Shape categorization in Autism: Does it follow the pattern of typical development?

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Abstract

When identifying basic-level categories (e.g., airplane, cow), typically developing (TD) children commonly use the overall shape of objects as basis for their judgments. This so-called shape bias is tied to the size of a child's vocabulary and as such might be a way of adaptively organizing an ever-growing vocabulary. The current study looks at whether the same is true for children with autism spectrum disorder (ASD). A group of participants with ASD and TD controls were asked to categorize objects that differed in the amount of item detail. Results show that vocabulary size was related to success in categorizing objects for TD participants, but not for ASD participants. We discuss the degree to which a link between shape bias and vocabulary size in ASD children may be an indication of differentiated patterns of adaptation.

Keywords: categorization; language development; autism

The overall shape of items is important when it comes to learning the words of basic-level categories. Whether we consider a dog, a car, an airplane, or a cake, the most salient difference among these items is their overall shape. Indeed, typically developing (TD) children show a pronounced bias toward the overall shape of objects (e.g., Diesendruck & Bloom, 2003). For example, when children are asked to group novel objects, they overwhelmingly group objects based on their overall shape rather than other features (e.g., texture, color etc.; Samuelson & Smith, 2005). The global feature of overall shape supersedes details.

While the "shape bias" has been documented repeatedly, it was found only recently that this bias is linked to the size of a child's vocabulary (Pereira & Smith, 2009). In Pereira & Smith (2009), participants were TD toddlers with varying vocabulary sizes. They participated in multiple trials of a task in which they were asked to decide which of three toy objects (e.g., a car, a plane, a cake) matched the label offered by the experimenter (e.g., "show me the car"). Importantly, the degree of detail of the presented objects differed as a function of trial type. In some trials, objects were highly detailed, providing information about color and fine-grain shape. In others trials color was omitted, leaving details only about the fine-grain shape. And finally, in the third trial type, the objects were mere shape abstractions, missing both color and fine-grain shape. Results indicated that a child's productive count noun vocabulary (as compared to receptive vocabulary or general vocabulary) had a significant effect on performance. While children could categorize the detailed objects equally well, only children with larger count-noun vocabularies could identify the objects represented as shape abstractions.

In a similar vein, research has demonstrated that TD children with small vocabularies benefit from teaching props that focus their attention to the overall shape of items (Son, Smith & Goldstone, 2008). Son and colleagues (2008) taught children the names of new objects that either had large amount of detail (e.g., texture, color, fine-grain shape) or were mere shape abstractions. In this latter case, shape abstractions approximated the overall shapes of the objects. Results show that training with shape abstractions yielded better performance later identifying detailed objects from the same category than the training with detailed objects. Focusing children's attention on the overall shape of objects by removing irrelevant information promoted better learning. The ability to see gist, Gestalts, and global features appears integral to how TD children learn, categorize, and identify objects.

Detail Focus in ASD

Compared to their TD peers, children with ASD have a tendency to focus on specific details. This may include fixation with the parts of objects (e.g., the wheels of a toy car) or having very limited and particular interests (e.g., former Secretaries of the Interior). Indeed, these types of detail orientation are included in the diagnostic criteria for ASD (American Psychiatric Association, 2000). Theorists have argued that the focus on detail may stem from what they describe as "weak central coherence" (WCC), or a decreased push toward Gestalts (e.g., Happé & Frith, 2006; Happé & Booth, 2008). This account of ASD does not postulate that children with ASD are incapable of processing global information, but rather that they tend to gravitate toward details. That is, when absolutely pressed, children with ASD are able to see Gestalts, but all things equal, will focus on detail.

The best example of this difference in focus was established with the classical Navon task, a task in which stimuli consist of many small letters configured in the arrangement of a large letter (cf., Navon, 1977). For TD participants, results show a distinct interference of large letters on the perception of small letters, both in children (Plaisted, Swettenham, & Rees, 1999) and in adults (e.g., Navon, 1977). In particular, when participants are asked to focus on small letters, reaction time is longer for trials in which large and small letters differ than on trials in which large and small letters match. This global interference is indetectable in participants with ASD: They perform equally fast in both letter-mismatch trials and letter-match trials, in both cases with high accuracy (e.g., Plaisted et al., 1999).

Another example of weak central coherences in ASD comes from face perception tasks. The identity of a face is defined not only by its individual parts (e.g., nose, eyes, mouth), but also by the holistic configuration of these parts, something that appears to be disrupted when faces are presented upside down. For TD children, recognition accuracy decreases when faces are presented upside down, compared to trials in which faces are presented upright (Mondloch, Le Grand, & Maurer, 2002). In contrast, children with ASD do not perform differently as a function of face orientation (e.g., Tantam, Monaghan, Nicholson, & Stirling, 1989). Along the same lines, participants with ASD could classify faces better when local rather than global features were exaggerated (through the use of a high-pass vs. low-pass filter; Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, & Da Fonséca, 2008). The inverse pattern of results was obtained for TD children.

Applied to language learning, children with ASD do not show evidence of the same shape bias found in TD children (Tek, Jaffery, Fein, & Naigles, 2008). While TD children demonstrated movement toward categorizing objects by global shape, ASD children did not. Compared to their TD peers, children with ASD also often have difficulty communicating, frequently displaying atypical language development (American Psychiatric Association, 2000). However, it is not clear whether the connection seen between vocabulary size and object categorization style exists in ASD as it does in TD. The current study aims to explore this explicitly, potentially providing evidence for differentiated patterns of adaptive mental functioning.

Rationale for the Current Study

Very little research exists exploring how children with ASD categorize typical objects and what role shape might play. For TD children, the development of a bias toward categorizing objects based on shape may relate to the emergence of an overall tendency to focus on Gestalts, which may have an adaptive function. Compared to TD children, children with ASD tend to focus on details and do not show a natural shape bias. This may indicate an atypical pattern of adaptive functioning. To begin exploring this line of research, the current study aims to compare TD children and children with ASD who possess similar productive count-noun vocabularies on a task in which they are asked to identify objects that afford various degrees of detail.

Method

Participants

Seventy TD children (39 boys and 31 girls) were recruited from Cincinnati area schools and a local children's museum Ages ranged from 14-29 months (*M* = 20.78, *SD* = 3.67). Twenty-five children with ASD (22 boys and 3 girls) were recruited from Cincinnati area treatment centers and special needs schools. Their ages ranged from 2 years, 9 months -17 years, 5 months (*M* = 5 years, 11 months; *SD* = 3 years, 7 months) Diagnoses of ASD were confirmed through contacting their pediatricians or therapists after written consent was obtained from their guardians.

Language Measure

To assess each child's vocabulary, parents were asked to fill out the MacAurthur-Bates Communicative Development Inventories (MCDI; Bates, Dale & Thal, 1995), a survey for parents that is widely used in the language development literature. Parental report of language abilities has been demonstrated to be a valid measure of both TD and ASD language abilities (Luyster, Lopez & Lord, 2007; Tomasello, 1994). Parents completed the entire survey, but for the purposes of the current study, only the sum of items representing count nouns each child could understand and say were used for comparison and analysis. It was a child's productive count noun vocabulary that Pereira and Smith (2009) tied to his or her ability to categorize objects based on global features.

Materials

Stimuli were constructed to represent 12 noun categories commonly known by young children. These categories were: horse, cow, pig, fish, bird, butterfly, turtle, car, airplane, cake, shoe, and hamburger. Categories were represented by three objects, each from a different condition based on how much information they afforded the child.

The first object for each category, referred to as the *detailed object*, consisted of a toy or model purchased from toy stores. It contained detailed color, texture, and shape information (see Figure 1A). The second object, referred to as the *rich-shape object*, was constructed using a duplicate of the detailed object covered with black modeling clay. This clay served to remove the color and textural information while maintaining detailed shape (see Figure 1B). The object from the third condition, referred to as the *shape abstraction*, was made of Styrofoam. It was designed to represent the overall shape of the object category without providing any detailed information (see Figure 1C). Detailed objects served to confirm that children were able to identify the object categories. Shape abstractions, in contrast, provided information about whether children were able to identify global abstractions of objects. The intermediate, rich-shape condition served to help illuminate potential trends in identification abilities.

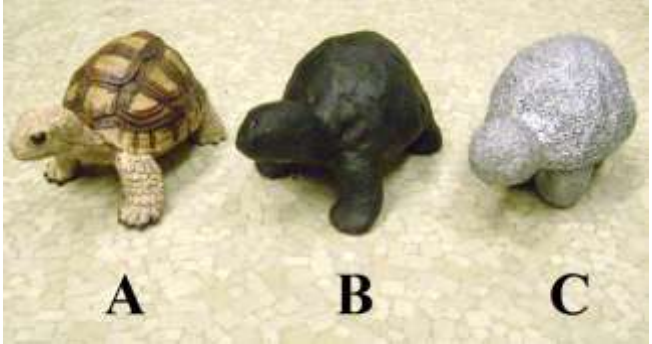

Figure 1: Examples of (A) a detailed turtle, (B) a rich-shape turtle, and (C) a shape abstraction turtle.

Procedure

The procedure for the current study was adapted from Pereira and Smith (2009). To begin, there were four practice trials, carried out on a laptop computer, designed to acclimate the child to the researcher and, for lower functioning children, to ensure that they were able to follow directions. During each practice trial, the researcher showed the child two photographs of easily discriminable, common nouns (e.g., dog, bunny, train, and kitty). The experimenter labeled the object on one of the photos and asked the child to point to it. Performance did not affect the child's eligibility to participate in the rest of the study.

For the main task, the experimenter told participants that they were going to play with some toys from a toy box. The experimenter then placed a red wooden tray (60 cm by 30 cm) in front of the child so that it was out of reach. This served as a platform for stimuli and to help children focus their attention on the testing space. For each test trial, the experimenter placed three detailed objects, three rich-shape objects, or three shape abstractions on the board (see Figure 2 for an example). One object served as a target, the other two as distractors. The experimenter then asked for the target (e.g., "Give me horse."), and pushed the tray within reaching distance of the child. Clear pointing or picking up the target were considered correct responses. Regardless of whether or not the child was correct, neutral feedback was given. The experimenter recorded responses on a laptop computer. This procedure was repeated for 12 testing trials. Children never saw multiple versions of an object category. For example, if presented with a shape distraction airplane, children would not see the detailed airplane. Types of object were balanced across participants.

Figure 2: Example test trial showing a fish, car and pig in the shape abstraction condition.

Results

For both TD children and children with ASD, productive count noun vocabularies ranged from 0-199 words (TD M = 78.17, SD = 66.5; ASD M = 79.59, SD = 66.91). Similar to previous work by Smith (2003), participants from both the TD and ASD groups were divided into subgroups based on their productive count noun vocabulary sizes: Children whose productive count-noun vocabulary was between 0 and 100 words were classified as being in the Low-Vocabulary group (the largest vocabulary in this group was 92), and children with a vocabulary between 100 and 200 nouns were classified as being in the High-Vocabulary groups (the smallest vocabulary in this group was 102). The vocabulary groups, as well as associated descriptive statistics are shown in Table 1. Because analyses conducted utilizing divisions based on mean and median vocabularies yielded similar results, the above method was utilized to maintain continuity with previous work.

Table 1: Descriptives of TD and ASD Participants, Mean Age and Number of Count-Nouns in Productive Vocabulary Separated by 2 Vocabulary Groups.

	Vocabulary Group	
	< 100 nouns	> 100 nouns
TD	*N* = 45 *M* age = 19.00 months (*SD* = 2.88) *M* vocab = 34.29 (*SD* = 28.46)	*N* = 25 *M* age = 24.00 months (*SD* = 2.60) *M* vocab = 157.16 (*SD* = 33.95)
ASD	*N* = 14 *M* age = 5 yrs, 10 months (*SD* = 4 yrs, 1 month) *M* vocab = 30.57 (*SD* = 34.48)	*N* = 11 *M* age = 6 yrs, 1 month (*SD* = 3 yrs) *M* vocab = 135.55 (*SD* = 41.23)

Categorization Performance: TD Sample

The average performance on detailed objects, rich-shape objects, and shape abstraction for TD children in the Low- and High-Vocabulary groups are shown in Figure 3.

A 2 X 3 (Vocabulary Group X Object Condition) mixed measures analysis revealed a significant effect of Vocabulary Group, $F(1,68) = 33.31$, $p < .001$, with better performance for the High- than the Low-Vocabulary Group (M_H = 88.46%, SD_H = 34.12%; M_L = 60.93%, SD_L = 27.25%). There was also a significant effect of Object Condition, $F(1,68) = 48.50$, $p < .001$, with highest performance for detailed objects (M = 80.71%, SD = 22.99%), followed by rich-shape objects (M = 68.57%, SD = 27.15%), and followed by shape abstractions (M = 58.21%, SD = 27.16%). While the interaction was not significant, $p > .90$, TD children in the Low-Vocabulary group performed better on detailed object trials than rich-shape trials, $t(48) = 2.07$, $p < .05$, and better on rich-shape trials than shape abstraction trials, $t(48) = 2.08$, $p < .05$. In contrast, performance for TD children in the High-Vocabulary group did not differ between rich-shape and shape abstraction trials, $t(48) = 1.31$ (though there was a difference between detailed object and rich-shape trials, $t(48) = 2.07$, $p < .05$).

Categorization Performance: ASD Sample

The average performance of children with ASD from the Low- and High-Vocabulary groups across the detailed, rich-shape, and shape abstraction trials is illustrated in Figure 4.

As was done with the TD sample, a 2 X 3 (Vocabulary Group X Object Condition) mixed measures analysis was conducted. Surprisingly, there was only a marginal effect of Vocabulary Group, $F(1, 23) = 3.18$, $p = .063$ (M_H = 89.39%, SD_H =25.79%; M_L = 72.02%, SD_L = 31.33%). However, as was found with TD children, there was a significant effect of Object Condition, $F(1, 23) = 7.07$, $p < .02$. Across vocabulary groups, performance was best for detailed objects (M = 88.00%, SD = 22.96%), second best for rich-shape objects (M = 78.00%, SD = 32.33%), and lowest for shape abstractions (M = 73.00%, SD = 32.21%).

Importantly, the interaction was not significant, $p > .50$. Looking at simple effects within vocabulary groups, performance did not differ between detailed object and rich-shape trials, *ps* > .30. There was also no difference between rich-shape and shape abstraction trials, *ps* > .30.

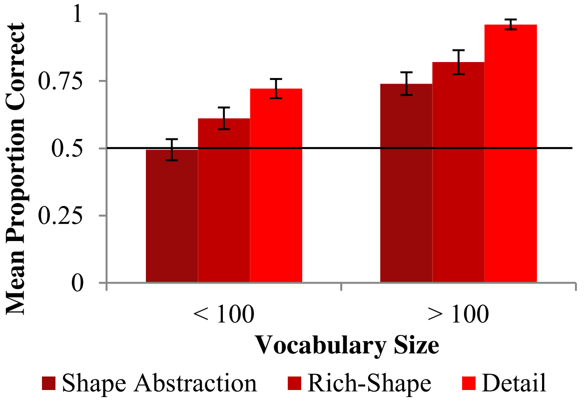

Figure 3: Mean proportion correct responses across object conditions for TD children as a function of vocabulary size.

Categorization Performance: Comparing Samples

Categorization performance was compared between diagnostic groups for both the Low- and High-Vocabulary groups. For children in the Low-Vocabulary groups, performance did not differ between children with ASD and TD children on detailed object and rich-shape trials, *ps* > .37. However, children with ASD from the Low-Vocabulary group performed significantly better than TD children with similar vocabularies on shape abstraction trials, $t(57) = 2.43$, $p < .02$. Children with ASD from the High-Vocabulary group outperformed TD children on detailed object trials, $t(24) = 2.14$, $p < .05$, but differences were not significant for rich-shape or shape abstraction trials, *ps* > .33.

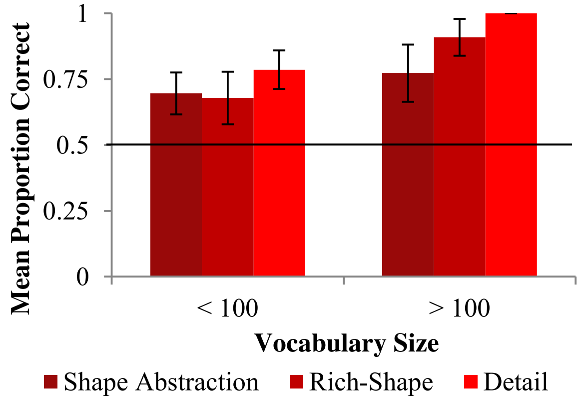

Figure 4: Mean proportion correct responses across object conditions for children with ASD as a function of vocabulary size.

Discussion

Results provide evidence for a difference in the relation between count-noun vocabulary sizes and categorization abilities in TD children versus children with ASD. In particular, while there was a characteristic difference between TD children in the Low- versus High- Vocabulary group, this difference disappeared for ASD Children. Note that the TD finding is not as robust as previously found (e.g., Pereira & Smith, 2009; Smith, 2003). Nevertheless, TD children in the High-Vocabulary group performed equally well in the rich-shape and shape abstraction conditions, whereas TD children in the Low-Vocabulary group performed differently across all three object conditions.

In contrast, children with ASD from both vocabulary groups demonstrated similar performance patterns across conditions. When performance patterns between diagnostic groups were compared directly, children with ASD from the Low-Vocabulary group performed better than their TD peers on shape abstraction trials, and equally well in other trials. Performance across the rich-shape and shape abstraction trial types were equivocal for TD children and children with ASD from the High-Vocabulary groups.

Before interpreting how the current results relate to global processing and contextual changes, the current study makes several assumptions. The first assumption is that vocabulary size is a contextual factor. The second assumption is that categorization of shape abstraction objects translates to the ability to process Gestalt information. The third assumption is that Gestalt processing is an adaptive function that arises when contexts make tasks difficult (in this case, as vocabulary size increases). Under these assumptions, the fact that children with ASD did not demonstrate stratified performance seen in TD children may suggest that they do not adapt to contextual changes in the same manner. The generally high performance for children with ASD across object conditions regardless of vocabulary size is in line with the argument that the focus on detail commonly seen in ASD does not equate to an inability to process global information, but rather a preference for local features.

Could alternate claims explain the findings? Most prominent is the issue of how vocabulary was measured. The MCDI only allows parents to indicate words that they believe their child does not understand, words that they understand, but cannot say, and words that they understand and say. Many children with ASD use alternate forms of communication, such as sign language or exchange cards. Thus, the MCDI may not have been an accurate measure of each child's true productive count-noun vocabulary. Furthermore, the MCDI only lists words that TD children tend to learn in the first few years of life. Children with ASD who learn language later in life may not learn the same first words. Thus, it is possible that a greater proportion of their produced words were not captured by this measure. Given the issues with the MCDI, it is possible that a more detailed assessment of language, including receptive vocabulary, could influence results.

Other issues that could affect the interpretation of results include the current sample size of children with ASD and the methods used to confirm diagnoses. Only 25 children with ASD were included in the final sample. The current study also based diagnosis on physician confirmation, rather than using standardized measures, such as the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). Though best diagnostic practice suggests the use of standardized measures (Ozonoff, Goodlin-Jones, & Solomon, 2005), the individual practices of clinicians may vary.

Nevertheless, even given the alternate explanations for the results of this study, there is evidence from previous research which supports the current claims. First, previous work that explored how children with ASD see Gestalts demonstrated that they have the ability to identify both global and local features (e.g., Ozonof et al., 1994; Plaisted et al., 1999). Second, there is an indication that the shape bias in children with ASD is different from the shape bias of TD children (Tek et al., 2008). Combined, these studies suggest that there is also a weakened connection between global processing and vocabulary. In the current study, children with ASD tended to perform well on shape abstraction objects regardless of their vocabulary size, indicating that they were, in general, able to categorize objects based on their overall shape.

Research involving children with language delays, so-called late talkers, may also provide evidence for current claims. In similar object categorization tasks, they demonstrate performance patterns are similar to both TD children and children with ASD. Like TD children, late talkers show a developmental trend in their ability to categorize objects by shape (Jones & Smith, 2005). Specifically, Jones and Smith (2005) found that neither a late talker's receptive count-noun vocabulary nor age was significantly related to their ability to categorize objects based on overall shape. Productive count-noun vocabulary size, instead, was related. However, like children with ASD, they tend to not show an innate tendency to categorize objects by shape, and thus have an atypical shape bias (Jones, 2003). Though this provides evidence that in another clinical group, productive count-noun vocabulary size relates to categorization abilities, it does not address the issue of the accuracy of the MCDI for children with ASD.

The current study is a preliminary step towards better understanding the relationship between vocabulary size and object categorization style in children with ASD. It appears that though they may not have a bias toward global features, even those with poor verbal language skills have the capacity to categorize objects based on overall shape. This may have important clinical implications.

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