704$, $p < .01$), the Vineland Daily Living Skills Subscale ($r = .787$, $p < .01$), the Vineland Social Subscale ($r = .586$, $p < .05$), and the Vineland Motor Subscale ($r = .70$, $p < .01$). All other correlations were nonsignificant (*p*s > .20). Thus, those children with higher adaptive functioning had a greater tendency to show a shape bias. No significant correlations were found between the degree of shape bias and standardized measures for the TYP group at Visit 3 (*p*s > .20).

Two mixed-design ANOVAs comparing the children's percent looking to the shape match to 50% chance level were run (for the NoName and the Name trials separately), with Group entered as the between-subjects variable and Performance (% looking to shape match vs. 50%) entered as the within-subjects variable. Children in neither group preferred the shape match above chance levels in the NoName trial. However, there was a significant effect of performance in the Name trial: children's shape preferences were significantly above 50% chance levels (F (1, 27) = 16.41, $p < .001$, $\eta^2 = .38$). There was also a significant interaction between performance and group (F (1, 27) = 10.70, $p < .01$, $\eta^2 = .28$), such that the TYP group's shape preferences were significantly above 50% chance levels (t (14) = 5.00, $p < .001$) whereas the ASD group's performance did not differ from chance ($p > .20$). These ANOVAs were repeated including only children whose count noun vocabularies exceeded 100 count nouns in both ASD and the TYP groups, with almost identical results.

Visit 4: Figures 3a and 3b show the percent looking to the shape match for the NoName and Name trials for the TYP and ASD groups at Visit 4. The mixed-design ANOVA revealed only a significant interaction between trial and group (F (1, 27) = 4.38, $p < .05$, $\eta^2 = .14$). The t-test for the TYP group revealed a significant effect of trial (t (14) = 2.84, $p < .05$); the t-test for the ASD group was nonsignificant ($p > .40$). We again reanalyzed the data only including those children with ASD whose count noun vocabularies were comparable to the TYP group (i.e., more than 100 count nouns). This t-test revealed no shape bias (no preference for the shape during the Name compared with the NoName trials) for the children in the ASD group ($p > .20$).

A significant correlation emerged for the ASD group between their degree of shape bias and total vocabulary on the CDI ($r = .67$, $p < .05$); other correlations between the shape bias and the remaining standardized measures and the number of ABA hours were not significant for the ASD group (ps > .10). No significant correlations were obtained for the TYP group (ps > .10).

Two mixed-design ANOVAs comparing the percent looking to the shape match to 50% chance level were run (for the NoName and the Name trials separately), with Group entered as the between-subjects variable and Performance (% looking to shape match vs. 50%) entered as the within-subjects variable. Children in neither group preferred the shape match above chance levels in the NoName trial. However, there was a significant effect of performance in the Name trial: the children's shape preferences were significantly above 50% chance levels (F (1, 27) = 7.45, $p < .05$, $\eta^2 = .21$). There was also a significant interaction between performance and group (F (1, 27) = 9.37, $p < .01$, $\eta^2 = .26$), such that the TYP group's shape preferences were significantly above 50% chance levels (t (14) = 4.8, $p < .001$), whereas the ASD group's performance did not differ from chance ($p > .20$). These ANOVAs were repeated including only the children whose count noun vocabularies exceeded 100 count nouns in both ASD and the TYP groups, with almost identical results.

In sum, the typically developing children did not show a shape bias at Visit 1 (at 20 months of age), but did demonstrate significant shape biases at Visits 2, 3, and 4. That is, they chose the shape match significantly more during the Name trials than during the NoName trials, indicating that they had mapped the referent of the *word*, specifically, onto the shape of the novel object. In contrast, the ASD children, as a group, did not demonstrate a significant shape bias at any visit, nor did they demonstrate any significant shape preferences outside of the word learning scenario. A few standardized measures correlated with the ASD children's tendency to demonstrate a shape bias, including their Mullen and Vineland scores at Visit 1, their Vineland scores at Visit 3 and their total CDI scores at Visit 4. However, at none of the visits did the high vocabulary children (producing more than 50 or 100 count nouns) consistently demonstrate a shape bias.

To further validate these findings, we conducted three follow-up analyses. First, because the ASD group consisted of only boys whereas the TYP group included two girl participants, we reran the analyses including only the male participants in the TYP group (n = 13). Exclusion of the girls from the analyses yielded the same results obtained at Visit 1 through Visit 4. Second, we investigated whether children who sat on non-headphone-wearing parents' laps might have had an advantage during the IPL videos (i.e., possible cuing from a parent who could both see the videos and hear the test audio). These children's performance was compared with those who sat alone and who sat on headphone-wearing parents' laps; none of the comparisons were found to be significant across all four visits (*p*s > .30). Third, we scrutinized the individual shape bias scores (i.e., Name -NoName) within the ASD group at all visits. Only four children averaged positive shape bias scores across visits; these were 13.36 (*SD* = 12.55), 9.90 (*SD* = 13.43), 7.97 (*SD* = 8.54), and 11.94 (*SD* = 7.62) for Visits 1, 2, 3, and 4. However, none of these children had positive shape bias scores across all visits, and all showed dips in performance (i.e., negative scores) in Visits subsequent to attaining a positive score. Moreover, on many measures including the ADOS, Mullen Scales of Early Learning, Vineland scales, and the number of ABA hours, their scores were not significantly different from the other children in the ASD group (*p*s > .30).

Pointing Task

Visit 1: The data from the pointing task are presented in Figures 4a and 4b. The dependent variable was the percent to shape match across items. A mixed design ANOVA was run, where the Trial was the within-subjects factor, and the Group was the between-subjects factor. No significant effects emerged for either group (*p*s > .20). Two mixed-design ANOVAs were performed comparing the percent pointing to shape to 50% chance levels for each trial separately. The children's shape preferences were above chance levels in both the NoName (F (1, 27) = 10.10, $p < .01$, $\eta^2 = .27$) and the Name trials (F (1, 27) = 7.09, $p < .05$, $\eta^2 = .21$). No significant group effect was found in either trial type. Thus, the children chose the shape match in both the NoName and the Name trials of this task.

Correlations were conducted to investigate whether the shape bias performance (% of pointing to the shape match during the Name trials minus % of pointing to the shape match during the NoName trials) of the children was related to the degree of autism (i.e., ADOS), language (i.e. CDI), adaptive functioning (i.e. Vineland), general cognitive ability (i.e. Mullen), and the number of ABA hours (for the ASD group) at Visit 1. There were significant correlations between the shape bias and the CDI ($r = .56$, $p < .05$), Vineland Expressive Language Subscale ($r = .60$, $p < .05$), and Mullen Expressive Language Subscale ($r = .69$, $p < .01$) for the TYP group. No significant correlations emerged for the ASD group (*ps* > .10).

Visit 2: The data from Visit 2 are presented in Figures 4a and 4b. The dependent variable was the percent to shape match across items. A mixed design ANOVA was run, where the Trial was the within-subjects factor, and the Group was the between-subjects factor. No significant effects emerged for either group (*p*s > .20). Two mixed-design ANOVAs were performed comparing the percent pointing to shape to 50% chance levels for each trial separately. The children's shape preferences were above chance levels in both the NoName (F (1, 27) = 12.00, $p < .01$, $\eta^2 = .31$) and the Name trials (F (1, 27) = 16.73, $p < .001$, $\eta^2 = .38$). No significant group effect was found in either trial type. Thus, the children chose the shape match in both the NoName and the Name trials of this task.

At this visit, none of the correlations between the shape bias and the standardized tests as well as the ABA hours for the ASD group were significant for either group (*p*s > .10).

Visit 3: The data from Visit 3 are presented in Figures 4a and 4b. The dependent variable was the percent to shape match across items. A mixed design ANOVA was run, where the Trial was the within-subjects factor, and the Group was the between-subjects factor. A significant effect of Trial was obtained (F (1, 27) = 5.43, $p < .05$, $\eta^2 = .167$) with no significant interactions. Planned *t* tests revealed that only the TYP group showed a shape bias (t (14) = 2.13, p < .05; ASD group's *p* value > .10). Two mixed-design ANOVAs were performed comparing the percent pointing to shape to 50% chance levels for each trial separately. The children's shape preferences were above chance levels in both the NoName (F (1, 27) = 18.74, $p < .001$, $\eta^2 = .41$) and the Name trials (F (1, 27) = 63.25, $p < .001$, $\eta^2 = .70$). No significant group effect was found in either trial type. Thus, the children chose the shape match in both the NoName and the Name trials of this task.

At this visit, none of the correlations between the shape bias and the standardized tests as well as the ABA hours for the ASD group were significant for either group (*p*s > .20).

Visit 4: The data from Visit 4 are presented in Figures 4a and 4b. The dependent variable was the percent to shape match across items. A mixed design ANOVA was run, where the Trial was the within-subjects factor, and the Group was the between-subjects factor. No significant effects emerged for either group (*p*s > .20). Two mixed-design ANOVAs were performed comparing the percent pointing to shape to 50% chance levels for each trial separately. The children's shape preferences were above chance levels in both the NoName (F (1, 27) = 80.41, p < .001, $\eta^2 = .75$) and the Name trials (F (1, 27) = 40. 07, p < .001, $\eta^2 = .60$). No significant group effect was found in either trial type. Thus, the children chose the shape match in both the NoName and the Name trials of this task.

At this visit, none of the correlations between the shape bias and the standardized tests as well as the ABA hours for the ASD group were significant for either group (*p*s > .10).

In sum, the pointing task yielded somewhat different findings from the IPL task. Whereas the TYP children showed a shape bias via the IPL task by 24 months, they only showed a shape bias via the pointing task at Visit 3 (28 months). At all visits, though, the TYP children consistently pointed to the shape match regardless of whether they were learning a new word or not. The ASD group did not show a consistent shape bias across all four visits in either the IPL or pointing tasks, but, similar to the TYP children, did consistently *point to* the shape match regardless of whether they were learning a new word or not. In the next analyses, we compare the groups' shape bias development over the course of their four visits.

Growth Curve Analyses—We conducted a series of growth curve analyses to see how shape bias performance with IPL and pointing changed from Visit 1 through Visit 4. By charting changes over time, we can determine the extent to which individuals vary from the mean pattern of change, as well as the association between predictors and the patterns of change (Singer & Willett, 2003). In the current analyses, we created an overall measure of shape bias in the IPL task by subtracting children's percent looking to shape for the Name trials from their percent looking to shape for the NoName trials at each time point. Shape bias performance across groups was found to be nonlinear over time (see Figure 5a); therefore, we converted the shape bias scores to natural logarithms. The variable Time (i.e. Visit) was centered at Time 1, which is the period when the first data was collected. The variable Group was included to see whether the TYP and the ASD groups would differ in their initial shape bias scores or in their rate of change across time points.

First we performed the Level I analyses, in which only the variable Time is included as a predictor. The *unconditional means model*, which tests the average change in the shape bias performance over time without inclusion of predictors at every level, fit the data well (χ^2 (1) = 3.43, p = .06). Thus, the average shape bias performance of an average child changed significantly from Visit 1 through Visit 4 (t (28) = 58.59, p < .001). The *unconditional growth model*, which tests both the average change and the average rate of change (i.e. the variable Time) in the shape bias performance over time also fit the data well (χ^2 (3) = 13.73, p < .01). According to this model, the average rate of change for the shape bias performance was not different from zero (i.e. constant). In the Level II analyses, we added the predictor Group so that our final model included the predictors Time and Group as well as the Time and Group interaction. Overall, the final model also fit the data well (χ^2 (3) = 15.55, p < . 01). As Figure 5a shows, the shape bias performance of an average child in the TYP group changed significantly over time (t (28) = 30.46, p < .001), and the children's shape bias scores increased steadily across visits (t (27) = 2.58, p < .01). The estimated differential in the rate of change in shape bias performance between the TYP and the ASD groups was also significant (t (58) = 3.11, p < .01). In other words, the TYP group showed a steady increase in their shape bias performance over time, whereas the shape bias performance of the children in the ASD group remained relatively stable.

We conducted the same growth curve analyses with the shape bias pointing data. The overall measure of shape bias in the pointing task was created by subtracting children's percent pointing to shape for the Name trials from their percent pointing to shape for the NoName trials at each time point. Shape bias performance across groups was found to be nonlinear over time (see Figure 5b); therefore, we converted the shape bias scores to natural logarithms. The variable Time (i.e. Visit) was centered at Time 1, which is the period when the first data was collected. The variable Group was included to see whether the TYP and the ASD groups would differ in their initial shape bias scores or in their rate of change across time points. The growth curve analyses did not reveal a significant change or rate of change in the shape bias performance with the pointing data over time. Furthermore, the ASD and the TYP groups did not differ in the rate of change in their shape bias pointing performance across four visits (see Figure 5b). In other words, children preferred the shape match in *both* trials (i.e., regardless of whether they were learning a new word or not) to approximately the same degree across groups and visits.

General Discussion

In this study, we compared typical children and children with ASD in their ability to use the shape bias as a word learning strategy. There was no evidence of a shape bias in either group at Visit 1. However, this may be attributable to the children's small count noun vocabularies (most had fewer than 50 nouns), as Smith and her colleagues predict that the shape bias develops after children have acquired at least 50-100 count nouns (Samuelson & Smith, 1999; Smith et al., 2002). Supporting this view, the TYP children showed a shape bias at Visits 2, 3 and 4 in the IPL task, and starting at Visit 2, the TYP children's mean production vocabulary included more than 100 count nouns. In contrast, the group with ASD did not demonstrate a shape bias even with a mean vocabulary of 132 count nouns at Visit 4, nor did we find evidence for a shape bias in just those ASD children whose count noun vocabulary exceeded 100.

This absence of a shape bias in the ASD children cannot be attributed to any overall difficulty with word learning, nor with obvious difficulty in participating in the IPL paradigm. The ASD children's increasing vocabulary size across visits (Table 3) is one good indicator of their ability to learn words; another is their ability to perform well on the Noun Bias video they saw at Visit 1 (Figure 2, replicating Swensen et al., 2007). Moreover, with another video they viewed at Visit 4, they demonstrated successful mapping of novel verbs onto the appropriate actions (Naigles et al., 2008; see also Schulman & Guberman, 2007, for a similar study). These latter studies, together with the current children's successful performance on the Noun Bias video, also demonstrate that the current children's difficulty with the Shape Bias video is not rooted in the IPL task itself. That is, with several IPL videos in our lab, children with autism have demonstrated that they are able to process the 6-second video clips and to use the audios to look preferentially at one video over the other. Other labs have also begun to find good language comprehension performance in ASD individuals using eye-tracking methods (Edelson, Fine & Tager-Flusberg, 2008;Brock, Norbury, Einav, & Nation, 2008). Thus, the specific word-learning strategy of the *shape bias* seems to be what is challenging to these children with autism.

The ASD children's absence of a shape bias in the IPL videos also cannot be attributed to an inability to notice the shape similarities across the match-to-sample format. This is because their performance on the pointing task consistently favored the shape match over the color match, even as early as Visit 1 (Figure 4a). These findings showed that the children with autism preferred to point to a shape match regardless of whether the target had been given a label; notice, though, that this is *not* the canonical shape bias because the shape bias is, by definition, a word-learning strategy (Landau et al., 1990; Smith, 1998). The ASD children may have chosen the shape matches overall in the pointing task because the same-shape objects were more visually salient, or they may have noticed the shape similarities early in the task and then perseverated on shape throughout. What they did not do is preferentially select the shape match more when the novel word was being tested; thus, they demonstrated that the presentation of the novel word was of little importance to their choice. This is where they differed most strikingly from the TYP children, who were also—in the pointing task—drawn to the shape match overall, but did show a significantly greater preference for the shape match during the Name trials at Visit 3. In sum, the ASD group's overall shape preference in pointing indicates that they noticed the shape similarities across objects; the absence of a further preference for shape for *labeled* objects suggests that they are not using a shape bias—either implicitly or explicitly—in novel word learning.

There are several possible reasons why children with autism might have difficulties with acquiring and/or using a shape bias in word learning. Vocabulary size could be raised as a possible reason, as Smith et al. (2002) proposed that the shape bias only emerges once children have acquired a vocabulary of 50-100 count nouns, and our TYP group only showed a shape bias via IPL once their count noun lexicons had exceeded 100 nouns (Table 3, Figure 3b). Moreover, when correlations did emerge between children's standardized test performance and their shape bias performance, higher language scores were associated with better shape bias performance. However, by Visit 4, our ASD group, on average, had over 100 count nouns yet did not demonstrate a shape bias. Moreover, those individual children whose count noun vocabularies exceeded 100 did not also demonstrate a shape bias. These findings seem inconsistent with Smith et al.'s proposal; however, consistency may be found by considering the rationale behind the lexical threshold. According to Smith et al. (2002), a lexicon of 100 count nouns is needed for children to perform an ‘off-line’ analysis that (a) extracts the shape similarities across remembered instances of objects that share a label, (b) notices that sets of objects with different labels also differ most prominently in shape, and so (c) abstracts the pattern that ‘object words go with shape distinctions’ that becomes the shape bias strategy. By hypothesis, these analyses (or some subset) are the ones that children with ASD have difficulty with (see also Minshew et al., 2002). Thus, our findings demonstrate that even though children with ASD can learn and produce words, they do not seem to organize them into abstract conceptual units even from the beginning of word learning. Hence, our data show that lexical development and lexical organization or categorization can be dissociated in children with ASD early in development.

The shape bias can be considered an indicator of category processing, because it provides a demonstration of how children can preferentially weigh some perceptual characteristics over others when words are present (Gelman, 2003; Markman, 1989; Waxman, 1999). Therefore, our study suggests that the difficulty children with autism have with the shape bias is an early example of their basic difficulties with categorization, and consistent with an increasing literature that has shown that individuals with ASD have difficulty in prototype and category formation (Dunn & Bates, 2005; Gastgeb et al., 2006; Johnson & Rakison, 2006; Kelley et al., 2006; Klinger & Dawson, 2001; Minshew et al., 2002). These difficulties with categorization could be the 'mirror image' of the enhanced perceptual functioning that has also been observed in individuals with autism (e.g., Happe & Frith, 2006). The current evidence of ASD children's early difficulties with the shape bias could be an indication that this enhanced perceptual functioning is operating very early as well. It is also interesting that, within the ASD group, relatively good performance with the shape bias (IPL, Visits 1, 3 and 4) was positively associated with both language measures (Mullen Expressive and Receptive Language, CDI) and non-language measures (Vineland Socialization and Daily Living). These latter correlations support the possibility that the ability to use the shape bias is part of a larger, more domain-general ability.

It is possible that the shape bias is only "delayed" in children with autism, such that it will eventually emerge in older children. We are continuing our data collection to investigate this possibility. On the other hand, a lack of shape bias throughout development may not be a deficit specific to autism. Jones (2003) has demonstrated that 2- to 3- year-old late talkers did not extend novel names across objects with the same shape as compared to age-matched children with larger vocabularies. However, her participants included children whose total vocabularies ranked below the 30th percentile for their age whereas in the present study, our groups had equivalent vocabulary sizes at Visit 1. Therefore, a lack of shape bias in children with ASD cannot be attributed simply to a limited vocabulary. Similarly, Jones and Smith (2005) demonstrated that late talkers (mean age = 28.6 months) had more difficulty recognizing objects that were presented in abstract shapes than identifying them if they were presented in realistic forms. Interestingly, children who failed to recognize objects in their abstract representations were nevertheless able to label realistic forms accurately. According to Jones and Smith (2005), when late talkers learn words, they do not necessarily learn their more abstract but category-relevant features.

The shape bias is a word learning mechanism that facilitates rapid vocabulary growth in young word learners. In our study, the children with autism did not demonstrate a shape bias; however, their amount of vocabulary was very similar to the control group, possibly because of intense Applied Behavior Analysis. One clinical implication that our study suggests is that children with autism may rely on different language mechanisms, and possibly different brain networks, to acquire new words. Brain mechanisms that process language in individuals with autism, in fact, can be underintegrated with an increased reliance on visual networks to process language comprehension (Kana et al., 2006).

Our study suggests that difficulties with lexical/categorical organization are present from the onset of language development in children with ASD. However, it should be noted that for most results the effect sizes were small to medium (.2 to .38). Therefore, the results can also reflect the variation within the ASD group. Even though we matched the children with autism with the typical children in vocabulary production at the beginning of the study, the children with ASD, as is common, showed greater variation at later visits. Thus, our findings may reflect underlying difficulties with the shape bias only in a subgroup of children with autism. Recall, for example, that children with higher Vineland scores at Visit 3, and higher CDI scores at Visit 4, did show more of a shape bias. For future research, it will also be necessary to assess a greater variety of conceptual and lexical abilities in these children with autism, to investigate how this early difficulty with the shape bias might predict later difficulties in more "abstract" areas of language.

Acknowledgments

We thank the National Institutes of Health (DCD R01 DC07428) for supporting this research, and the 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 extremely grateful to all the parents and children for their cheerful participation. Thanks go to Christie Roche, Anissa Potvin, Jenna Mittelhammer, Stacey Psichopaidas, Leah Borno, Victoria Casal, Ellen Lazarus, Elizabeth Northrup, Erin Dougherty, Marjan Zanjani, Claire Harrington, Danielle Sokol, Roberta Bing, Sarah Urso, Jonela Karaja, and Jessica Bellatoni for their help in the data collection and coding process.

This research was funded by the National Institute on Deafness and Other Communication Disorders: NIHDCD, R01 DC07428.

References

American Psychological Association. Diagnostic and Statistical Manual of Mental Disorders; Volume IV-TR. American Psychological Association; Washington, DC: 2000.

Brock, J.; Norbury, C.; Einav, S.; Nation, K. Do people with autism process words in context? Evidence from language-mediated eye-movements; Paper presented at the International Meetings for Autism Research; London, England. 2008;

Cohen H, Amerine-Dickens M, Smith T. Early intensive behavioral treatment: Replication of the UCLA model in a community setting. Journal of Developmental & Behavioral Pediatrics. 2006; 27(2):145–155. [PubMed: 16682882]

Dunn M, Bates J. Developmental change in neutral processing of words by children with autism. Journal of Autism and Developmental Disorders. 2005; 35:361–376. [PubMed: 16119477]

Dunn M, Gomes H, Sebastian M. Prototypicality of responses in autistic language disordered and normal children in a verbal fluency task. Child Neuropsychology. 1996; 2:99–108.

Edelson, L.; Fine, A.; Tager-Flusberg, H. Comprehension of nouns and verbs in toddlers with autism: An eye-tracking study; Paper presented at the International Meetings for Autism Research; London, England. 2008;

Eigsti IM, Bennetto L, Dadlani MB. Beyond pragmatics: morphosyntactic development in autism. Journal of Autism and Developmental Disorders. 2007; 37:1007–1023. [PubMed: 17089196]

Fein, D.; Dunn, M.; Allen, D.; Aram, D.; Hall, N.; Morris, R.; Wilson, B. Language and neuropsychological findings. In: Rapin, I., editor. Preschool Children with Inadequate Communication. MacKeith Press; London, UK: 1996. p. 123-154.

Fenson, L.; Dale, P.; Reznick, J.; Thal, D.; Bates, E.; Hartung, J.; Pethick, S.; Reilly, J. MacArthur Communicative Development Inventories. San Diego State University; San Diego: 1991.

Fernald A, Simon T. Expanded intonation contours in mothers' speech to newborns. Developmental Psychology. 1984; 20:104–113.

Gastgeb H, Strauss M, Minshew N. Do individuals with autism process categories differently? The effect of typicality and development. Child Development. 2006; 77:1717–1729. [PubMed: 17107456]

Gelman, S. The Essential Child. Origins of Essentialism in Everyday Thought. Oxford University Press; New York: 2003.

Gelman S, Markman E. Categories and induction in young children. Cognition. 1986; 23:183–209. [PubMed: 3791915]

Gentner D. What looks like jiggy but asks like a zimbo? A study of early word meaning using artificial objects. Paper and Reports on Child Language Development. 1982; 15:1–6.

Golinkoff RM, Hirsh-Pasek K, Cauley KM, Gordon L. The eyes have it: Lexical and syntactic comprehension in a new paradigm. Journal of Child Language. 1987; 14:23–45. [PubMed: 3558524]

Happe F, Frith U. The weak coherence account: detail-focused cognitive style in autism spectrum disorders. Journal of Autism and Developmental Disorders. 2006; 36(1):5–25. [PubMed: 16450045]

Jensen VK, Sinclair LV. Treatment of autism in young children: Behavioral intervention and applied behavior analysis. Infants and Young Children. 2002; 14(4):42–52.

Johnson C, Rakison D. Early categorization of animate/inanimate concepts in young children with autism. Journal of Developmental and Physical Disabilities. 2006; 18:73–89.

Jones SS. Late talkers show no shape bias in a novel name extension task. Developmental Science. 2003; 6(5):477–483.

Jones SS, Smith LB. Object name learning and object perception: a deficit in late talkers. Journal of Child Language. 2005; 32:223–240. [PubMed: 15779885]

Kana R, Keller T, Cherkassky V, Minshew N, Just M. Sentence comprehension in autism: thinking in pictures with decreased functional connectivity. Brain. 2006; 129:2484–2493. [PubMed: 16835247]

Kelley E, Paul J, Fein D, Naigles L. Residual language deficits in optimal outcome children with a history of autism. Journal of Autism and Developmental Disorders. 2006; 36(6):807–828. [PubMed: 16897404]

Kjelgaard M, Tager-Flusberg H. An investigation of language impairment in autism: Implications for genetic subgroups. Language and Cognitive Processes. 2001; 16:287–308. [PubMed: 16703115]

Klinger L, Dawson G. Prototype formation in autism. Development and Psychopathology. 2001; 13:111–124. [PubMed: 11346046]

Landau B, Smith LB, Jones SS. The importance of shape in early lexical learning. Cognitive Development. 1988; 3:299–321.

Lovaas IO. Behavioral treatment and normal educational and intellectual functioning in young autistic children. Journal of Consulting and Clinical Psychology. 1987; 55:3–9. [PubMed: 3571656]

Lord C, Rutter M, Goode S, Heemsbergen J, Jordan H, Mawhood L, Schopler E. Autism Diagnostic Observation Schedule: A standardized observation of communicative and social behavior. Journal of Autism and Developmental Disorders. 1989; 19:185–212. [PubMed: 2745388]

Markman, E. Categorization and Naming in Children. MIT Press; Cambridge, MA: 1989.

Minshew N, Meyer J, Goldstein G. Abstract reasoning in autism: A disassociation between concept formation and concept identification. Neuropsychology. 2002; 16:327–334. [PubMed: 12146680]

Mullen, EM. Mullen Scales of Early Learning. American Guidance Service; Circle Pines, MN: 1995.

Naigles L. Children use syntax to learn verb meanings. Journal of Child Language. 1990; 17:357–374. [PubMed: 2380274]

Naigles, L.; Jaffery, G.; Tek, S.; Fein, D. Grammatical strengths in the language of young children with autism; Poster presented at the International Meetings for Autism Research; London, England. 2008, May;

Quine, W. Word and Object. MIT Press; Cambridge, MA: 1960.

Samuelson L, Smith LB. Early noun vocabularies: Do ontology, category organization and syntax correspond? Cognition. 1999; 73(1):1–33. [PubMed: 10536222]

Schopler, E.; Reichler, R.; Renner, B. The Childhood Autism Rating Scale. Western Psychological Services; Los Angeles, CA: 1988.

Shulman C, Guberman A. Acquisition of verb meaning through syntactic cues: A comparison of children with autism, children with specific language impairment (SLI), and children with typical language development (TLD). Journal of Child Language. 2007; 34:411–424. [PubMed: 17542163]

Shulman C, Yirmiya N, Greenbaum C. From categorization to classification: A comparison among individuals with autism, mental retardation, and normal development. Journal of Abnormal Psychology. 1995; 104:601–609. [PubMed: 8530762]

Singer, JD.; Willett, JB. Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence. Oxford University Press; New York: 2003.

Smith LB, Jones SS, Landau B, Gershkoff-Stowe L, Samuelson L. Object name learning provides on-the-job training for attention. Psychological Science. 2002; 13(1):13–19. [PubMed: 11892773]

Smith, LB. Becoming a word learner: A debate on lexical development. Oxford University Press; New York: 2000. Learning how to learn words: An associative crane; p. 51-80.

Son, J.; Smith, LB.; Goldstone, R. Generalizing from simple instances: An uncomplicated lesson from kids learning objects categories; Proceedings of the Twenty-eighth Annual Conference of the Cognitive Science Society; Hillsdale, New Jersey: Lawrence Erlbaum Associates. 2006;

Sparrow, SS.; Cicchetti, DV.; Balla, DA. Vineland Adaptive Behavior Scales: Second Edition (Vineland II), Survey Interview Form/Caregiver Rating Form. Pearson Assessments; Livonia, MN: 2005.

Swensen L, Kelley E, Fein D, Naigles L. Processes of language acquisition in children with autism: evidence from preferential looking. Child Development. 2007; 78(2):542–557. [PubMed: 17381789]

Tager-Flusberg H. Basic level and superordinate level categorization by autistic, mentally retarded, and normal children. Journal of Experimental Child Psychology. 1985; 40:450–469. [PubMed: 4078544]

Tager-Flusberg H. Strategies for conducting research on language in autism. Journal of Autism and Developmental Disorders. 2004; 34:75–80. [PubMed: 15098960]

Tager-Flusberg H, Calkins S, Nolin T, Baumberger T, Anderson M, Chadwick-Dias A. A longitudinal study of language acquisition in autistic and Down syndrome children. Journal of Autism and Developmental Disorders. 1990; 20:1–21. [PubMed: 2139024]

Ungerer J, Sigman M. Categorization skills and receptive language development in autistic children. Journal of Autism and Developmental Disorders. 1987; 17:3–16. [PubMed: 3571142]

Waxman, S. The dubbing ceremony revisited: Objects naming and categorization in infancy and early childhood. In: Medin, D.; Atran, S., editors. Folkbiology. M.I.T. Press; Cambridge: 1999. p. 233-284.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

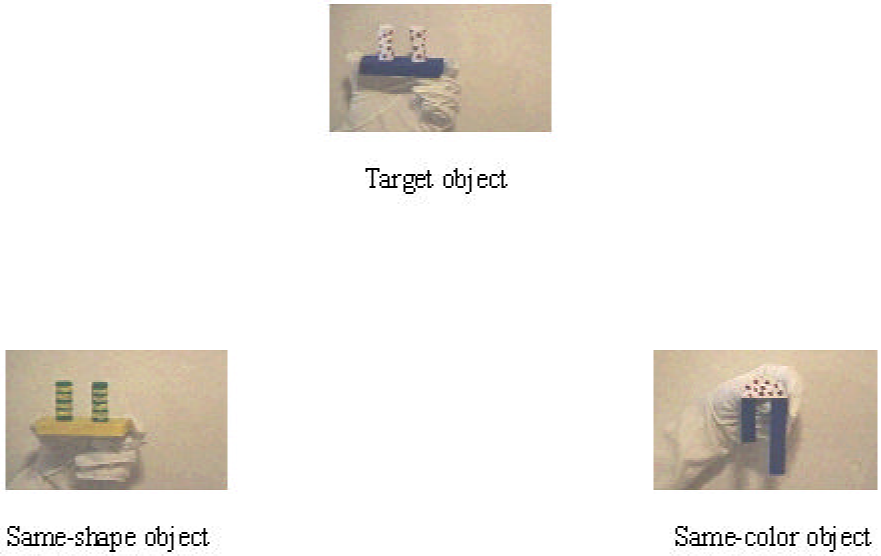


Figure 1.
Sample stimuli for the shape bias video and pointing task

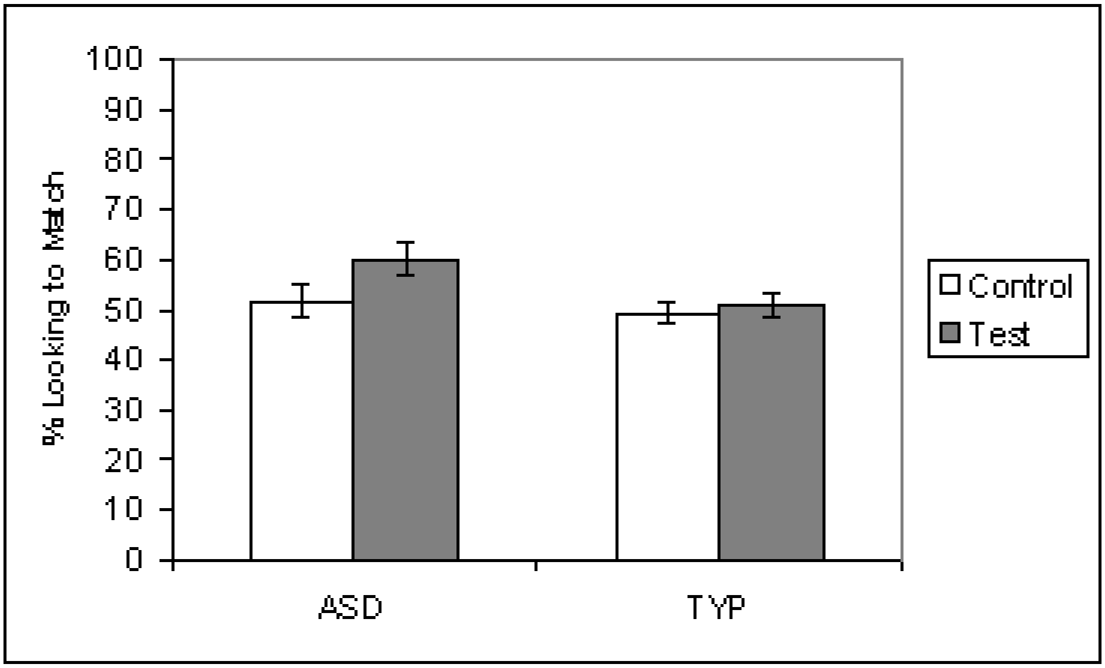
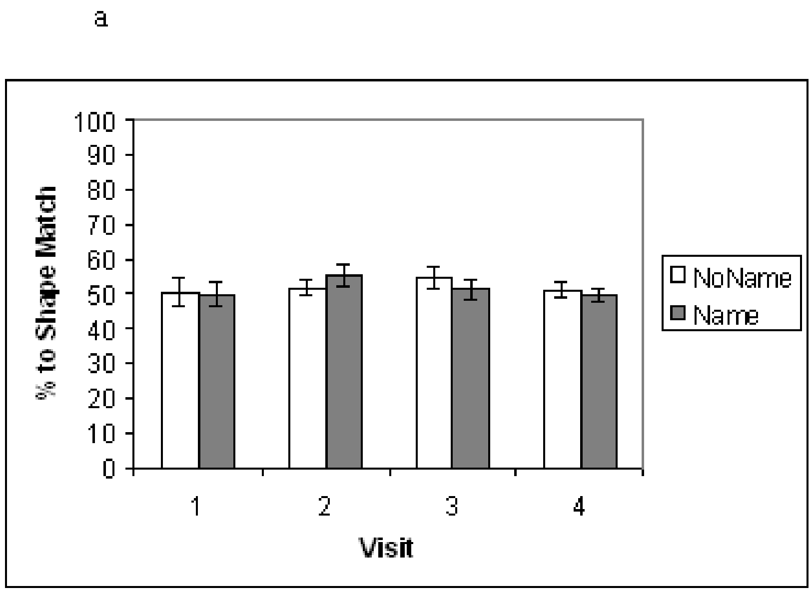


Figure 2.
Children's percent looking to the matching (object) screen for the Noun Bias video at Visit 1. Control refers to Trial 4, where no directing audio was presented. Test refers to Trial 5, where the test audio was presented.



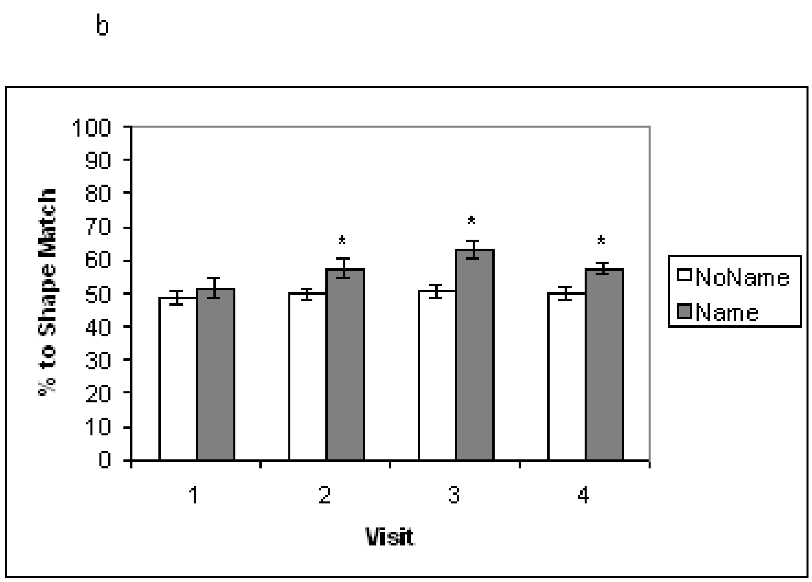
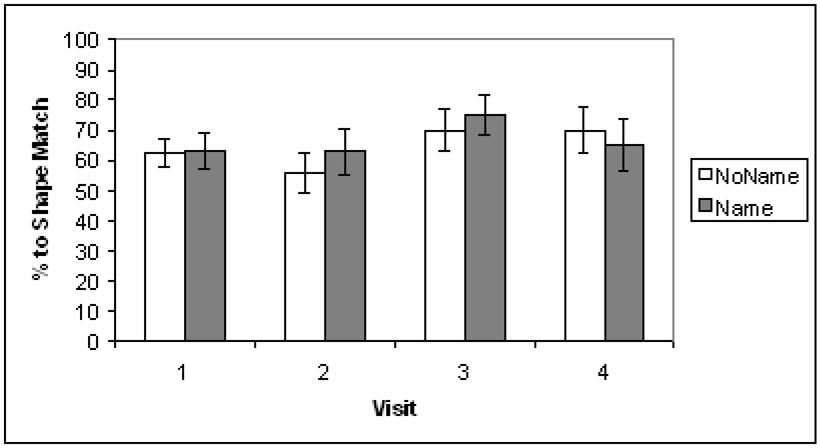


Figure 3.
a. ASD group percent looking to the shape match, across visits
b. TYP group percent looking to the shape match, across visits

a



b

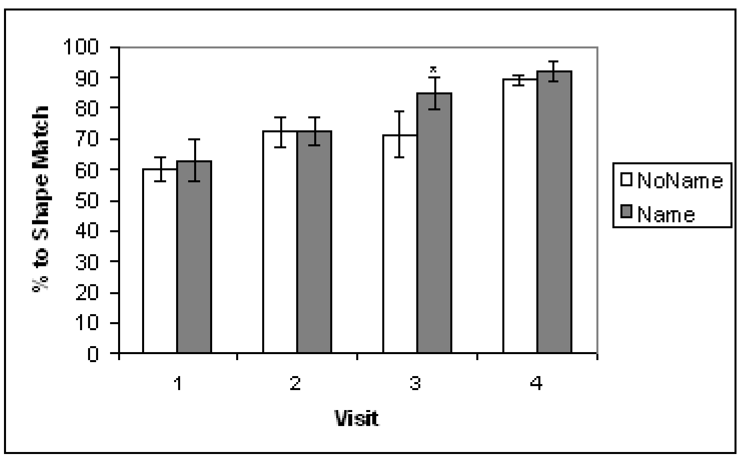


Figure 4.
a. ASD group percent pointing to the shape match, across visits
b. TYP group percent pointing to the shape match, across visits

NIH-PA Author Manuscript

NIH-PA Author Manuscript

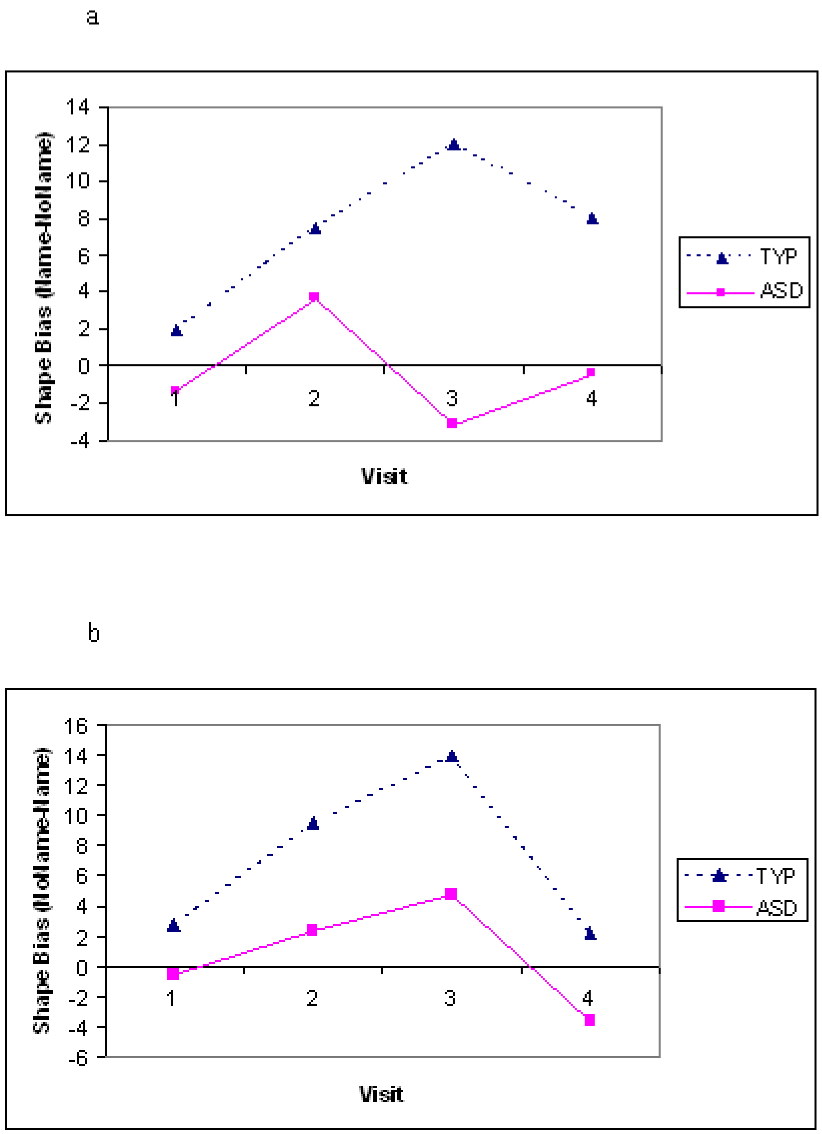


Figure 5.

a. Overall group differences in change in shape bias IPL performance across visits

b. Overall group differences in change in shape bias pointing performance across visits

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 1

Number of ABA Hours across Visits

	Visit 1	Visit 2	Visit 3	Visit 4
M	20.71	24.57	25.98	26.21
SD	13.82	9.37	11.94	9.21
Range	9-44	19.5-35	22.25-40	19-40

Table 2

Language and Standardized Test Scores at Visit 1

	ASD			TYP		
	n = 14			n = 15		
	M	*SD*	Range	*M*	*SD*	Range
Age in months	33.42	3.5	28.2-37.1	20.6	1.7	18.8-23.9
ADOS[a]	13.90	4.20	8-21	0.11	0.32	0-1.0
Autistic Disorder (n = 8)	16.87	2.99	13-21			
ASD (n = 6)	10.00	1.26	8-11			
CARS[aa]	34.35	5.74	27-42	15.39	0.76	15-18
Mullen Scales of Early Learning						
Visual Reception						
Raw Scores	26.35	6.18	13-34	26.11	3.23	21-30
T Scores	36.00	15.14	20-60	67.21	8.56	40-74
Fine Motor						
Raw Scores	23.78	4.30	16-32	21.83	1.54	20-26
T Scores	30.55	13.05	20-57	48.50	7.78	36-56
Receptive Language						
Raw Scores	23.21	8.44	13-36	25.33	2.93	20-30
T Scores	36.50	18.48	20-70	57.78	10.03	28-70
Expressive Language						
Raw Scores	19.21	7.76	9-33	19.44	4.46	15-30
T Scores	32.27	14.69	20-64	58.00	10.69	33-70
Vineland standard scores						
Communication	78.42	15.87	61-101	103.83	8.16	94-117
Daily Living	76.14	11.17	59-102	105.61	7.75	91-119
Socialization	73.50	5.30	63-82	100.50	6.70	90-115
Motor	80.93	10.13	64-100	102.44	5.91	84-111

[a]Cutoff score for a diagnosis of autism is 12, and cutoff score for a diagnosis of autism spectrum disorders (ASD) is 7

[aa]Cutoff score for a diagnosis of autism is 30

Table 3

CDI Scores across Visits

	Visit 1	Visit 2	Visit 3	Visit 4[a]	
	Infant Form	Toddler Form	Toddler Form	Toddler Form / CDI-III	
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
	Range	Range	Range	Range	Range
CDI - ASD					
Total Words Produced	102.70	223.07	306.66	48.00	60.60
	(96.75)	(191.13)	(224.16)	(83.95)	(12.44)
	0-258	0-548	0-580	0-197	45-74
Count-Nouns Produced	55.35	120.42	132.92	24.80	23.60
	(58.14)	(102.34)	(105.05)	(12.44)	(48.33)
	0-159	0-262	0-291	0-98	14-31
CDI - TYP					
Total words produced	118.5	335.53	503.8		68.00
	(114.4)	(159.08)	(156.65)		(27.01)
	8-316	100-601	138-657		22-99
Count-Nouns Produced	76.00	185.57	258.06		26.00
	(73.18)	(76.05)	(44.28)		(6.87)
	2-210	61-272	195-311		22-32

Note: "Total Understands and Says" from the Infant Form, and "Total Words Produced" from the Toddler Form and Level III forms are presented in this table. Maximum number of words that a child can produce on CDI Infant Form is 396, on Toddler Form is 680, and on Level III is 100.

[a]The Toddler Form was used for children with ASD who had produced fewer than 250 words at Visit 3 (n = 5), and the Level III was used for children with ASD whose vocabularies had included more than 250 words at Visit 3 (n = 9). The Level III form was used for all of the TYP children.

Table 4
Sample Layout of Noun Bias Videos

Video 1	*Audio*	*Video 2*
1 Possum puppet digs with nose	Here's TOOPEN!	Black
2 Black	See, TOOPEN!	Possum puppet digs with nose
3 Possum puppet digs with nose	Look, TOOPEN!	Possum puppet digs with nose
4 Possum sways side to side	They're different now!	Beetle digs with nose
5 Possum sways side to side	Where's TOOPEN?	Beetle digs with nose

Table 5
Sample Layout of Shape Bias Videos

NoName Trials		
Video 1	***Audio***	***Video 2***
1 Wooden U-shaped block	Look at this!	Black
2 Black	Look at this!	Wooden U-shaped block
3 Wooden X-shaped block	They're different now!	Sparkly U-shaped block
4 Wooden X-shaped block	Which one looks the same?	Sparkly U-shaped block
Name Trials		
Video 1	***Audio***	***Video 2***
5 Wooden U-shaped block	Here's the DAX!	Black
6 Black	Look, a DAX!	Wooden U-shaped block
7 Wooden X-shaped block	They're different now!	Sparkly U-shaped block
8 Wooden X-shaped block	Where's the DAX?	Sparkly U-shaped block