

The Shape Bias Shapes More Than Just Attention: Relationships Between Categorical Biases & Object Recognition Memory

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Abstract

The “shape bias” describes the finding that, starting around 24 months of age, children generalize object categories based upon shape to a greater degree than other perceptual features. To date, research on the shape bias has consisted of debates about how attentional mechanisms engender the development of the shape bias. The current work moves beyond theoretical explanations grounded in attention processes and examines potential consequences of the shape bias in memory processes. In this experiment, children and adults’ memory performance for features of objects was examined in relation to their categorical biases. The results of the experiment demonstrated that, across the lifespan, learners with a shape bias were more likely to remember the shape of objects than they were the color and size. Taken together, this work suggests the development of a shape bias may lead to more than just differences in attention to features of objects, but a memory bias for shape information.

Keywords: shape bias; object recognition memory; word learning; categorization; language and cognitive development

Introduction

Categorization is a central process in human cognition and development. As a result, much research has examined the developing ability to categorize the world. In particular, research has examined the children’s ability to categorize objects and generalize this information to novel objects. Children’s categorization of objects has been described as particularly impressive because there are a seemingly infinite number of ways that objects in the world can be partitioned and generalized.

One explanation for how children develop the ability to categorize objects is that they acquire categorical biases, which are used to narrow the possible ways in which objects can be categorized. An example of one of these biases is the “shape bias”, which describes the finding that, starting around 24 months of age, learners generalize object categories based upon shape to a greater degree than other perceptual features (Baldwin, 1992; Colunga & Smith, 2008; Gershkoff-Stowe & Smith, 2004; Landau, Smith, & Jones, 1988; Samuelson, 2002; Perry & Samuelson, 2011). In a typical paradigm (e.g., Landau et al., 1988), participants are presented with a novel object and a novel linguistic label (e.g., “toma”). Participants are then presented with three additional objects, one that matches the target object’s shape and two additional objects that match one of the target object’s other dimensions, such as color, size, or texture. The experimenter then prompts participants to pick which one of the three objects is also a “toma”. The majority of

children and adults will pick the shape match over the color, size, or texture match, suggesting that learners assume shape is a more defining feature of object categories than other perceptual features.

To date, the shape bias literature largely consists of arguments regarding the types of information children attend to during categorization and generalization, such as perceptual, linguistic, or conceptual information (for an overview of extant theories, see Samuelson & Bloom, 2008). As an example, according to the Attentional Learning Account (ALA) of the shape bias (e.g., Colunga & Smith, 2008), attention is shifted to properties of objects that have historically been relevant for the task context. The relevant properties of objects are likely to be determined by statistical regularities amongst perceptual features of objects. That is, children’s early experiences learning words and categories leads them to notice statistical regularities amongst objects (e.g., shape), enabling children to shift attention to these regularities and make generalizations from the categories they know to novel categories.

Given the focus on attentional processes, the shape bias literature has a striking limitation: this work has focused on the information that children attend to when comparing multiple objects in one moment in time. In real-world learning situations, there are likely to be frequent temporal gaps between encountering a new object and subsequently generalizing to a second object of the same category. However, little research has examined how learners access their learning history (i.e., when the first object is no longer in the learner’s view) and how this ability relates to categorization and generalization. Indeed, a central tenant of all theoretical accounts of the shape bias is that learners access and use their learning history to guide generalization across time (for a discussion, see Keil, 2008). Consequently, it is essential to understand how learners remember and retrieve information about objects across time. Rather than argue for one theory over the other, this work moves beyond arguments of what is attended to in-the-moment, but what is retained across time.

The current work builds upon the existing literature by examining categorical biases in relationship to learners’ memory for perceptual features of objects. As proposed by extant theories, such as the ALA account, the shape bias creates enhanced attention to shape (e.g., Colunga & Smith, 2008). The hypothesis is this work is that enhanced attention to shape has consequences beyond in-the-moment processing of objects. In particular, it is predicted that enhanced attention leads to the ability to remember shape to a greater degree than other perceptual features of objects.

That is, the development of a shape bias engenders a memory bias for shape information.

If the development of a shape bias engenders a memory bias for shape information, we would expect to observe differences in how learners remember shape information after being presented with an object. For example, for learners that demonstrate a shape bias, we would expect to see higher memory performance for shape than other perceptual features. Moreover, for learners that do not demonstrate a shape bias, we would not expect to see higher memory performance for shape, but perhaps higher memory performance for other perceptual features. Observing these findings would suggest that there is a relationship between the shape bias and the ability to retrieve information over time. Indeed, recent research has suggest that memory processes, such as forgetting and retrieval, are critical processes in children's categorization and generalization of objects (Vlach, et al., 2008, 2012).

Alternatively, the shape bias may be limited to an in-the-moment attentional phenomenon, without resulting in differences in memory performance. Recent eye-tracking studies have demonstrated that increases in children's visual attention to objects is not necessarily related to increased memory for objects (Smith & Yu, 2013; Vlach & Johnson, 2013). Thus, enhanced attention to the shape of objects may not necessarily lead to enhanced memory for shape information. This finding would suggest that cognitive processes other than memory for features are contributing to the observed relationship between the shape bias and language and cognitive development. The current experiment was designed to examine these possibilities.

Current Study

In this experiment, children and adults' memory for features of objects was examined in a series of object memory trials. Memory for three visual features of objects was tested: shape, color, and size. The features were chosen because they are features that have been used in previous studies of the shape bias (e.g., Landau et al., 1988). Memory performance was assessed on three timescales: immediately after learning, after a 2 minute delay, and after a 5 minute delay. These timescales were chosen to mirror delays used to previous studies of young children's memory (e.g., Vlach et al., 2008) and to elucidate the ability to retrieve information immediately after being presenting with an object and when accessing objects from long-term memory.

This experiment was designed to examine the developing ability to remember and retrieve perceptual features of objects across time. In particular, this experiment sought to elucidate whether differences in memory performance were related to learners' categorical biases, such as a shape bias. Thus, this experiment examined memory and categorization during the onset of the shape bias, starting around 24 months of age (e.g., Landau et al., 1988; Smith et al., 2002), and during a time period in which almost all learners demonstrate a persistent shape bias, adulthood (e.g., Landau et al., 1988).

Method

Participants

The participants were 18, 24-36-month-old children and 40 adults. All children were monolingual English speakers and recruited from local daycare centers. Adult participants were undergraduate students recruited from the department's subject pool.

Apparatus & Stimuli

Participants were presented with all tasks on an iPad. Stimuli for the tasks, 2D objects, were constructed in Adobe Photoshop. Objects were designed so that, when necessary for the task, objects were exact shape matches, exact color matches, and exact size matches (i.e., same number of pixels). Examples of these objects can be seen in Figure 1.

Procedure

Participants were presented with two tasks: a feature memory task and a shape bias task. The order of these tasks was counterbalanced across participants. The order of the trials within each task was randomly assigned.

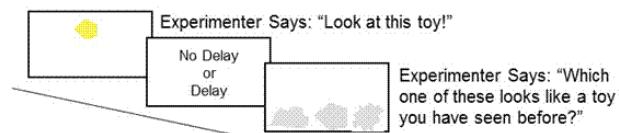
Feature Memory Task. Participants were presented feature memory trials for shape, color, and size. Participants' memory for the features was tested on three timescales: immediately after learning, after a 2-minute delay, and after a 5-minute delay. Thus, there were a total of nine trials in the feature memory task.

In each trial, participants were presented with a target object (see Figure 1, for an example). The experimenter would say, "Look at this toy!". The experimenter would then prompt the iPad to pull up a blank screen. In the immediate testing trials, the experimenter would proceed directly to the testing screen. In the 2-minute delay and 5-minute delay trials, the experimenter would present participants with a distractor task. Child participants were given the option to put stickers on paper and/or play with Play-doh for the delay period. Adult participants played Angry Birds for the delay period. After the distractor task/testing delay, the experimenter would proceed to the testing screen.

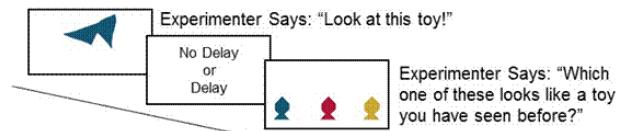
The testing component of each trial consisted of three objects (see Figure 1). One of the three objects matched the target object, but only matched on one feature. As a result, each testing trial assessed participants' memory for one feature of the object seen previously in the trial. For example, in color memory trials, all of the objects would be the same shape and size, but a different shape and size than the target object. The only dimension on which the three objects differed was color; one of the test objects had the same color as the target object. Consequently, participants could only respond correctly if they remembered the color of the target object. After presenting the three testing objects, the experimenter would say, "Which of these looks like a toy you have seen before?" and then point in the general direction of the screen. The experimenter recorded

Feature Memory Task: Example Trials

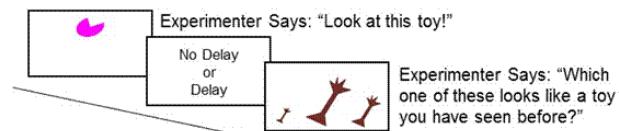
Shape Memory Trial



Color Memory Trial



Size Memory Trial



Shape Bias Task: Example Trial

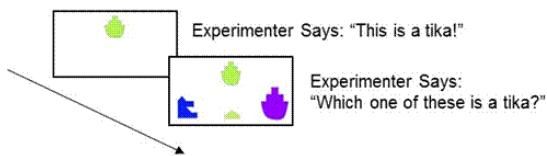


Figure 1. Examples of tasks in the experiment. The ordering of the tasks was counterbalanced across participants. The ordering of trials within each task was randomly assigned.

which object the participants chose and continued to the next trial of the task until all trials were complete.

Across the nine trials, the placement of the correct features (shape, color, and size) was counterbalanced across the trials. Additionally, the features used in this task were not repeated across trials (i.e., distinct shapes, colors, and sizes on each trial) nor used in the shape bias task.

Shape Bias Task. The shape bias task was modeled after tasks used in previous research (e.g., Landau et al., 1988). In each trial of the task (see Figure 1, for an example), participants were first shown an object and then provided with a novel linguistic label for that object. For example, the experimenter would say, "This is a tika!" and point to the target object on the screen.

After presenting the target object, the experimenter would prompt the iPad to display three test objects below the target object (see Figure 1). One object had the same shape as the target object, one object had the same color as the target object, and one object had the same size as the target object. The experimenter then asked the participants to infer which one of the three test objects was also a member of the same category as the target object. For example, the experimenter would say, "Which one of these toys is a tika?" and then point in the general direction of the screen. The experimenter recorded which object the

participants chose and continued to the next trial of the task until all trials were complete.

There were a total of nine trials in the shape bias task. The placement of the feature matches (shape, color, and size) was counterbalanced across the trials. Additionally, the features used in this task were not repeated across trials (i.e., distinct shapes, colors, and sizes on each trial) nor used in the feature memory task.

Results

Feature Memory Task Performance. A central goal of this experiment was to examine children and adult's memory for features of objects. Children and adults' memory performance for each of the three features was plotted across the three testing timescales, by feature (shape, color, and size). As can be seen in Figure 2, adults appeared to have overall higher memory performance for each feature than did the children.

To examine the differences across the age groups, a mixed repeated measures ANOVA was conducted with age (child or adult) as a between-subjects factor and testing delay (no delay, 2-minute delay, or 5-minute delay) and feature (shape, color, or size) as within-subjects factors. The results of this analysis revealed a main effect of age, $F(1, 56) = 27.948, p < .001$, a main effect of testing delay, $F(1, 56) = 7.376, p = .009$, and a main effect of feature, $F(1, 56) = 5.823, p = .019$. There was also a significant interaction of feature and age, $F(1, 56) = 4.186, p = .045$.

To examine the nature of the interaction, the data were separated by age group (children or adults). For the adults, a repeated measures ANOVA was conducted with testing delay (no delay, 2-minute delay, or 5-minute delay) and feature (shape, color, or size) as within-subjects factors. The results of this test revealed a marginally significant main effect of testing delay, $F(1, 39) = 7.376, p = .097$, and a main effect of feature, $F(1, 39) = 21.686, p < .001$. Next, a set of planned comparisons, with Bonferroni corrections, was used to examine differences in performance between the features. The corrected p-values are reported. These t-tests revealed that performance on the shape trials was significantly higher than the color trials at the no delay, $t(39) = 3.122, p = .003$, two minute delayed, $t(39) = 2.966, p = .005$, and five minute delayed tests, $t(39) = 3.204, p = .003$. Performance on the shape trials was also significantly higher than the size trials at the no delay, $t(39) = 4.333, p < .001$, two minute delayed, $t(39) = 4.149, p < .001$, and five minute delayed tests, $t(39) = 4.149, p < .001$. There were no significant differences in performance between the color and size trials at each testing delay, $ps > .10$.

The same analysis was used for children's memory performance: a repeated measures ANOVA was conducted with testing delay (no delay, 2-minute delay, or 5-minute delay) and feature (shape, color, or size) as within-subjects factors. The results of this test revealed a main effect of testing delay, $F(1, 17) = 3.620, p = .046$, but no main effect of feature, $F(1, 17) = .031, p = .863$. Next, a set of planned comparisons, with Bonferroni corrections, was used to

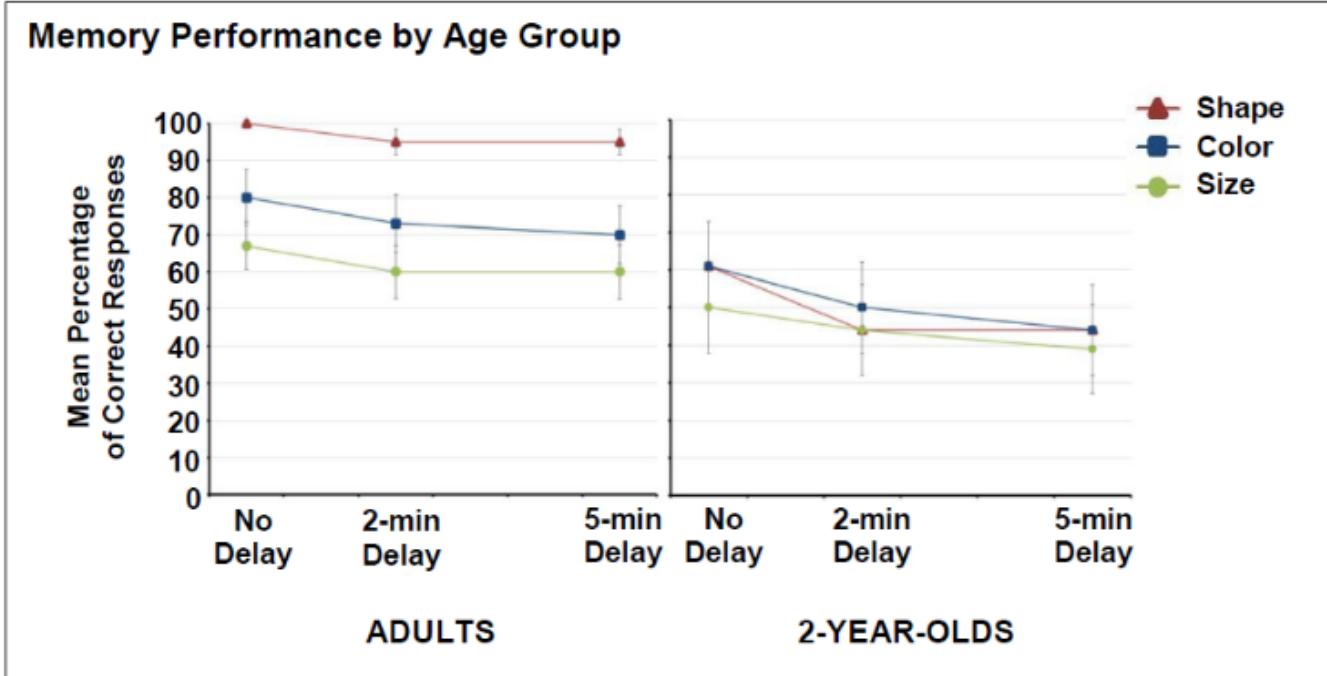


Figure 2. Mean percentage of correct responses on the feature memory task trials. Participants are grouped by age. Adults had significantly higher memory performance for shape than color and size. Conversely, 2-year-old children did not appear to have differences in memory performance across the three features. Error bars represent one standard error.

examine differences in performance across the testing delays within each feature. The corrected p-values are reported. These t-tests revealed that children had significantly higher performance on the immediate test for shape and color than on the 5 minute delayed test, $ps < .05$.

In sum, adult participants demonstrated significantly higher performance than children across the perceptual features. Moreover, adult participants demonstrated significantly higher memory performance for the shape of objects than the color or size of objects. Conversely, children did not demonstrate differences in memory performance between the three features.

Categorical Biases and Memory Performance. A second goal of this experiment was to examine whether participants' categorical biases, such as a shape bias, would affect memory performance for specific features of an object. It was predicted that learners demonstrating a shape bias would have higher memory performance for shape information than other perceptual features. Indeed, the results described above indicate that, on the group level, adults had higher memory for shape than other features.

First, each participant was classified as having/not having a categorical bias. There were a total of nine shape bias trials; to be classified as having a bias (e.g., a shape bias), participants would have chosen the particular feature match on more than half of the trials (e.g., choosing the shape match on 5 or more trials). Table 1 outlines the breakdown of bias by age group. All of the adult participants demonstrated a shape bias (replicating Landau et al., 1988) and thus these data were not re-analyzed. Children's performance for each of the three features was

plotted across the three testing timescales, by feature (shape, color, and size) and by categorical bias (shape vs. no/other bias). This data provided forgetting functions for each of the three perceptual features. As can be seen in Figure 3, there appeared to be differences in performance between the shape group and a no/other bias group.

Table 1: Number of participants with categorical biases by age group

Age Group	Shape	Color	Size	No Bias
2-year-olds	9	3	2	4
Adults	40	0	0	0

To examine the differences across the categorical bias groups, a mixed repeated measures ANOVA was conducted with bias (shape or no/other bias) as a between-subjects factor and testing delay (no delay, 2-minute delay, or 5-minute delay) and feature (shape, color, or size) as within-subjects factors. The results of this analysis revealed no significant main effects, but a significant interaction of feature and bias, $F(1, 16) = 6.969, p = .018$. To examine the nature of the interaction, the data were separated by categorical bias group (shape bias or no/other bias).

For the shape bias group, a repeated measures ANOVA was conducted with testing delay (no delay, 2-minute delay, or 5-minute delay) and feature (shape, color, or size) as within-subjects factors. The results of this test revealed a significant main effect of feature, $F(1, 8) = 4.558, p = .035$. Next, a set of planned comparisons, with Bonferroni corrections, was used to examine differences in performance

Children's Memory Performance by Categorical Bias

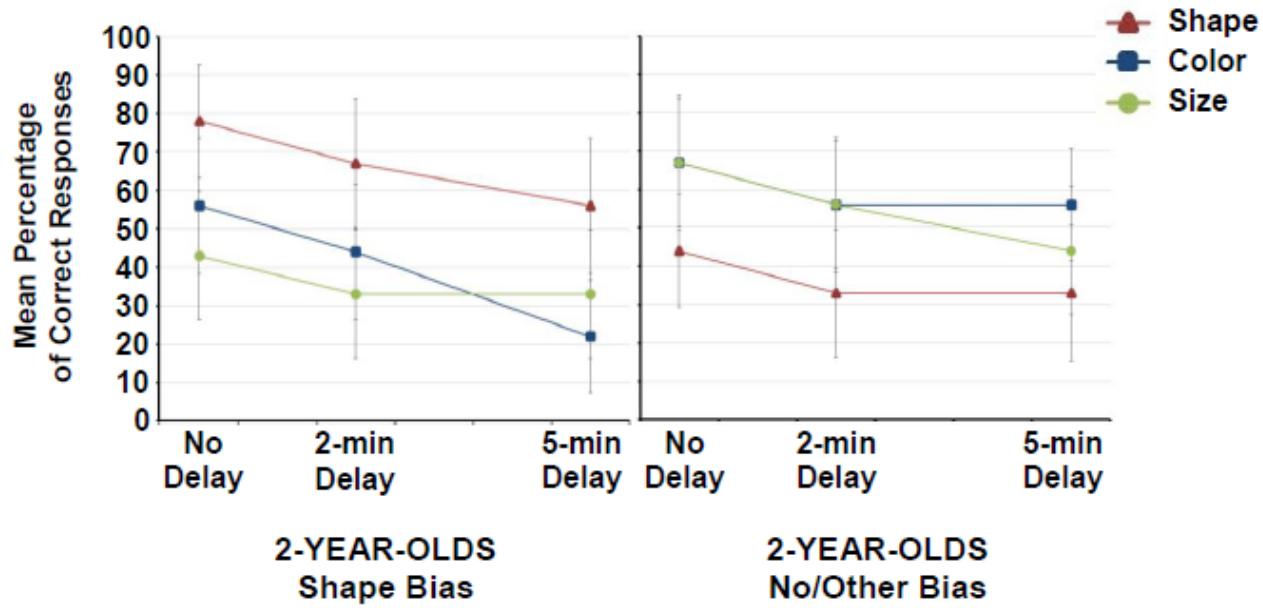


Figure 3. Mean percentage of correct responses on the feature memory task trials. Child participants are grouped by categorical bias (shape vs. no/other bias). On the group level, 2-year-old children did not appear to have differences in memory performance across the three features (see Figure 2). However, when grouped by categorical bias, children demonstrated significantly difference memory performance for the three features of objects. Error bars represent one standard error.

between the features. These t-tests revealed that performance on the shape trials was marginally significantly higher than the color trials at the no delay, $t(8) = 2.414$, $p = .097$, two minute delayed, $t(8) = 2.512$, $p = .086$, and five minute delayed tests, $t(8) = 2.414$, $p = .097$. Performance on the shape trials was also significantly higher than the size trials at the no delay, $t(8) = 2.414$, $p = .097$, two minute delayed, $t(8) = 2.414$, $p = .097$, and five minute delayed tests, $t(8) = 2.512$, $p = .086$. There were no significant differences in performance between the color and size trials at each testing delay, $ps > .10$.

A similar analysis was conducted for the no/other bias group: a repeated measures ANOVA was conducted with testing delay (no delay, 2-minute delay, or 5-minute delay) and feature (shape, color, or size) as within-subjects factors. The results of this test revealed a significant main effect of feature, $F(1, 8) = 3.667$, $p = .041$. Next, a set of planned comparisons, with Bonferroni corrections, was used to examine differences in performance between the features. These t-tests revealed that there were no significant differences in performance between the color and size trials at each testing delay, $ps > .10$. However, performance on the shape trials was marginally significantly lower than the color trials at the no delay, $t(8) = 2.414$, $p = .097$, and the size trials at the no delay test, $t(8) = 2.414$, $p = .097$.

In sum, on the group level, the 2-year-old children did not demonstrate differences in memory performance across the three features. However, when children were grouped by categorical bias (shape vs. no/other bias), there were

differences in memory performance between the features. In particular, children with a shape bias had significantly higher memory performance for shape than color and size. Conversely, children that did not have a shape bias had significantly higher memory performance for color and size than shape at the immediate test. These findings suggest that the development of an attentional bias may result in differences in the ways that learners remember the features of objects, as discussed below.

Discussion

The results of this experiment revealed developmental differences in memory abilities for features for objects. Overall, adults had higher memory performance than children. Adult participants demonstrated higher memory performance for shape than color and size. Moreover, all of the adult participants demonstrated a shape bias. Conversely, on the group level, 2-year-old children did not demonstrate differences in their memory abilities for perceptual features of objects or a consistent categorical bias. However, when children were divided into two groups (i.e., shape bias and no/other bias), those in the shape bias group had significantly higher memory performance for shape than children in the no/other bias group. In sum, the results of this experiment reveal evidence to support the hypothesis that learners have different memory abilities for perceptual features of objects and that the shape bias is related to these differences in memory performance.

How do the current results relate to extant theories of the shape bias? As mentioned in the Introduction section, the shape bias literature consists primarily of debates regarding which types of information children attend to when generalizing across objects in one moment in time. However, extant theories have many commonalities, such as the idea that learners access their learning histories when acquiring and generalizing object categories across time (Keil, 2008). The current experiments were designed to be a step in this direction – to begin to outline how the development of the shape bias may change the way that learners access knowledge about objects in the world.

Moreover, the results of the current experiments begin to bridge a gap in our understanding of how performance on an in-the-moment task, such as the shape bias task, relates to long-term developmental outcomes across years at a time. The shape bias and/or lack of shape bias has been linked to several long-term developmental outcomes in language development and categorization (Gershkoff-Stowe & Smith, 2004; Jones, 2003; Perry & Samuelson, 2011; Samuelson, 2002; Tek, Jaffery, Fein, & Naigles, 2008). For example, individual differences in children's early productive vocabulary predict the type of categorical bias that they acquire and performance on a novel noun generalization task (Perry & Samuelson, 2011). Moreover, providing children with shape category training can engender an early shape bias, resulting in marked increases in vocabulary growth (Samuelson, 2002). Finally, children with atypical language development often do not demonstrate a robust shape bias (Jones, 2003; Tek et al., 2008).

Why do we observe that the shape bias is related to these long-term outcomes in language and cognitive development? This work identifies one potential mechanism to explain the relationship between the shape bias and long-term developmental outcomes in language and cognitive development: enhanced memory for shape over other perceptual features of objects over time. That is, the development of the shape bias may engender a memory bias for shape information.

How does a memory bias for shape promote children's categorization and generalization? A memory bias for shape allows learners more readily retrieve shape information than other types of information, such as other perceptual features of objects. Thus, when encountering new category exemplars at later points in time, learners are more likely to remember the shape of previous category exemplars and may more readily generalize based upon this feature than other perceptual features. Indeed, what we remember may influence how we categorize the world, and our developing organization of our experiences may change how we remember information. This bi-directional, circular process between memory and categorization may result in the development of a memory system that mirrors the ways in which we categorize the world, supporting our ability to generalize knowledge across moments in time.

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