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PAPER

Individual differences in the shape bias in preschool children with specific language impairment and typical language development: theoretical and clinical implications

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Abstract

We investigated whether preschool children with specific language impairment (SLI) exhibit the shape bias *in word learning: the bias to generalize based on shape rather than size, color, or texture in an object naming context ('This is a wek; find another wek') but not in a non-naming similarity classification context ('See this? Which one goes with this one?'). Fifty-four preschool children (16 with SLI, 16 children with typical language [TL] in an equated control group, and 22 additional children with TL included in individual differences analyses but not group comparisons) completed a battery of linguistic and cognitive assessments and two experiments. In Experiment 1, children made generalization choices in object naming and similarity classification contexts on separate days, from options similar to a target object in shape, color, or texture. On average, TL children exhibited the shape bias in an object naming context, but children with SLI did not. In Experiment 2, we tested whether the failure to exhibit the shape bias might be linked to ability to detect systematicities in the visual domain. Experiment 2 supported this hypothesis, in that children with SLI failed to learn simple paired visual associations that were readily learned by children with TL. Analyses of individual differences in the two studies revealed that visual paired-associate learning predicted degree of shape bias in children with SLI and TL better than any other measure of nonverbal intelligence or standard assessments of language ability. We discuss theoretical and clinical implications.*

Research highlights

- On average, preschool children with specific language impairment (SLI) did not show the shape bias for object names, unlike same-age peers with typical language development.
- On average, preschool children with specific language impairment (SLI) were significantly worse at simple visual paired-associate learning than same-age peers with typical language development.
- Visual paired-associate learning predicted shape bias in children with specific language impairment (SLI) and children with typical language development better than measures of nonverbal intelligence and standard assessments of language ability used in this study.

Introduction

Specific Language Impairment (SLI) is primarily typified by poor grammatical learning in the absence of obvious cognitive, socio-emotional, or sensory deficits (Bishop, 1992; Leonard, 1998). Despite these accepted criteria, language development in children with SLI is heterogeneous and often includes lexical delays (Tomblin, Zhang, Buckwalter & O'Brien, 2003). While the challenges children with SLI experience when learning object words and meanings are well described (e.g. Gray, 2003, 2005; Leonard & Deevy, 2004; Oetting, Rice & Swank, 1995; Rice, Buhr & Nemeth, 1990), underlying causes of these difficulties remain poorly understood. One salient aspect of typical language (TL) development that has not been

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deeply investigated in SLI involves *word learning biases* that are believed to support typical lexical acquisition (Golinkoff, Mervis & Hirsh-Pasek, 1994; Markman, 1989; Markman & Hutchinson, 1984). These biases include the *whole-object assumption* (Golinkoff *et al.*, 1994; Markman, 1989, 1991), the *taxonomic assumption* (or the principle of *categorical scope* or *noun-category bias*; Markman & Hutchinson, 1984), and the *mutual-exclusivity assumption* (Markman & Wachtel, 1988). Another bias believed to be important to object word learning, and the focus of this paper, is the *shape bias*.

The shape bias is the propensity for children to generalize novel object names to other solid objects that share the same shape as the referent rather than objects that share other features (e.g. color, texture, size) in a naming context ('this is a dax; find another dax'). In contrast, choices in non-naming contexts ('look at this; find another like this') are not biased towards shape (Landau, Smith & Jones, 1988). This heightened sensitivity to shape in object word learning has been experimentally demonstrated using novel noun extension tasks in which children are taught a name for a novel object and are asked to extend this new name by choosing another exemplar of the object from objects similar to the target in features such as shape, size, color, or texture (Landau *et al.*, 1988). The preference for shape over other properties in a naming context has been found as early as 15 months (Graham & Diesendruck, 2010), as well as in young children (Booth, Waxman & Huang, 2005; Graham & Poulin-Dubois, 1999; Imai, Gentner & Uchida, 1994) and adults (Landau *et al.*, 1988).

In addition to facilitating object word learning, the shape bias may accelerate lexical acquisition; toddlers who did not yet exhibit the shape bias and were trained to attend to shape in object naming contexts exhibited reliably greater object noun acquisition outside the lab over a period of weeks than control participants (Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002). A word learning bias that advances object word learning holds clinical potential for children whose lexical acquisition is slow and inefficient. It also begs the question of whether 3–4-year-old children with language impairment exhibit a shape bias; if they do not, this could provide insight into why they lag in word learning.

The theoretical implications of the shape bias are a matter of debate. Some contend that the relationship between object words and shape is privileged and exists because young children believe that count nouns refer to kinds of objects and consequently are able to recognize that shape is a reliable cue to deeper conceptual properties (Booth & Waxman, 2002; Diesendruck & Bloom, 2003). Evidence supporting this 'shape-as-cue' account includes demonstrations that the shape bias can be moderated by linguistic information concerning animacy, that toddlers at very early stages of word production show a shape bias, and that infants show a shape bias in a more general induction task that requires them to generalize nonobvious object properties (Booth *et al.*, 2005; Graham & Diesendruck, 2010). Others assert that the shape bias exists because young children attune to statistical regularities in their environment that are advantageous to word learning. That is, many early-learned nouns refer to categories that are visually organized by similarities in shape (Samuelson, 2002; Samuelson & Smith, 1999; Smith, 2001), and children learn this statistical regularity from experience, leading them to attend to shape in such contexts.

The shape bias, attentional learning, and implications for language impairment

Young children recognize that the act of naming serves as a strong signal of an object word learning context. The key linguistic cues are count noun phrases (e.g. 'this is a [novel word]', 'it's a [novel word]'). Children are remarkably sensitive to changes in meaning signaled by minor modifications to these linguistic cues. For instance, when an adjectival frame with count nouns is used (e.g. 'find the [novel word] one'), preschool children are more likely to select a test object that matches the target's texture or color instead of its shape (Landau, Smith & Jones, 1992; Smith, Jones & Landau, 1992). Likewise, when a mass noun phrase ('this is some [novel word]') is used, young children select non-rigid substances, such as foam and gel (Soja, 1992). When the instruction includes words signaling that one should group objects based on similarity (e.g. 'matches', 'belongs with', 'goes together' or 'makes a group'), preschool children no longer systematically prefer shape (Landau *et al.*, 1988). Smith and colleagues have proposed the *Attentional Learning Account* (ALA) to explain the generalizations and biases children exhibit in word learning (see, e.g. Colunga & Smith, 2008, for a review). The fundamental argument of the ALA is that as children detect (implicitly or explicitly) coherent covariation between linguistic and nonlinguistic information (e.g. the tendency for linguistic naming contexts to imply categories best generalized on the basis of shape), they heuristically exploit these regularities in word learning, directing attention to object dimensions that in their experience have correlated with linguistic frames.

Children become sensitive to many complex regularities that exist between linguistic and nonlinguistic information in the environment. Typically developing children, from a very young age, show sensitivity to various object dimensions in a variety of experimental tasks (Colunga & Smith, 2005; Graham & Diesendruck, 2010; Smith, 2003), and reliance on shape vs. texture or other aspects of material shifts with context. For example, Jones, Smith and Landau (1991) predicted that adding eyes to artifacts would modulate the shape bias, since instances of animate kinds tend to be similar in texture as well as shape; as predicted, in a naming context, children relied primarily on shape for generalization with eyeless objects, but on both shape and texture for objects with eyes. Another example is that the shape bias for naming contexts is found for solid objects (Samuelson & Smith, 1999); children instead exhibit a *material bias* in a naming context for nonsolid objects (Soja, Carey & Spelke, 1991). Yet another example comes from Samuelson and Horst (2007). While biases such as the shape and material biases are presumed to emerge gradually over experience on a fairly long time scale, Samuelson and Horst demonstrated that relative reliance on dimensions such as shape and material can be affected dynamically by short time scale influences such as the sequence of preceding trials, a child's own previous responses for solid exemplars in previous trials, etc. Samuelson and Horst also review seeming discrepancies between studies showing greater reliance on shape (Samuelson & Smith, 1999) vs. greater reliance on material properties (Soja *et al*., 1991) and point out that the shape bias can be overwhelmed when, e.g. material and color are correlated in experimental materials (in which case, younger children may rely on overall similarity [two matching dimensions], whereas they rely reliably on shape when generalization choices share only one feature with a target object [shape, texture, or color]). One more crucial example comes from Smith *et al*. (2002), who found that laboratory experience directing attention to connections between shape and object names accelerated object name learning outside the laboratory.

Thus, the attentional learning account holds that the emergence of useful biases in word learning results from exquisite sensitivity to subtle correlations between linguistic forms and structures and complex constellations of object properties. Even slight impairments in processing of any relevant linguistic or nonlinguistic dimension may disrupt normal development of attentional biases and impede word learning. Children with SLI may be at particular risk for object word learning difficulties because a hallmark of SLI is difficulty understanding and using morphology and syntax, particularly with short words such as articles (Leonard, Eyer, Bedore & Grela, 1997; Rice, 2003). Weakness in building associations within or between visual and auditory modalities would also place preschool children with SLI at risk for delayed object word learning. Although SLI is strongly associated with difficulty processing auditory information, it is associated with impaired processing of visual input as well, including poor visual spatial working memory (Bavin, Wilson, Maruff & Sleeman, 2005; Hick, Botting & Conti-Ramsden, 2005; Hoffman & Gillam, 2004) and visual discrimination abilities (Powell & Bishop, 1992). Children with SLI also exhibit impairments in selective and sustained attention (Finneran, Francis & Leonard, 2009; Noterdaeme, Amorosa, Mildenberger, Sitter & Minow, 2001).

Most shape bias investigations have focused on typically developing children (Booth *et al*., 2005; Jones *et al*., 1991; Landau *et al*., 1988), with two notable exceptions. Tek, Jaffery, Fein and Naigles (2008) tracked the development of the shape bias over a 1-year period in preschool children with autism spectrum disorder (ASD), and Jones (2003) investigated this bias in late talking toddlers. Tek and colleagues reported that their 2- to 4-year-old children with ASD did not differentially attend to shape in a novel name extension task that was repeated four times over the period of a year. Similarly, Jones' sample of late talkers (25 to 41 months old) made significantly fewer shape choices than children with TL. A reduced or absent shape bias in late-talking toddlers has significant implications for SLI because 25–50% of children classified as late talkers meet criteria for SLI by kindergarten (Leonard, 1998). An obvious question then is whether children with SLI show a reduced shape bias, as one might suspect from the late-talker results. We address this question in Experiment 1. In light of the heterogeneity of linguistic and nonlinguistic strengths and weaknesses in SLI, in Experiment 2 we use a simple paired visual association learning task to explore individual differences in the shape bias in children with TL and SLI and the cognitive and linguistic abilities that predict these differences.

Experiment 1

To provide a strong test of shape as a bias specific to object noun learning, we used two conditions. In *similarity classification*, the target was introduced without a label and children were asked 'Which one goes with this one?' We predicted that children with SLI would perform similarly to children with TL in this condition, i.e. without systematic biases to choose based on shape, texture, or color. In *novel name extension*, the target was introduced with a label ('This is a [novel word]') and children were instructed to 'Find another [novel word]'. Children with TL typically exhibit the shape bias in this condition (Landau *et al*., 1988). However, we predicted that children with SLI would not show the same level of sensitivity to linguistic and visual information and would, therefore, not reliably exhibit the shape bias (the tendency shown by late talkers; Jones, 2003). Lack of a robust shape bias would suggest that 3–4-year-old children with SLI are not yet sensitive to coherent covariation between linguistic and visual cues that serve as reliable signals of an object word learning context for children with TL.

Method

Participants

We recruited 32 3- and 4-year-old children from a variety of urban and rural preschool programs in Connecticut (see Table 1 for selection and equating measures). Sample diversity was assessed through parent report of race, ethnicity, as well as mother's level of education, a proxy for socioeconomic status (SES; Wright & Bean, 1974). Sixteen children diagnosed with SLI were equated with 16 children with TL from a larger sample of 38 children meeting criteria for TL (results from the 22 TL children not included in the equated group [labeled 'TL-excluded'] are included whenever we examine individual performance for Experiments 1 and 2). As shown in Table 1, the equated groups did not differ reliably in SES, age or nonverbal IQ, and were approximately equated in sex, race, and ethnicity. Furthermore, with the exception of one participant with SLI, all children were recruited from the same childcare and preschool programs meaning that the children in both groups were involved in similar daily educational and play experiences.

Table 1 *Variables used to select and match groups*

	SLI Group		TL Group			
Measure	Mean (*SD*)	Range	Mean (*SD*)	Range	*t*	*p*
Age	4;1 (5)	3;7–4;9	4;2 (5)	3;6–4;10	0.5	.649
SES	14.0 (2)	10–18	14.8 (2)	12–18	1.2	.255
KABC-II	108 (7)	97–120	110 (8)	95–120	0.6	.558
CELF-P2	78 (8)	63–85	111 (9)	100–127	11.2	<.001
PPVT-4	93 (10)	75–112	111 (12)	91–133	4.9	<.001

Note SLI = Specific Language Impairment; TL = Typical Language. The proxy for SES was years of maternal education. The bottom three rows are standardized measures with normative standard mean of 100 and standard deviation of 15: KABC-II = Nonverbal index (NVI) of the Kaufman Assessment Battery for Children – Second Edition (Kaufman & Kaufman, 2004); CELF-P2 = Clinical Evaluation of Language Fundamentals – Preschool 2 (Semel, Wiig & Secord, 2004); PPVT-4 = The Peabody Picture Vocabulary Test – Fourth Edition (Dunn & Dunn, 2007). The groups were equated in Age, SES, and KABC-II NVI, and selected to differ in CELF-P2 performance. Differences in PPVT-4 were correlated with CELF-P2 but were not a basis for group assignment. '*t*' is the *t*-value from an unpaired, two-tailed *t*-test, and '*p*' is the corresponding *p*-value. There were 11 and 9 males in the SLI and TL groups, respectively. The SLI group included two African American children, two identified as both white and African American, eight white children, and four who declined to respond. The TL group included two African American children, two identified as both white and African American, 11 white children, and one who declined to respond. Regarding ethnicity, the SLI group included seven Hispanic children, six non-Hispanic children, and three declined to respond; the TL group included three Hispanic children and 13 non-Hispanic children.

All children met these inclusionary and exclusionary criteria: English as their native language, hearing within normal limits bilaterally at the time of testing based on an audiometric pure-tone hearing screen conducted at 1, 2, and 4 KHz at 20 dB HL (ASHA, 1990); normal color vision based on a passing score of at least 8 out of 9 correct object detections on the *Color Vision Testing Made Easy* color vision test (Waggoner, 2002); and normal nonverbal intelligence based on a performance standard score of 85 or greater on the nonverbal index (NVI) of the Kaufman Assessment Battery for Children – Second Edition[1] (KABC-II; Kaufman & Kaufman, 2004).

For children with SLI, language delay was diagnosed based on a standard score at or below 85 ($\geq$ 1 *SD* below the mean) on the Clinical Evaluation of Language Fundamentals Preschool – 2[2] (CELF-P2; sensitivity = 85%, Semel, Wiig & Secord, 2004) and clinical judgment of language impairment based on a conversational exchange with a certified speech-language pathologist. Children with SLI were excluded if they had a history of frank neurological impairment, autism spectrum disorder, psychological/emotional disturbance or attention deficit disorder as reported by parents or teachers. For children with TL, typical development was established based on (a) no report of motor, cognitive, hearing, vision, speech, and language concerns by parents, (b) a

[1]We administered core NVI subtests of the KABC-II that are appropriate for ages 3 and 4: Conceptual Thinking, Face Recognition, Triangles, and Hand Movements. Conceptual Thinking requires the child to select which of four pictures does not belong with the others. In Face Recognition, the child looks at one or more faces for 5 seconds and then must choose the correct face or faces in different poses among a set of distractors. In Triangles, the child arranges foam triangles to match a picture. In Hand Movements, the child copies series of taps the examiner makes with fist, palm, or side of hand.

[2]We administered the SS, WS, and EV subtests of the CELF-P2. SS = Sentence Structure is a receptive measure of a child's ability to interpret/comprehend sentences of increasing complexity; child points to one of four pictures (one target: three foils) when given a sentence (e.g. 'I can eat this'). WS = Word Structure, an expressive measure of a child's ability to use English morphology using a cloze procedure with picture support (e.g. 'This boy [test administrator points] is standing. This boy is [test administrator points] ________' [expected response: 'sitting']). EV = Expressive Vocabulary; child is shown pictures of people, objects and actions of increasing sophistication and provides a label.

standard score above 85 (< 1 *SD* below the mean) on the CELF-P2 (specificity = 82%), (c) a null history of speech, language, or special education services and (d) clinical judgment of typically developing language skills based on a conversational exchange with a certified speech-language pathologist. The Peabody Picture Vocabulary Test – 4 (PPVT-4; Dunn & Dunn, 2007) was administered to document receptive vocabulary level. We selected 16 of the 38 children who met the criteria for TL to serve as the TL comparison group. Our selections were made without reference to performance on experimental measures described below. Selections were based initially on a standard score at or above 100, consistent with average language skills, on the CELF-P2, with iterative replacements to arrive at statistical equating with the SLI group on KABC-II NVI performance and approximate equating of sex, race, and ethnicity.

Materials

Stimuli consisted of eight sets of three-dimensional novel objects constructed from a variety of materials (see Figure 1). Four sets were used in similarity judgment, and four different sets were used in novel name extension. Each set, modeled after stimuli described in Jones (2003), contained one target shape and test objects that varied from the target on a single dimension (shape, color, or texture). The eight sets of novel objects were counterbalanced between the similarity classification and novel name extension conditions, such that half the children in each group saw one set of four objects in similarity classification, while the other half saw the same set in the novel name extension condition.

To ensure that children were not able to associate any shape with an existing artifact, a total of 64 shapes were presented to seven typically developing 7-year-old first graders, whom we asked to identify items that resembled real objects. Seven shapes were removed from the stimulus set because they were identified as instances of real objects by at least one child. One additional shape was replaced during early pilot testing for the same reason. A total of 56 unique shapes comprised the final stimulus set.

Figure 1 *Examples of materials used in Experiment 1. The eight novel sets were constructed out of bubble wrap, hard plastic, batting, and textured foam (one set) and wood, Styrofoam, sponge, and fabric fur (the second set). The objects measured 5 × 5 × 1.25 or 5 × 5 × .75 cm. Note that there were three sets of distractors. In each, the shape choice was in a different position, and differed from the target in texture and color.*

Procedures

The novel name extension task always followed the similarity classification task by 2 days. This order was held constant due to potential for the novel name extension task to influence the similarity classification task. In between-subjects designs, generalizations tend to be unsystematic in similarity tasks, but biased towards shape in novel name extension tasks (Landau *et al*., 1988; Smith, 2001). Thus, while the latter has the potential to introduce a systematic bias with potential for carry-over, the former does not. We used a three-alternative forced choice paradigm to moderate the potential of a 'yes' bias (see Booth *et al*., 2005; Jones & Smith, 2002; Jones, 2003). Children were tested individually at preschool, daycare, or home.

Practice phase: similarity classification. A practice phase preceded the similarity classification test to ensure that children were able to make one selection from an array of three. Once the child was seated comfortably and the workspace was cleared of any distractions, the training task was introduced. The experimenter said 'See this?' as she placed a miniature toy on the table. Three miniature toys were then presented horizontally in front of the first, which remained on the table. One test object was identical to the target and the other two were highly dissimilar to the target in shape, color, and texture (e.g. if the target object was a toy wheel, a possible test object array would be an identical toy wheel, a toy whistle, and a toy tree). The examiner asked, 'which one…' (and pointed to the choices) '…goes with this one?' (and pointed to the target). The examiner inverted her palm so the child could place his selection in the examiner's hand. During the practice phase, we reinforced the directions and provided additional clues to facilitate comprehension ('Which one matches this one?' and 'Which one belongs with this one?'). All children heard each phrase once per training trial. The arrangements of the three test objects were randomized. A trial was scored as correct if the first test object that the child picked up and handed to the examiner was the identical match. Children were verbally reinforced (e.g. 'wow, great job, this one matches this one!'). Four training trials were completed before immediately moving on to the similarity classification testing phase. The criterion for moving to the testing phase was 3 out of 4 correct. All children met this criterion.

Practice phase: novel name extension. A similar practice was conducted prior to the novel name extension phase but employing a different set of toy objects and instructions that used a count noun phrase. When the target toy was placed on the table, the examiner said 'See this? This is a [object label]'. When the three choice objects were placed on the table in front of the target, the examiner pointed to the target and said; 'Find another [object label]', 'Give me another [object label]'. Again, there was an identical object among the choices. All children successfully completed the four training trials prior to immediately moving on to the novel name extension testing phase.

Testing phase: similarity classification. Children were introduced to a novel target and were provided with six trials to extend the target to one of three test objects, each differing from the others in shape, color, and texture. Test objects matched the target in shape, color, or texture, and differed from the target in the other two dimensions. Four complete sets of novel categories were presented resulting in a total of 24 unique trials. The test phase procedure was identical to the practice phase with similar instructions ('See this? Which one goes with this one?'). The horizontal arrangement of test objects was randomized across participants as was the order of the four categories. Each trial was scored as either a shape, texture, or color match to the novel, unnamed target.

Testing phase: novel name extension. Four complete sets of novel categories were presented, with novel targets called 'dax', 'wek', 'mot', and 'pim'. The testing phase procedure was identical to the classification task, with the exception that the target was named ('See this? This is a [dax]'). Three test objects were arranged horizontally in front of the target which remained on the table. While pointing to the target, the experimenter instructed the child: 'Find another [dax]', 'Give me another [dax]'. Each trial was scored as a shape, texture, or color match to the named target.

Reliability measures

Seventy-nine percent of the experimental trials administered and scored in real time by the experimenter were also scored on a separate score sheet in real time by an undergraduate or graduate research assistant. Four files from each group (SLI and TL) were selected at random and point-by-point accuracy between the experimenter's and the research assistant's scores was assessed by an undergraduate research assistant who did not participate in the administration of the experimental tasks. Point-by-point agreement was 100%.

Results and discussion

Frequencies of shape, texture, and color matches in the similarity classification and novel name extension tasks are presented in Figure 2. The TL group showed a large increase in shape choices from the Similarity task to the Naming Extension task, but the SLI group showed no apparent difference. Since the theoretical questions in this study hinge on rate of shape choices, we conducted a 2 (Group) × 2 (Task) ANOVA on shape responses.[3] There was a borderline effect of Group, with more shape choices made by TL children (M = 13.0, SD = 6.9) than children with SLI (M = 9.0, SD = 7.4; $F(1, 30) = 3.3$, $p = .079$, $\eta_p^2 = 0.10$). There was an effect of Task, with

[3]It would not be appropriate to do a full Group × Task × Dimension (shape, color, texture) analysis. Since these are count data, the effect of group would be unanalyzable; the Group means (collapsing across Task and Dimension) would have to be identical (though some previous reports in this literature have used that approach, and proceeded directly to interactions without considering main effects). Chi-square does not provide a solution for a three-factor design (chi-square could be used to examine whether counts differ reliably from expectations overall, but not to diagnose the locus of differences). However, the key question is: do the groups differ in their shape responses when the linguistic context indicates that an object name is being used? The TL group is expected to show the classic effect of more shape choices in the Name Extension task compared to the Similarity task; does the SLI group demonstrate statistically different behavior? The simplest, fully analyzable approach is to consider Group × Task with shape choices as dependent variable. Neither Group nor Task means are constrained, since only one of three response choices is included, allowing us to use standard ANOVA.

more shape choices in novel name extension (M = 13.3, SD = 6.9) than similarity classification (M = 8.8, SD = 8.3; $F(1, 30) = 11.5$, p = .002, η_p^2= 0.28). Crucially, there was a significant interaction of Group and Task: $F(1, 30) = 5.3$, p = .028, η_p^2 = 0.15. Planned comparisons revealed that this was due to a large effect of Task for TL (Naming: M = 16.8, SD = 5.1; Similarity: M = 9.3, SD = 8.8; $F(1, 15) = 12.5$, p = .003, η_p^2 = 0.46) but only a negligible trend for SLI (Naming: M = 9.7, SD = 6.8; Similarity: M = 8.3, SD = 8.1; $F(1, 15) < 1$). Thus, statistical analysis confirmed clear trends in Figure 2: the naming context significantly shifted shape choices for TL children, but not for children with SLI. Figure 3 plots individual shape choices in Similarity Classification by shape choices in Naming. While a few children with SLI patterned with the TL-match group, most did not.[4]

These results clearly demonstrate that on average, 3–4-year-old children with SLI do not show a shape bias.[5] Recall that Smith and colleagues (Gershkoff-Stowe & Smith, 2004; Landau *et al.*, 1992; Smith, 2001) have argued that the shape bias is the result of detecting one way in which language maps systematically onto real-world properties of objects. As the shape bias emerges, it provides children with a basis for attending to informative object characteristics in a naming context. The failure of children with SLI, on average, to exhibit this bias suggests that they fail to rely on coherent covariation between linguistic and nonlinguistic properties. But why might they tend to fail to develop the shape bias to begin with? It might be a specifically linguistic problem (linguistic difficulties impede detection of linguistic–nonlinguistic correlations). However, it could also result from, or be exacerbated by, a general weakness in visual memory and learning. That is, just as linguistic impairments would impede detection of linguistic–nonlinguistic regularities, so could nonlinguistic perceptual difficulties. Experiment 2 begins to address this possibility by examining children's simple visual association learning.

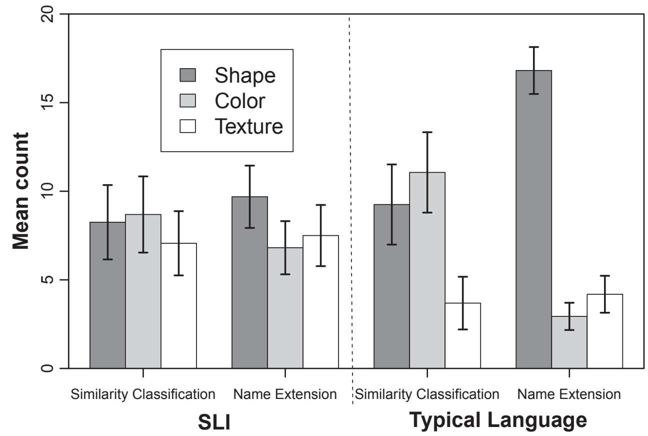

Figure 2 *Frequencies of different choices in the Similarity Classification and Novel Name Extension tasks. Error bars indicate standard error. SLI = Specific Language Impairment, Typical Language = children with typical language equated with the SLI group on age, sex, SES, and nonverbal IQ (see text for details).*

Experiment 2

A variety of experimental paradigms demonstrate that children with SLI show weaknesses in word learning. In fast-mapping contexts, children with SLI perform below typically developing peers (Dollaghan, 1987) or require more exposures before demonstrating similar patterns of recognition and production (Rice *et al.*, 1990; Rice, Buhr & Oetting, 1992). In contexts where novel words are introduced via multiple exposures with corrective

[4] Readers may wonder why we provide trendlines for the SLI and TL-equated groups, and one for all children (SLI, TL-equated, TL-excluded), a practice we follow in later figures as well. We do this because linguistic and nonlinguistic abilities are continuous between TL and SLI children; there are not categorical differences in performance (children at the high end of the SLI range and children at the low end of the TL range pattern very similarly). Following the conventional practice of comparing our clinical group to an equated sample of children with typical language development is crucial for our experimental comparisons. One might question why we include the non-equated TL children for any analyses, given that factors such as SES and age vary more widely in that sample. For regression-based examinations of how performance on standardized and experimental measures relate to one another, including the non-equated TL children provides greater statistical power and an opportunity to observe how strongly relationships among variables generalize to a larger sample, despite the greater heterogeneity in subject variables.

[5] Given that Smith and Samuelson (1999) found that children who had fewer than approximately 150 nouns in their productive vocabularies were unlikely to exhibit the shape bias, one might worry that children in our SLI sample might not have reached that threshold. While we did not include a direct measure of productive vocabulary, we can extrapolate from our measure of receptive vocabulary. Our youngest TL and SLI children were 42 and 43 months, respectively. Their PPVT-4 standard scores were 91 and 94, respectively, placing them both within the average range and near the 30th percentile (29th and 34th, respectively). Now consider comparable percentiles from the MacArthur-Bates Communicative Development Inventories (Second Edition) expressive vocabulary norms for much younger children – 30-month-olds. The productive vocabulary norm for 30-month-old children at the 30th percentile is 443 words. Given that nouns constitute approximately 50% of young children's vocabularies (Tardif, Gelman & Xu, 1999), we can be confident that 30-month children at the 30th percentile would know more than 150 nouns. Given that our youngest children were a year older than this, we are confident that even the youngest children in our samples were well beyond the 150-noun mark.

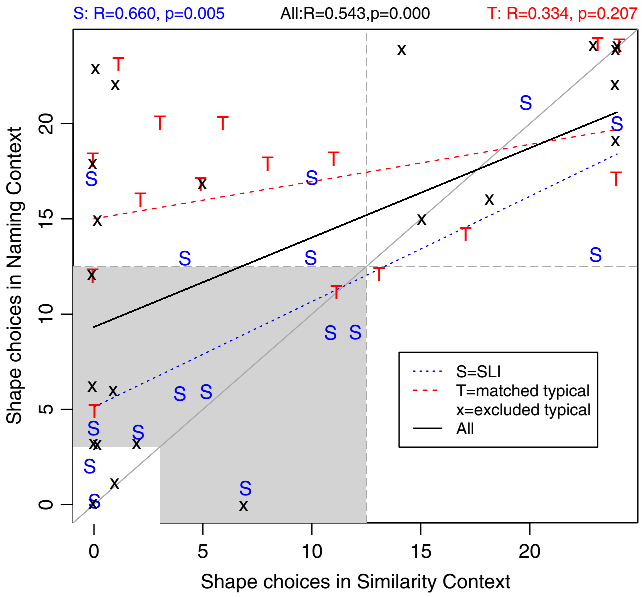

Figure 3 *Individual performance in Experiment 1; shape choices in the Similarity task compared to those in the Naming task. Horizontal and vertical dashed lines show the chi-square threshold for a single participant to show a significant shape bias in either task. The white square at lower-left delimits the complementary limits for showing a reliable anti-shape bias.*

feedback, children with SLI require significantly more trials to comprehend and produce novel words (Gray, 2003). These various paradigms were designed to investigate whether children with SLI could acquire new words as readily as children with TL. As with the shape bias paradigm, however, these paradigms cannot differentiate the relative contribution of potential deficits in *linguistic* processing, memory, or learning vs. *visual* processing, memory or learning. While several studies have suggested that phonological deficits may impede mapping auditory forms to meaning for children with SLI (Archibald & Gathercole, 2006; Gathercole & Baddeley, 1990), less is known about the nature of the visual associations. Weaknesses in word learning in SLI could result from faulty phonology; however, it is possible that deficits in visual memory or learning would exacerbate linguistic weaknesses to make it difficult for a child with SLI to detect linguistic-pragmatic-visual contingencies thought to support the shape bias (Smith, 2001). One way to disentangle the relative contributions of linguistic and visual learning abilities is to investigate children's ability to form associations in a single domain.

Converging lines of evidence suggest that children with SLI may be at a disadvantage in learning visual associations. For example, Powell and Bishop (1992) found poorer visual discrimination in 6–12-year-old children with SLI. Similarly, Hoffman and Gillam (2004) found weaker visual recall abilities in 8–11-year-old children with SLI in visual memory under varying task conditions (e.g. presentation rate). In contrast, Lum, Gelgic and Conti-Ramsden (2010) found that children with SLI (7;3 to 8;4 years) performed comparably to typically developing controls in a visual memory test (Paired Associates Learning, PAL), a norm-referenced measure from the Cambridge Neuropsychological Testing Automated Battery (CANTAB), but the children with SLI performed significantly worse in verbal associate learning. They concluded that visual memory abilities may not be impacted as much as verbal memory in SLI. These results conflict with Hoffman and Gillam (2004), who concluded that school-aged children with SLI *do* exhibit visual recall difficulties. It is possible that the discrepancy is a consequence of ceiling effects in the Lum *et al.* study, since different tasks were used in the two studies.

We are aware of only one study of visual processing in preschool children with SLI. Bavin *et al.* (2005) used the same Paired Associates Learning task as Lum *et al.* (2010) to compare visual memory abilities of preschool children with SLI (4–5 years) to age-matched typically developing counterparts. Among these younger participants, children with SLI took longer than controls to learn. Thus, preschoolers with SLI are likely to show weakness in visual learning. This suggests that weaknesses in visual processing, memory, and/or learning may compound – or partially underlie – linguistic weaknesses in SLI. Given Smith's (e.g. 2001) theory that the shape bias emerges when children become sensitive to statistical regularities between visual and linguistic information, our goal in Experiment 2 was to design a simple task that would allow us to isolate visual mapping and learning abilities. If a child is impaired in simple visual learning, it is likely that that child would be similarly impaired in the multimodal learning required to detect the relationship between shape and object naming. Specifically, we used a paired visual associate (PVA) learning task to test this hypothesis.

Method

Participants

The same participants from Experiment 1 participated in Experiment 2, with the exceptions of one child with SLI, one child from the equated-TL group, and six from the excluded TL participants, with whom we piloted a slightly different PVA task that was too difficult. Removing these children from Experiment 1 does not change the patterns of significance in our group equating (Table 1) or experimental results.

Materials and apparatus

Stimuli were 10 color picture–symbol pairs. Color clipart pictures depicted novel artifacts with no readily associable label, and symbols were arcane, esoteric items unfamiliar to young children. These were selected from an initial set of 43 pictures and 20 symbols that were pretested with five typically developing children (ages 4–9), who were asked to generate labels for each item. Items that even one child could label were removed. From the remaining set, we chose 10 pictures and 10 symbols we gauged to be particularly unnamable by young children (the full set is shown in Figure 4). We combined them in two sets of random pairings to mitigate the influence of any accidental associations we may have failed to detect. Stimuli were presented to the children on a laptop with a 15″ display, using DirectRT™ (Version 2008, 1.0.13, Empirisoft Corporation, New York). The picture and symbol stimuli were 3″ × 3″ in diameter.

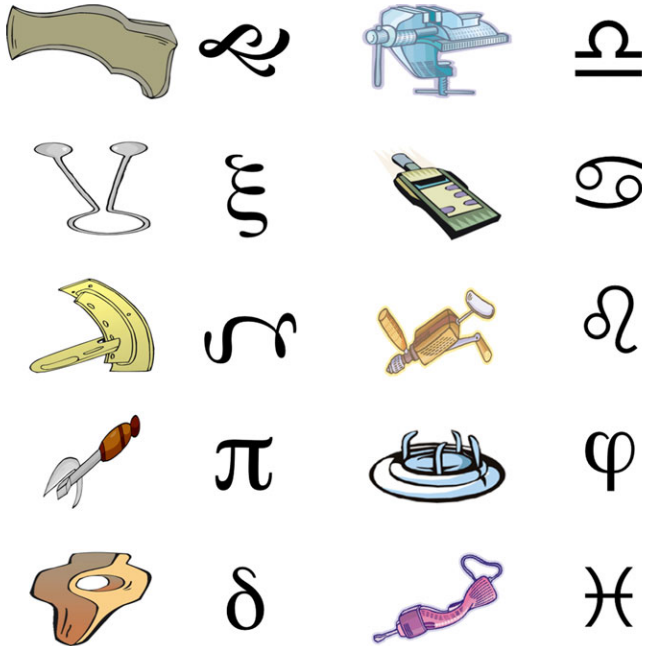

Figure 4 *One set of paired images used in Experiment 2.*

Procedure

Exposure phase. Each child was seated in front of a laptop computer in a work space cleared of any distractions. The task was introduced with a general phrase such as: 'Now we are going to do something cool on the computer'. Children were first shown an image of a 'secret agent', a novel object, and a novel symbol on the computer screen. They were advised that they would be 'secret agents' and would be required to remember which 'gadget' went with which 'code' (while the examiner pointed to each image in turn). Participants were informed that they would be asked to demonstrate how many 'codes' they remembered after seeing all the 'gadget' and 'code' pairs on the computer. While observing an example page depicting a novel image and symbol, the evaluator said, 'Today, you get to be a secret agent. Your job is to remember which gadget goes with which code. I am going to show them to you. When we are finished looking at all of the gadgets and all of the codes, we will see how many you remember. I want you to point to each gadget and each code like this [the examiner demonstrated by pointing first to the image on the left side followed by pointing to the symbol on the right side]. You do it [the examiner monitored the child point to the image on the left side of the screen and the symbol on the right side of the screen]. Remember to pay careful attention because I am going to ask you to remember them at the end. Are you ready?' All children demonstrated understanding by pointing to the example image and symbol during the instruction phase. No further explanation or practice was required. The exposure phase followed immediately. Ten image and symbol pairs were presented three times to the children in random order. On each trial the novel image and symbol were presented and remained on the screen for 4 seconds.

Testing phase. After the exposure phase, we used a two alternative forced choice paradigm without feedback to assess learning. We asked children to point to which of two symbols (presented simultaneously at the bottom of the laptop screen) went with the target image (presented at top center). Symbols were randomly assigned to left or right position. Foils were associates of other images. Each symbol appeared once with its target and once as a foil in each testing session. The examiner sat to the right of the child facing the screen and coded each response via keypress. Children were not given feedback about accuracy, but were reinforced for paying attention and staying on task with phrases such as, 'good job paying attention!' A research assistant, trained to administer the experimental task, sat directly behind the children facing the screen and double scored the child's responses by hand in real time. Ninety-nine percent (111/112) of tests were double scored. Point-by-point agreement was 97%. In the case of disagreement, the experimenter's score was used.

Additional exposure and testing sessions. To examine learning over time, we repeated exposure and test phases with the same 10 image–symbol pairs on three subsequent visits on three consecutive days for a total of four sessions. Presentation order in both exposure and test phases, as well as foil assignment, were randomized each day. Children were tested individually at their respective preschool, daycare, or home.

Results and discussion

Figure 5 plots accuracy by group on Days 1–4.[6] As can be seen, the TL group showed steady progress across Days, while the SLI group's average performance remained near chance even on Day 4. We began with a 2 (Group) × 4 (Day) ANOVA on count data (number correct). There was a main effect of Group ($F(1, 28) = 9.1$, $p = .005$, $\eta_p^2 = 0.17$), with children with SLI performing significantly worse ($M = 55\%$ [5.5 / 10] correct) than TL children ($M = 70\%$ [7 / 10]), but neither the main effect of Day ($F(3, 84) = 1.0$, $p = .378$) nor the interaction of Group and Day ($F(3, 84) < 1$) were significant, as children with SLI lagged consistently behind TL children. Thus, on average, children with SLI were impaired in learning simple visual associations. Next, we investigate to what degree individual differences in this task and in our standardized assessments provide insight into why most children with SLI and some children with TL failed to exhibit a shape bias in Experiment 1.

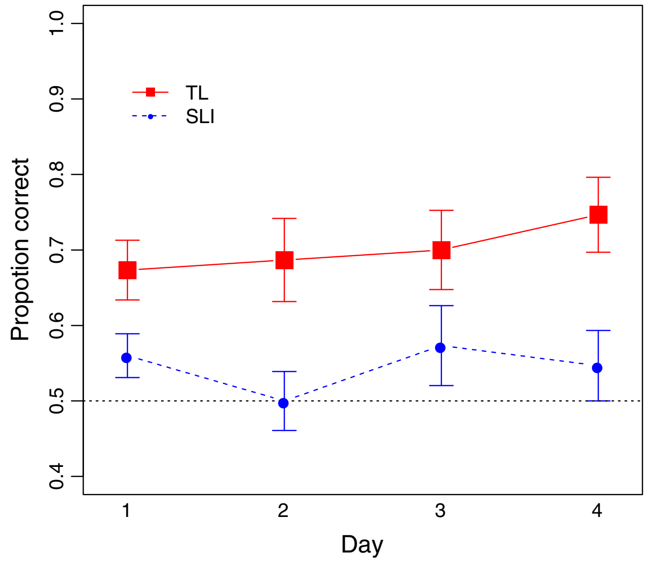

Figure 5 *Paired visual associate learning accuracy by Group and Day for the equated SLI and TL groups.*

Individual differences

Together, the standardized assessments we included for confirming our SLI vs. TL categories and the PVA task may provide a basis for digging deeper into possible bases for group differences in shape bias. In Table 2, we present correlations among participant variables (Age, SES), assessments, and experimental variables (shape choices in Similarity and Naming, and Day 4 performance in the paired visual associate learning). Correlations for children from both the SLI and equated-TL groups are above the diagonal; correlations below the diagonal include those groups as well as the additional 'unequated' TL individuals (TL-excluded). For the children in the SLI and equated-TL groups (above the diagonal), PPVT-4 and CELF-P2 are highly correlated (unsurprisingly, given that CELF-P2 includes a vocabulary subtest), but KABC-II NVI is not strongly related to either of them. Below the diagonal, which includes all children rather than just the equated groups, all three are related. For the equated groups, SES correlates significantly with PPVT-4, but not with variables that were used for matching and group assignment (KABC-II NVI and CELF-P2); below the diagonal, SES correlates with KABC-II, CELF-P2, and PPVT-4, as would be expected. SES does not correlate with experimental variables (Naming, PVA4).

Shape choices in Naming and Similarity contexts are also highly correlated.[7] With respect to participant variables, there is a trend towards a relationship between Naming and Age for the equated groups, which we shall consider shortly. For now, we note that since TL and SLI groups were equated on mean age and age range, Age cannot explain group differences in Naming; rather, this relationship indicates that, ignoring group, Age accounts

[6]Because we used two lists of random picture–symbol pairs, we tested for effects of List. There were no main effects of List, nor any interactions.

[7]It may seem like a simple change score (Naming minus Similarity) could provide a useful index of a shape bias. However, recall that the key aspect of the shape bias is generalization based on shape in Naming contexts. At young ages, group averages tend to demonstrate a strong contrast between Naming and Similarity – as we observed in Figure 2. However, there is a difficulty with a simple change score; several individuals would have change scores near zero despite making robustly greater-than-chance shape choices in Naming, because they made a similar number of shape choices in the Similarity task. Rather than suggesting that there is no bias for some individuals, in fact, these children are demonstrating an adult-like pattern, as adults tend to generalize based on shape in both Naming and Similarity contexts (Landau *et al.*, 1988). Thus, it does not make sense to describe children with greater-than-chance shape choices in Naming and similar shape choice rate in Similarity as failing to show an expected pattern; rather, those individuals are showing an advanced pattern. Thus, we have included shape choices in both Similarity and Naming rather than a change score.

Table 2 *Correlations among participant variables, assessment measures, and experimental measures*

	Age	SES	KABC	CELF	PPVT	Similarity	Naming	PVA4
Age		−0.29	0.09	.014	0.04	0.08	**0.31**$^{+}$	0.30
SES	−0.05		−0.20	0.17	**0.51****	−0.04	0.09	0.08
KABC	0.10	**0.24**$^{+}$		0.24	0.14	0.17	0.23	0.18
CELF	**0.23**$^{+}$	**0.33***	**0.45*****		**0.78*****	−0.06	**0.43***	**0.46***
PPVT	0.21	**0.50*****	**0.45*****	**0.82*****		−0.18	0.29	**0.37***
Similarity	0.04	0.07	0.16	−0.05	−0.06		**0.46****	**0.35**$^{+}$
Naming	0.13	0.20	**0.25**$^{+}$	0.22	0.17	**0.54*****		**0.45***
PVA4	**0.40****	0.03	**0.26**$^{+}$	**0.44****	**0.40****	**0.38***	**0.42****	

Note Similarity and Naming are proportion shape choices in those two tasks; PVA4 is proportion correct in the paired visual associate task on Day 4. Values above the diagonal are for the equated SLI and TL groups. Values below the diagonal are based on all participants, including the 22 children with TL not included in the equated group. Those correlations in bold are considered significant at the following levels: ***$p < .001$; **$p < .01$; *$p < .05$; $^{+}p < .10$.

for a moderate amount of variance in shape choices in Naming for the equated groups, but this relationship dissipates with the larger and more variable sample below the diagonal.

Finally, Day 4 PVA performance correlates with CELF-P2, PPVT-4, and Naming, with a trend towards a relationship with Similarity above the diagonal (for equated groups), and a similar pattern below the diagonal (unequated-TL children added to the equated groups), though with strengthened relationships with Similarity (significant) and KABC-II NVI ($p < .10$). It is possible that PVA ability derives from linguistic ability; perhaps children who perform best on PVA exploit phonological recoding by assigning names to novel objects. This seems implausible, however, given the steps we took to remove label-able items, and that items could not be considered easily nameable. Furthermore, on Day 5, a subsample of 13 children were asked to label the images. Responses provided by these children (e.g. 'don't know','thing', 'can't make up a name') suggested that they were not able to employ metalinguistic strategies in this task. We find it more plausible that general ability in associative learning would promote language development, and possible that the relationship between PVA and shape choices indicates that weaker associational learning ability results in weakness in detecting the visual-linguistic covariation assumed to underlie the shape bias (Smith, 2001).

We used multiple regression to assess whether Naming performance was best predicted by language variables, nonverbal intelligence, paired visual associate learning, or a combination. Caution is required in selecting predictors for the regression, given the low ratio of subjects to predictors, and multicollinearity among predictors. To increase power, and to avoid missing range issues (i.e. the equated-TL and SLI groups were selected to have a gap in language ability between the groups), we included all children who had completed the fourth day in the PVA task ($n = 45$) in the regression.

Based on the zero-order correlations in the lower diagonal of Table 2, the most plausible variables to include would be KABC-II, CELF-P2, and PVA4. Figure 6 plots shape choices in Naming as a function of these variables. Recall the chain of logic behind the shape bias: it emerges when a child detects the coherent covariation between shape and naming contexts; detecting this regularity requires a solid foundation of perceptual ability and learning. An extreme prediction from this perspective would be that PVA4 should predict shape bias better than other variables. Indeed, a model predicting shape choices in Naming that includes only PVA4 ($F(1, 43) = 5.78$, $p = .021$; $r^2 = 0.120$, adjusted $r^2 = 0.098$) performs better than a simultaneous model including all three variables ($F(3, 41) = 2.29$, $p = .093$; $r^2 = 0.143$, adjusted $r^2 = 0.081$), hierarchical models with KABC-II or CELF-P2 entered first ($ps > .14$), or models including only those variables ($ps > .08$). Further, no model accounted for more variance than the model including only PVA4 (indexed by adjusted r^2).

As can be seen in Figure 6 (bottom panel), despite a strong predictive relationship between Naming and PVA for most children, there is a small cluster who do not pattern with the others. Although we have too few cases to draw strong inferences about small clusters, there are nine children who made fewer than 7 Naming shape choices and yet had PVA accuracy greater than 0.6, and thus appear to deviate from the overall pattern. We examined all measures for these children, but there was nothing that systematically set them apart, except that they all also made very few shape choices in the Similarity context (range: 0–7, mean: 2.3). While it appears that PVA ability may be unconnected to shape choices of children who fail to rely on shape in either Similarity or Naming, we can only note this as a puzzle to be addressed in future research, given too few cases for robust analysis.

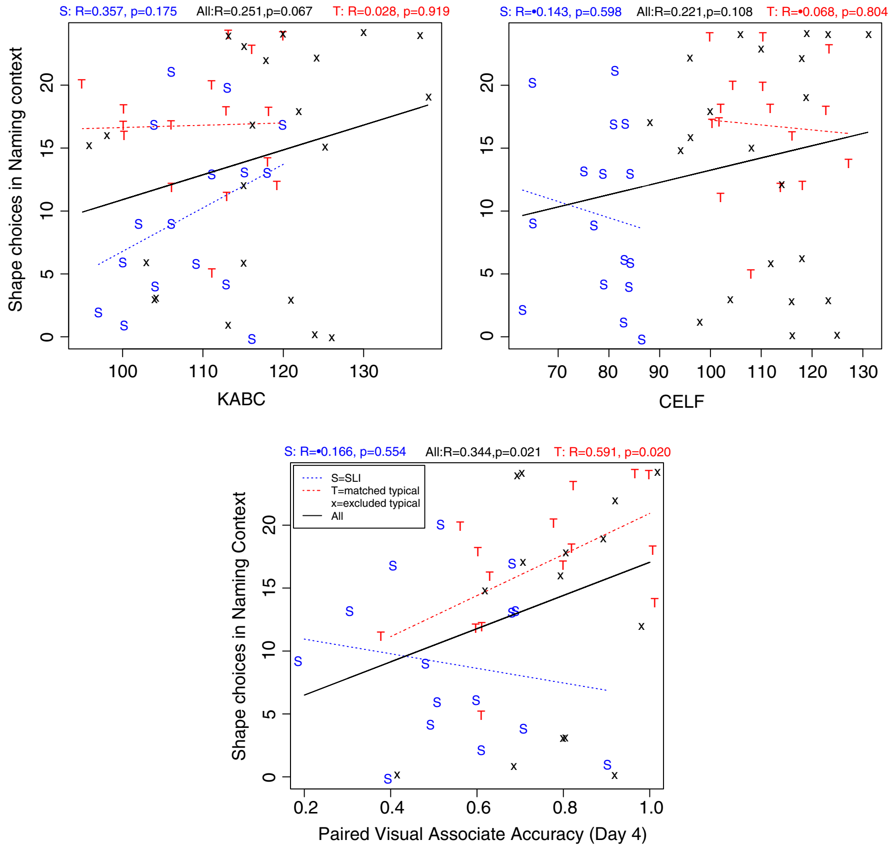

Figure 6 *Individual differences in Naming as function of KABC, CELF, and PVA. Data points are jittered to reveal coincident points. S = Specific Language Impairment; T = Typical Language Matched; x = Typical Language Excluded (not included in the equated sample). Dotted lines indicate best fit for the S observations. Dashed lines indicate best fit for T observations. Solid lines indicate fit for all observations (S, T, x).*

However, when considering the full sample, paired visual associate learning ability provided the best prediction of Naming, and including language or nonverbal intelligence measures actually decreased fit. The results of Experiment 1 suggest that children with SLI differ from equated-TL children in their ability to apply the constraints on object learning afforded by the shape bias. Experiment 2 suggests that children with SLI also differ from equated-TL peers in their ability to form visual associations. The analyses of individual differences suggest a firmer link between paired visual associate learning and Naming, since the best model of Naming includes only PVA4.

General discussion

It is well established that infants, children and adults with typical language (TL) development exhibit a shape bias in word learning: when syntactic cues indicate that a novel word is the name of a present object, they predominantly generalize the name to objects that share shape (rather than color, texture, or other properties) with the first object (Landau *et al.*, 1988). This is only one aspect of attentional learning, however; children also learn more complex contingencies between linguistic and nonlinguistic dimensions, such as the presence of eyes indicates animacy and that animate kinds are likely to share texture and other material properties in addition to shape (Jones *et al.*, 1991), or that non-solid kinds are more likely to share material properties than shape (Soja *et al.*, 1991). While previous studies have indicated that children with Autism Spectrum Disorder (Tek *et al.*, 2008) and late talkers (Jones, 2003) show a reduced or absent shape bias, the current study is the first to examine this question in children diagnosed with SLI. We also used a broad set of standardized assessments of language and perceptual abilities to investigate individual differences in the experimental tasks.

Our first objective was to investigate whether preschool children with SLI exhibit the shape bias observed in preschool children with TL. We did this by testing all participants in object extension conditions, where linguistic cues (i.e. adjective phrase syntax) signaled a similarity classification context vs. one where linguistic cues (i.e. noun phrase syntax) signaled a word learning context. On average, preschool children with SLI tended not to be able to exploit this distinction. Instead, they extended roughly equally based on shape, color, and texture in both similarity classification and novel name extension. Children with TL demonstrated dramatic increases in shape choices in novel name extension compared to similarity classification.

Our second objective was to examine whether children with SLI differ from equated peers in simple paired visual associate learning. Our logic was that a weakness in picking up on visual regularities could impede a child's ability to detect contingencies between object properties and object names. In Experiment 2, we found that children with SLI performed much more poorly than equated-TL children on paired visual associate (PVA) learning. We then turned to analyses of individual differences in order to examine links between shape bias and visual learning in greater depth. Visual paired-associate learning predicted shape bias in children with SLI and typical language development better than measures of nonverbal intelligence or standard assessments of language ability.

Previous studies have identified positive correlations between the shape bias and vocabulary size (Gershkoff-Stowe & Smith, 2004; Graham & Diesendruck 2010). This association also held in our data. Yet, while preschool children with SLI often show vocabulary deficits, the hallmark characteristic of this impairment is extraordinary difficulty learning grammar (Leonard, 1998; Rice, 2003). In particular, they have difficulty mastering closed class forms (e.g. articles) and grammatical inflections (Leonard *et al.*, 1997). In contrast, an abundance of shape bias investigations highlight the remarkable sensitivity typically developing children display to subtle meaning changes signaled by closed class forms and their accompanying syntactic frames, and their ability to effectively use this information to guide word learning. Grammatical cues that very clearly signal a word learning opportunity to children with TL (e.g. 'this is *a* dax') may be incompletely processed by preschool children with SLI linguistically, impeding detection of a word learning context.

Our results also suggest, however, that linguistic factors alone may not account for differences in showing a shape bias between children with SLI and children with TL. Weaknesses in detecting visual or visual–auditory correlations could also impede a child from detecting word learning contexts. Of linguistic and nonlinguistic measures that best predicted degree of shape bias in the novel name extension task, the simplest regression model that could not be significantly improved by adding other factors included PVA performance only. This result underscores the need to look beyond linguistic abilities in order to fully understand the basis for word learning difficulties in children with SLI. Jones and Smith (2005) suggested that the reason why the late talkers in Jones' (2003) investigation failed to show a shape bias was that late talkers lagged behind their peers with typical lexical development in their perception and representation of shape. They tested this hypothesis by exposing late talkers and typically developing controls to real toys and matched abstract shape forms of each. While both groups recognized the real toys equally, the late talkers were delayed in their recognition of the abstract forms. Research describing subtle visual perceptual difficulties experienced by children with SLI (Powell & Bishop, 1992; McGregor, Neman, Reilly & Capone, 2002) reinforces the possiblity that preschool children with SLI are not able to fully exploit visual information characterizing objects in their environment and use it to assist in object word learning.

Theoretical accounts of SLI focus primarily on the auditory domain (e.g. Gathercole & Baddeley, 1990; Leonard, 1998; Tallal, Miller, Bedi, Buma, Wang, Nagarajan, Schreiner, Jenkins & Merzenich, 1996). However, many shape bias investigations with typical learners demonstrate that visual sensitivity to the perceptual properties of objects is also likely to be important to successful word learning (Smith, 2001, 2003; Samuelson & Horst, 2007). Our results also support this hypothesis. If preschool children with SLI do not process linguistic information efficiently, but also have difficulties in visual associative learning more generally, they will be unlikely to detect systematicities between modalities.

The importance of the shape bias to learning object words holds clinical potential for children with SLI because it identifies points of intervention for modifiable factors. In a study where young typical learners were guided to the shape bias earlier than is typically observed, by reinforcing the statistical regularities between object names and shape, object word learning outside the laboratory was accelerated (Smith *et al.*, 2002). A technique like this with very young children with language learning difficulties may produce the same positive object word learning influence. Whether the shape bias can be induced in preschool children with SLI, and more importantly, whether the shape bias has the effect of boosting their capacity to learn object words outside of the treatment room, is the focus of our continued investigations in this area.

Conclusions

A substantial number of preschool children with SLI struggle to learn words. Indeed, a limited productive vocabulary is often the first clinical sign that a child may be experiencing difficulty learning language. The underlying causes for the poor word learning observed in this population are not yet clearly understood. Our results suggest that preschool children with SLI are not able to rely on the shape bias that their peers with typical language development exploit early in development to make object name learning more efficient (Experiment 1). Our study of visual associative learning ability (Experiment 2) revealed that children with SLI also demonstrate weakness in picking up visual regularities even when isolated within the visual modality alone. Consistent with the attentional learning account of Smith and colleagues, our results suggest that successful emergence of the shape bias depends on the interplay of linguistic and visual information, and lend support to the hypothesis that both sources of information, along with associative learning, may be compromised in children with SLI. Consequently, detection of regularities within and between modalities may contribute to poor word learning in this population. This raises the possibility that interventions designed to highlight the utility of shape for object naming could have a beneficial impact on word learning in children with SLI.

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