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How we categorize objects is related to how we remember them: The shape bias as a memory bias

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Abstract

The “shape bias” describes the phenomenon that, after a certain point in development, children and adults generalize object categories based upon shape to a greater degree than other perceptual features. The focus of research on the shape bias has been to examine the types of information that learners attend to in one moment in time. The current work takes a different approach by examining whether learners' categorical biases are related to their retention of information across time. In three experiments, children's ($N = 72$) and adults' ($N = 240$) memory performance for features of objects was examined in relation to their categorical biases. The results of these experiments demonstrated that the number of shape matches chosen during the shape bias task significantly predicted shape memory. Moreover, children and adults with a shape bias were more likely to remember the shape of objects than they were the color and size of objects. Taken together, this work suggests the development of a shape bias may engender better memory for shape information.

Keywords

word learning; categorization; novel-noun generalization; language development; cognitive development

Categorization and generalization are fundamental processes in human cognition. As a result, much research has examined the developing ability to categorize objects and generalize this information to novel objects. Children's ability to categorize objects has been described as particularly impressive because there are a seemingly infinite number of ways that objects in the world can be partitioned. How do children acquire and generalize object categories?

One proposal has been that children develop 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, after a certain point in development, learners generalize named object categories based upon shape to a greater degree than other

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perceptual features (Baldwin, 1992; Colunga & Smith, 2008; Diesendruck & Bloom, 2003; Gershkoff-Stowe & Smith, 2004; Hupp, 2008; Imai, Gentner, & Uchida, 1994; Landau, Smith, & Jones, 1988; Samuelson, 2002; Smith, Jones, Gershkoff-Stowe, & Samuelson, 2002; Perry & Samuelson, 2011; Yee, Jones, & Smith, 2012; Yoshida & Smith, 2003). 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 simultaneously 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. While all four objects are in the learner's view, the experimenter then prompts participants to pick which one of the three unnamed objects is also a “toma”. Many children above the age of two and most 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.

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 theories, see Samuelson & Bloom, 2008). As an example, according to the Attentional Learning Account (ALA) of the shape bias (e.g., Colunga & Smith, 2008; Samuelson & Horst, 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 among perceptual features of objects, language (e.g., linguistic labels), and categorical organization (e.g., relations between categories). That is, children's early experiences learning words and categories leads them to notice statistical regularities among objects (e.g., shape), enabling children to shift attention to these regularities when comparing multiple novel objects. In brief, the ALA account proposes that learners with a shape bias have learned to allocate more attention to shape than other perceptual features of objects.

The shape bias has been linked to several long-term outcomes in language development and categorization (Gershkoff-Stowe & Smith, 2004; Jones, 2003; Perry & Samuelson, 2011; Perry, Samuelson, Malloy, & Schiffer, 2010; Samuelson, 2002; Smith et al., 2002). 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; Smith et al., 2002). Given that the shape bias has been linked to several long-term outcomes, it is important to outline the mechanisms that give rise to the relation between the shape bias and cognitive development (for a discussion, see Perry & Samuelson, 2011). That is, how does the shape bias promote word learning and categorization across time?

To date, 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 (Horst & Samuelson, 2008; McMurray, Horst, & Samuelson, 2012; Vlach,

Sandhofer, & Kornell, 2008). 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 (for recent exceptions, see Perry, Axelsson, & Horst, 2015; Perry & Saffran, 2016). Indeed, a central tenet of all theoretical accounts of the shape bias is that learners access and use their learning history to guide generalization across time (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 (i.e., perceptual vs. conceptual/linguistic information), but what is retained across time.

The current work builds upon the existing literature by examining categorical biases in relation to learners' memory for perceptual features of objects. As proposed by current theories, such as ALA, the shape bias creates enhanced attention to shape in the moment of categorization and generalization (e.g., Colunga & Smith, 2008; Samuelson & Horst, 2008). The hypothesis in this work is that the development of the shape bias has consequences beyond in-the-moment attention, categorization, and generalization. In particular, it is predicted that learners' categorical bias (e.g., shape bias) will be related to their memory for 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 who demonstrate a shape bias, we would expect to see better memory performance for shape than other perceptual features.

Moreover, for learners who do not demonstrate a shape bias, we would not expect to see better memory performance for shape, but perhaps better memory performance for other perceptual features. Observing these findings would suggest that the ability to retrieve information over time may be a mechanism underlying the relation between the shape bias and cognitive development. Indeed, recent research has suggested that forgetting and retrieving information are critical processes in children's categorization of objects (Vlach, et al., 2008; Vlach, Sandhofer & Bjork, 2014; Vlach, Ankowski, & Sandhofer, 2012). In particular, having higher retention for features that are likely to be more relevant to categorization (i.e., shape) and lower retention of features that are likely to be less relevant to categorization (i.e., size) can promote generalization (forgetting-as-abstraction account; Vlach, 2014).

Alternatively, the shape bias may not be related to learners' memory for perceptual features of objects. Although this hypothesis is not particularly compelling, there is some evidence to support this claim. Previous research has shown that children's and adults' selective visual attention to whole objects does not necessarily result in better memory at test (Fitneva & Christiansen, 2011; Smith & Yu, 2013; Vlach & Johnson, 2013). Moreover, research has demonstrated that drawing attention to individual object features also does not necessarily result in better memory at test. For instance, in one study (Holland, Simpson, & Riggs, 2015), an experimenter guided children's attention to object features, such as shape or color, while learning a novel label ('koba') for that object feature. At a one week delayed test,

children did not remember shape words better than color or texture words. Thus, allocating more attention, and more attention to shape, during learning may not be related to better memory for shape information. This finding would suggest that other cognitive processes, such as general improvements in cognitive abilities across development (i.e., age), contribute to the observed relation between the shape bias and subsequent developments in language and categorization. The current experiments were designed to examine these possibilities.

The Current Research

Across three experiments, children's and adults' memory for features of objects was examined in a series of feature memory trials. Memory for three visual features of objects was tested: shape, color, and size. Shape, color, and size were chosen because all three features have been used in previous studies of the shape bias (e.g., Landau et al., 1988; Yee et al., 2012). 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 in previous studies of young children's categorization and long-term memory (Horst & Samuelson, 2008; Vlach et al., 2008) and to elucidate the ability to retrieve information immediately after being presented with an object and when accessing knowledge from long-term memory. Experiment 1 was conducted to examine whether there is a relation between learners' memory for features and shape bias. After observing that there is a relation, Experiment 2 served as a replication of Experiment 1 and determined if/how the relation between learners' memory for features and shape bias changes across early childhood and adulthood. Finally, Experiment 3 ruled out the possibility that the linguistic prompts used during the memory task were biasing participants' responses.

Experiment 1

In Experiment 1, 2-year-olds and adults were presented with a feature memory task and a shape bias task. 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' shape bias. Thus, this experiment examined memory and categorization during the onset of the shape bias, generally starting around 24-months of age (e.g., Landau et al., 1988; Gershkoff-Stowe & Smith, 2004), and during adulthood, a time period in which almost all learners demonstrate a persistent shape bias (e.g., Landau et al., 1988).

Method

Participants—The participants were 18 2-year-old children ($M = 29.8$ months; 7 girls) and 40 adult participants. All children were monolingual English speakers and recruited from local daycare centers and preschools. Children at this point in development were chosen based upon research demonstrating that children begin to develop a shape bias around 24-months of age (e.g., Landau et al., 1988; Gershkoff-Stowe & Smith, 2004). Adult participants were undergraduate students recruited from the department's subject pool. Adult participants received course credit for their participation.

Apparatus & Stimuli—Participants were presented with all tasks on an iPad. Stimuli for the tasks, 2D objects, were constructed in Adobe Photoshop. There 36 objects presented in the shape bias task (4 objects per trial) and 36 objects presented in the feature memory task (4 objects per trial), controlling for the number of objects children were exposed to across tasks in the experiment. 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 to prevent ordering effects; t-tests revealed no differences in memory performance or number of shape selections across the two orderings, $ps > .10$. The order of the trials within each task was randomly assigned.

Feature Memory Task: There were a total of nine trials in the feature memory task. Participants were presented with feature memory trials for shape, color, and size. Each feature (shape, color, and size) was tested at each testing timescale (immediate, 2-minute delay, and 5-minute delay). These timescales were chosen to mirror delays used in previous studies of young children's categorization and long-term memory (Horst & Samuelson, 2008; Vlach et al., 2008) and to elucidate the ability to retrieve information immediately after being presented with an object and when accessing knowledge from long-term memory.

In each trial, participants were presented with a target object for 4 seconds (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. The stickers and Play-doh were different colors, shapes, and sizes than the stimuli used in the experiment. 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 test objects (see Figure 1). One of the three test 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 test 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 test 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 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. That is, one third of the trials had the correct response on the left side of the screen, one third of the trials had the correct response in the middle of the screen, and one third of the trials had the correct response on the right side of the screen. 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; Yee et al., 2012). 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. For example, one third of the trials had the shape match on the left side of the screen, one third of the trials had the shape match in the middle of the screen, and one third of the trials had the shape match on the right side of the screen. 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—Children's and adults' memory performance (percentage of correct responses) was plotted across the three testing timescales, by feature. As can be seen in the top row of Figure 2, adults appeared to have overall better memory performance than children. A series of Pearson's chi-squared tests comparing children's and adults' total number of correct vs. incorrect responses, summed across all testing delays, confirmed that adults had overall better memory for shape, $\chi^2(1) = 52.42, p < .001$, color, $\chi^2(1) = 9.79, p = .002$, and size, $\chi^2(1) = 5.39, p = .020$.

The next set of analyses examined whether there were differences in memory performance across the three features (shape, color, and size). Because there were differences in memory performance between children and adults, the data were separated by age group. Fisher's exact tests were used to compare performance on the shape, color, and size trials at each testing delay. For the adults, the results of these tests revealed that participants had significantly better memory performance on shape trials than color trials, $ps < .01$, and size trials, $ps < .001$, at each testing delay. Moreover, there were no significant differences between memory performance on the color and size trials, $ps > .10$. For the children, there

were no significant differences in performance across any of the three perceptual features and three testing timescales, $ps > .10$.

The final set of analyses examined whether participants were remembering information above chance performance. Given that the responses on each trial of the feature memory task were categorical (i.e., correct or incorrect), one tailed binomial probability tests were used to determine if children and adults remembered object features on each of the nine trials (chance on each trial = $1/3$). For adults, the binomial test revealed that if 19 (47.5%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x = 19) = .039$. More than 19 (47.5%) adults responded correctly at each of the nine trials of the feature memory task (see Figure 2). This finding suggests that adult participants were able to remember information across all three perceptual features and three testing timescales. For children, the binomial test revealed that if 10 (55.5%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x = 10) = .041$. At the immediate testing trials, 10 (55.5%) or more participants responded with the correct answer at test for all three perceptual features. These findings suggest that children were able to remember features at the immediate test trials, but did not remember the features at the 2- or 5-minute delayed test trials.

In sum, adults demonstrated significantly better memory performance than children across all three perceptual features. Moreover, adult participants demonstrated significantly better 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 perceptual features.

Shape Bias Task Performance—The first set of analyses examined whether there were differences in the number of shape, color, and size choices during the shape bias task. For adults, a one way chi-squared analysis against chance performance ($1/3$) revealed that the total number of shape ($N = 346$), color ($N = 9$), and size choices ($N = 5$) was significantly different than chance performance, $\chi^2(2) = 638.52$, $p < .001$. For children, a one way chi-squared analysis against chance performance ($1/3$) revealed that the total number of shape ($N = 64$), color ($N = 57$) and size choices ($N = 41$) was significantly different than chance performance, $\chi^2(2) = 5.15$, $p = .001$. These analyses suggest that both groups demonstrated categorical biases during the shape bias task.

To examine the nature of these biases within individual participants, each participant was classified as having/not having a categorical bias. There were a total of nine trials in the shape bias task; to be classified as having a specific bias (e.g., a shape bias), participants must have chosen a particular feature match at test significantly more often than chance (chance performance was $1/3$ on each trial). A one-tailed binomial probability analysis was conducted to determine a criterion for classifying participants' biases and revealed that 6 or more selections had a cumulative probability that was significantly different than chance, $p(x = 6) = .040$. Thus, to be classified as having a bias, participants had to pick the same feature match on 6 or more test trials of the shape bias task (e.g., a participant choosing the shape match object on 6 or more trials would be classified as having a shape bias). Table 1

outlines the breakdown of categorical bias by age group. As can be seen in Table 1, the majority of the participants demonstrated a shape bias.

Categorical Biases and Memory Performance—The central goal of this experiment was to examine whether participants' categorical biases, such as a shape bias, would be related to memory performance for specific features of an object. It was predicted that learners demonstrating a shape bias would have better memory performance for shape information than other perceptual features. Almost 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 on the feature memory task was plotted across the three testing timescales, by feature (shape, color, and size) and by categorical bias (shape vs. no/other bias). As can be seen in the bottom row of Figure 2, there appeared to be differences in memory performance between the shape bias group and the no/other bias group.

The analyses examined if children in the two categorical bias groups (shape and no/other bias) were able to remember features across the three testing delays. Given that the responses on each trial of the feature memory task were categorical (i.e., correct or incorrect), one-tailed binomial probability tests were used to determine if children remembered object features on each of the nine trials (chance on each trial = 1/3). For the shape bias group, the binomial test revealed that if 6 (75%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x \geq 6) = .018$. If 5 (62.5%) or more participants responded with the correct answer at test, this cumulative probability was marginally significantly different than chance performance, $p(x \geq 5) = .085$. Children were able to remember shape information at the immediate and 2-minute delayed tests (see Figure 2). Children were only able to marginally remember color information at the immediate test and demonstrated chance performance on the other color trials and all size trials. Thus, children in the shape bias group had better memory performance for shape than color and size.

For the no/other bias group, the binomial test revealed that if 7 (70%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x \geq 7) = .018$. If 6 (60%) or more participants responded with the correct answer at test, this cumulative probability was marginally significantly different than chance performance, $p(x \geq 6) = .073$. Children were able to remember color at the immediate test and marginally remember color at the 2-minute and 5-minute delayed tests (see Figure 2). Children were able to marginally remember size at the immediate and 2-minute delayed tests, but not at the 5-minute delayed size trials or on any of the shape trials. Thus, children in the no/other bias group had better memory performance for color and size than shape.

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 better memory performance for shape than color and size. Conversely, children that did not have a shape bias had significantly better memory performance for color and size than shape at the

immediate test. These findings suggest that there is a relation between the ways that individual learners categorize objects and how they remember the features of objects, as discussed below and further examined in Experiment 2.

Discussion

The results of Experiment 1 revealed developmental differences in memory abilities for features for objects. Overall, adults had better memory performance than children. On the group level, adults, but not children, had better memory performance for shape than color and size and demonstrated a persistent shape bias. However, when children were divided into two groups, those in the shape bias group had significantly better memory performance for shape and those in the no/other bias group had significantly better memory performance for color and size. In sum, the results of this experiment confirm the hypothesis that learners have different memory abilities for perceptual features of objects and that categorical biases, such as the shape bias, are related to differences in memory for features of objects. The implications of this finding will be discussed in the General Discussion.

The results of this experiment revealed striking developmental differences between 2-year-old children's and adults' memory for perceptual features of objects. That is, on the group level, 2-year-old children did not demonstrate differences in memory performance across the perceptual features but adults did demonstrate differences in memory performance. At what point in development would we observe differences in memory performance for perceptual features on the group level? One possibility is that, across early childhood, there is a co-development of the shape bias and memory that produces the relation between memory performance and categorization. As more children develop a shape bias across early childhood, we should observe more noticeable differences in memory performance for perceptual features of objects. In this case, we may observe an adult-like pattern of performance (i.e., better memory performance for shape than color and size on the group level) by the end of early childhood. This finding would provide further evidence that the development of the shape bias is related to differences in memory for perceptual features of objects. Alternatively, changes in memory performance for perceptual features of objects may be a result of a more gradual developmental process, such as general improvements in cognitive abilities (i.e., age). In this case, we would not expect to observe an adult-like pattern of performance by the end of early childhood, when most children demonstrate a shape bias. Experiment 2 was designed to elucidate developmental differences in children's memory for perceptual features of objects to examine these possibilities.

Experiment 2

In this experiment, 2-, 3-, 4-year-old children and adults were presented with a feature memory task and a shape bias task. There were two goals of this experiment. First, this experiment served as a replication of Experiment 1. Second, this experiment examined memory and categorization across early childhood to reveal developmental differences in children's memory performance for perceptual features of objects. It was predicted that, if there is a relation between the shape bias and memory for perceptual features of objects, we

would expect to observe differences in children's memory performance by the end of early childhood, when most children have developed a shape bias.

Method

Participants—The participants were 18 2-year-old children ($M = 31.1$ months; 11 girls), 18 3-year-old children ($M = 41.6$ months; 6 girls), 18 4-year-old children ($M = 53.9$ months; 11 girls), and 40 adult participants. All children were monolingual English speakers and recruited from local daycare centers and preschools. Children in these age groups were chosen to examine the developing ability to remember features of an object across early childhood. Adult participants were undergraduate students recruited from the department's subject pool. Adult participants received course credit for their participation. Participants in this experiment had not participated in Experiment 1.

Apparatus, Stimuli, & Procedure—Same as Experiment 1.

Results

Feature Memory Task Performance—A goal of Experiment 2 was to examine children's and adult's memory for features of objects. Children's and adults' memory performance for each of the three features was plotted across the three testing timescales, by age group (2-, 3-, 4-year-olds, and adults) and feature (shape, color, and size). As can be seen in Figure 3, there appeared to be differences in memory performance across children and adults. A series of Pearson's chi-squared tests comparing 2-year-old children's and adults' total number of correct vs. incorrect responses, summed across all testing delays, confirmed that adults had overall better memory for shape, $\chi^2(1) = 41.73$, $p < .001$, color, $\chi^2(1) = 10.46$, $p = .001$, and marginally better memory for size, $\chi^2(1) = 3.20$, $p = .074$. These findings replicate Experiment 1. A series of Pearson's chi-squared tests comparing 3-year-old children's and adults' total number of correct responses across all tests confirmed that adults had overall better memory for shape, $\chi^2(1) = 33.80$, $p < .001$, and color, $\chi^2(1) = 7.73$, $p = .005$. Finally, a series of Pearson's chi-squared tests comparing 4-year-old children's and adults' total number of correct responses confirmed that adults had overall better memory for shape, $\chi^2(1) = 5.53$, $p = .012$, and color, $\chi^2(1) = 4.02$, $p = .045$. In sum, there were developmental changes in memory performance between childhood and adulthood; adults had better memory performance than children.

The next set of analyses examined whether there were differences in memory performance across the three features (shape, color, and size). Fisher's exact tests were used to compare performance on the shape, color, and size trials at each testing delay. Because there were differences in memory performance across children and adults, the data were separated by age group. For the adults, the results of these tests revealed that participants had significantly better memory performance on shape trials than color trials at the 2- and 5-minute delayed test trials, $ps < .01$, and all size trials, $ps < .001$. Moreover, there were no significant differences between memory performance on the color and size trials, $ps > .10$. These findings replicate the overall pattern of performance of Experiment 1.

For the child age groups, there were no differences in memory performance across the three features (shape, color, and size) for 2- and 3-year-old children. The 4-year-old children had marginally significantly better memory for shape than color at the 2- and 5-minute delayed test trials, $ps < .10$, and significantly better memory for shape than size at the immediate and 2-minute delayed test trials, $ps < .001$. There were no significant differences in memory performance between color and size in each age group, $ps > .10$. In sum, 2- and 3-year-old children did not demonstrate differences in their memory for shape, color, and size across the three testing delays. However, adults and 4-year-old children demonstrated better memory performance for shape than color and size.

The final set of analyses examined whether participants were remembering information above chance performance. Given that the responses on each trial of the feature memory task were categorical (i.e., correct or incorrect), one-tailed binomial probability tests were used to determine if children and adults remembered object features on each of the nine trials (chance on each trial = 1/3). For adults, the binomial test revealed that if 19 (47.5%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x \geq 19) = .039$. More than 19 adults responded correctly at each of the nine trials of the feature memory task (see Figure 3). This finding suggests that adult participants were able to remember information across all three perceptual features and three testing timescales, replicating Experiment 1.

For the child age groups, the binomial test revealed that if 10 (55.5%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x \geq 10) = .041$. 2-year-old children demonstrated memory for features at the shape and color immediate test trials. 3-year-old children demonstrated memory for all three features at the immediate test trials. Finally, 4-year-old children demonstrated memory for shape and color at the immediate test trials, memory for shape at the 2-minute delayed testing trials, and memory for shape at the 5-minute delayed testing trials (see Figure 3). These results suggest that, as children get older, their memory for features of objects improves.

Shape Bias Task Performance—The first set of analyses examined whether there were differences in the number of shape, color, and size choices during the shape bias task. For adults, a one way chi-squared analysis against chance performance (1/3) revealed that the total number of shape ($N = 339$), color ($N = 13$), and size choices ($N = 8$) was significantly different than chance performance, $\chi^2(2) = 599.62$, $p < .001$. For 2-year-old children, a one way chi-squared analysis against chance performance (1/3) revealed that the total number of shape ($N = 63$), color ($N = 58$) and size choices ($N = 41$) was marginally different than chance performance, $\chi^2(2) = 4.93$, $p = .085$. For 3-year-old children, a one way chi-squared analysis against chance performance (1/3) revealed that the total number of shape ($N = 90$), color ($N = 52$) and size choices ($N = 20$) was significantly different than chance performance, $\chi^2(2) = 45.48$, $p < .001$. Finally, for 4-year-old children, a one way chi-squared analysis against chance performance (1/3) revealed that the total number of shape ($N = 132$), color ($N = 21$) and size choices ($N = 9$) was significantly different than chance performance, $\chi^2(2) = 170.33$, $p < .001$. These analyses suggest that all age groups demonstrated categorical biases during the shape bias task. The proportion of children's

shape choices parallels that observed in other studies on the shape bias (e.g., Jones & Smith, 2002; Samuelson, Horst, Schutte, & Dobbertin, 2008).

To examine categorical biases on the individual level, each participant was classified as having/not having a categorical bias. The classification procedure was the same as outlined in Experiment 1. Table 1 outlines the breakdown of bias by age group for Experiment 2. As can be seen in Table 1, the majority of the participants demonstrated a shape bias.

Categorical Biases and Memory Performance—A central goal of Experiment 2 was to examine whether participants' categorical biases, such as a shape bias, would be related to memory performance for specific features of an object. It was predicted that learners demonstrating a shape bias would have better memory performance for shape information than other perceptual features. The majority of adults demonstrated a shape bias, so these data were not re-analyzed. This finding replicates the results of Experiment 1.

A series of logistic regressions were conducted to examine relations between children's age, shape bias task performance, and feature memory performance. In particular, Table 3 presents binary logistic regressions predicting memory performance (0 = not remembered, 1 = remembered) for shape and color at each testing delay. Memory performance for size was not examined in these models because of older children's low incidence of size choices during the shape bias task. A pattern of interactions were not observed in these analyses, and thus main effects are reported. The key finding from these analyses is that, across all testing delays, the number of shape choices during the shape bias task significantly predicted memory performance for shape (Table 3). However, children's age did not predict memory performance for shape.

The next set of analyses examined whether individual children's categorical biases were related to their memory performance. About half of the 2- and 3-year-old children demonstrated a shape bias while the other half demonstrated no/another bias. Most of the 4-year-old children demonstrated a shape bias, so their data was not re-analyzed. The 2- and 3-year-old 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). As can be seen in the both rows of Figure 4, there appeared to be differences in memory performance between the shape bias groups and the no/other bias groups. A Pearson's chi-squared confirmed that 2- and 3-year-old children in the shape bias group had more correct responses on the shape memory trials (35 correct, 13 incorrect) than 2- and 3-year-old children in the no/other bias group (18 correct, 42 incorrect), $\chi^2(1) = 19.65, p < .001$.

Given that the responses on each trial of the feature memory task were categorical (i.e., correct or incorrect), binomial probability tests were used to determine if children remembered object features on each of the nine trials (chance on each trial = 1/3). For the 2-year-olds in the shape bias group, the binomial test revealed that if 5 (71.4%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x \geq 5) = .043$. Children were able to remember information at the immediate shape test trial, but no other test trials of the feature

memory task (see Figure 4). Thus, children in the shape bias group had better memory performance for shape at the immediate test than color and size. For the 2-year-olds in the no/other bias group, the binomial test revealed that if 7 (63.6%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x = 7) = .037$. Children were able to remember information at the immediate color test trial, but no other test trials of the feature memory task. Thus, for 2-year-olds, children with a shape bias demonstrated better memory for shape and children with no/other bias demonstrated better memory for color.

Binomial probability tests were also used to examine 3-year-old's performance on the feature memory task by categorical bias group. In both categorical bias groups, the binomial test revealed that if 6 (66.6%) or more participants responded with the correct answer at test, this cumulative probability was significantly different than chance performance, $p(x = 6) = .040$. For the 3-year-olds in the shape bias group, children demonstrated memory for features on all three immediate test trials and the 2-minute-delayed test trial for shape (see Figure 4). For the 3-year-olds in the no/other bias group, children demonstrated memory for features on the immediate and 2-minute delayed color test trials. Thus, for 3-year-olds, children with a shape bias demonstrated better memory for shape and children with no/other bias demonstrated better memory for color.

Discussion

The results of Experiment 2 revealed developmental differences in memory abilities for perceptual features for objects in relation to categorical biases. On the group level, 4-year-old children and adults had better memory performance for shape than color and size. The majority of participants in these age groups also demonstrated a shape bias. We did not observe differences in memory performance for the three features in the 2- and 3-year-old age groups. However, when these children were divided into two groups, those in the shape bias group had significantly better memory performance for shape than children in the no/other bias group. In sum, the results of this experiment replicate Experiment 1 and confirm the hypothesis that learners have different memory abilities for perceptual features of objects, and that the shape bias is related to differences in memory for features of objects.

Experiment 2 was also designed to examine memory and categorization across early childhood to reveal developmental differences in children's memory performance for perceptual features of objects. It was predicted that, if there is a relation between the shape bias and memory for perceptual features of objects, we would expect to observe differences in children's memory performance by the end of early childhood, when most children have developed a shape bias. The results of Experiment 2 confirm this hypothesis; the majority of 4-year-old children demonstrated a shape bias and demonstrated better memory performance for shape than color and size. Indeed, the 4-year-old children's pattern of memory performance mirrors the pattern that we observe in adulthood. Moreover, the regression analyses confirmed that children's performance on the shape bias task (i.e., the number of shape choices) was more predictive of their memory for shape than children's age. Thus, these results suggest that the development of the shape bias, rather than gradual

improvements in children's cognitive abilities (i.e., age), explain the link between children's memory and categorization.

There is an alternative explanation for the findings in Experiments 1 & 2: participants' better memory for shape in the feature memory task could represent a stronger sensitivity to the linguistic prompts used during the learning and testing trials. That is, the language used during the feature memory task may have engendered better memory for shape. For instance, the word 'toy' may have primed participants to think of object categories and thus encode and retrieve the shape of the object to a greater degree than the other features. The data from Experiments 1 & 2 suggest that it is unlikely the word 'toy' caused participants to encode shape to a greater degree than the other perceptual features. For instance, a Pearson's chi-squared test on adults' performance at the immediate test in Experiment 2 revealed that adults did not demonstrate better memory for shape than color, $p > .10$. Indeed, a series of Pearson's chi-squared tests on children's performance at the immediate test in Experiment 2 revealed that children did not demonstrate better memory for shape than color either, $p > .10$.

However, the data from Experiments 1 & 2 cannot rule out the explanation that the word 'toy' or testing prompt may have influenced the way that adults retrieved knowledge from memory. To address this alternate explanation for performance on the feature memory task, Experiment 3 examined whether the linguistic prompt used during the testing trials of the feature memory task affected performance. If the prompt was influencing how adults' retrieved information from memory, it was expected that there would be differences in performance across the prompt conditions. However, if the participants were retrieving information from memory in a way that was unbiased by the linguistic testing prompt, there should be no differences in performance across the prompt conditions.

Experiment 3

In this experiment, adults were presented with a feature memory task and a shape bias task. The goal of this experiment was to determine whether the linguistic prompt used during the feature memory task influences adults' memory performance. There were four different prompt conditions. In Prompt Condition #1, participants were asked the same question used in Experiments 1 & 2: "Which of these looks like a toy you have seen before?" In Prompt Condition #2, participants were asked: "Which one of these looks like the one you saw before?" In Prompt Condition #3, participants were asked: "Which one is similar to the one you saw before?" In Prompt Condition #4: "Which one is of the same kind as the one you saw before?" Although this is not an exhaustive list of potential prompts for the feature memory task, the prompts in Conditions #2 – 4 were chosen to mirror testing prompts used in previous research on children's memory and categorization (e.g., Diesendruck & Bloom, 2003).

Method

Participants—The participants were 160 adults. Participants were randomly assigned to a testing prompt condition, resulting in 40 participants in each of the four testing prompt conditions. Participants were undergraduate students recruited from the department's subject

pool and received course credit for their participation. Participants in this experiment had not participated in Experiment 1 or 2.

Apparatus, Stimuli, & Procedure—Same as Experiments 1 & 2, with one exception: there were four testing prompt conditions of the feature memory task: “Which of these looks like a toy you have seen before?” (Prompt Condition #1), “Which one of these looks like the one you saw before?” (Prompt Condition #2), “Which one is similar to the one you saw before?” (Prompt Condition #3), and “Which one is of the same kind as the one you saw before?” (Prompt Condition #4).

Results & Discussion

Feature Memory Task Performance—The goal of this experiment was to determine whether the linguistic prompt used during testing trials affects participants' memory performance. The number of participants correctly responding on the memory trials, by feature (shape, color, and size), testing timescale (immediate, 2-minute delay, and 5-minute delay), and prompt condition (Prompt Conditions 1 – 4), can be seen in Table 2. A series of Pearson's chi-squared analyses comparing performance on the shape, color, and size across the four prompt conditions revealed no significant differences across the four testing prompt conditions, p s > .10. Thus, the testing prompt used during the feature memory task of Experiments 1 & 2 did not bias participants' memory for features in relation to the other testing prompts.

Moreover, the pattern of results observed in Experiments 1 & 2 was replicated in this experiment. For Prompt Condition #1, a series of Pearson's chi-squared tests revealed that participants had a significantly better number of total correct responses, summed across all testing delays, on the shape trials than the color trials, $\chi^2(1) = 11.74, p < .001$, and size trials, $\chi^2(1) = 44.48, p < .001$. For Prompt Condition #2, the same analyses revealed that participants had a significantly better number of total correct responses on the shape trials than the color trials, $\chi^2(1) = 18.52, p < .001$, and size trials, $\chi^2(1) = 29.55, p < .001$. For Prompt Condition #3, the same analyses revealed that participants had a significantly better number of total correct responses on the shape trials than the color trials, $\chi^2(1) = 15.38, p < .001$, and size trials, $\chi^2(1) = 33.76, p < .001$. Finally, for Prompt Condition #4, participants had a significantly better number of total correct responses on the shape trials than the color trials, $\chi^2(1) = 17.67, p < .001$, and size trials, $\chi^2(1) = 32.45, p < .001$. Thus, across all testing prompt conditions, participants had better memory for shape than color and size.

Categorical Biases and Memory Performance—To ensure that there were no interaction effects across tasks, participants' performance on the shape bias task was analyzed. Each participant was classified as having/not having a categorical bias using the classification procedure was the same as outlined in Experiment 1. Table 1 outlines the breakdown of bias by prompt condition group for Experiment 3. The majority of the adults demonstrated a shape bias; this finding replicates the findings of Experiments 1 & 2. A series of Pearson's chi-squared analyses on the data presented in Table 1, Experiment 3, revealed no significant differences in performance on the shape bias task across the prompt

conditions, $ps > .10$. Thus, there were no interaction effects between the shape bias task and prompt conditions of the feature memory task. These results suggest that the language used during the feature memory task did not influence the way in which participants were encoding and retrieving knowledge.

General Discussion

Across three experiments, children's and adults' memory for perceptual features of objects was examined in relation to their categorical biases. The results of these experiments revealed that learners' memory for features of objects was related to their biases in categorizing objects. That is, participants with a shape bias demonstrated better memory performance for shape than other perceptual features, such as color and size. Moreover, this work revealed developmental differences in the relation between memory performance and categorization. As children developed a shape bias across early childhood, we could observe the relation between memory and categorical biases on the group level by the end of early childhood (i.e., in the 4-year-old age group). Indeed, children's number of shape match choices during the shape bias task was a stronger predictor of shape memory performance than children's age.

Taken together, this work suggests that the development of the shape bias is more than just the development of attention to shape, but the development of a memory bias for shape information. In the sections below, the current findings are discussed in terms of how the development of a memory bias for shape may promote children's categorization and generalization. Early experiences attending to, remembering, and categorizing objects may set the stage for how we remember and generalize object categories across development and in adulthood. That is, the development of a memory bias for shape information may lead to the development of a memory system that mirrors the ways in which we categorize the world.

How Does the Shape Bias and Memory Bias Develop?

The current study's unique contribution to the literature is that it establishes a relation between the shape bias and learners' memory for perceptual features of objects. As a result, this study opens up new questions as to the causal pathways between memory for perceptual features and how learners categorize objects. One potential pathway is that learners first develop strong memory for shape information, leading them to attend to shape to a greater degree, resulting in the shape bias. A second potential pathway is that enhanced attention to shape leads to enhanced memory for shape information, and then a shape bias. However, the current results provide evidence against these two hypotheses. In Experiments 1 & 2, 2- and 3-year-old children without a shape bias, who are likely to acquire a shape bias by the end of early childhood, did not have better memory for shape. If stronger memory for shape precedes the shape bias, we would expect these children to also have a memory bias for shape information.

A third potential pathway is that enhanced attention to shape leads to a shape bias, and the shape bias engenders better memory for shape information. It may be that, once children learn to categorize and generalize object labels in a specific manner, they begin to prioritize

relevant categorical features in memory. If children identify a specific perceptual feature as important for categorization, they may more deeply encode this information so that it can be readily accessed from memory across time. Moreover, hearing a novel linguistic label in conjunction with seeing a new object may cue children to more deeply encode and retain shape information.

A final possibility is that all three causal pathways are simultaneously occurring during development. There may be a co-development of attention and memory that bi-directionally influence each other, speeding up the differentiation in children's memory performance for perceptual features of objects. That is, learning to attend to, remember, and categorize objects all contribute to a memory bias for shape information. Future research should examine this possibility.

How Does a Memory Bias Promote Categorization and Generalization?

As discussed in the Introduction section, in real-world learning situations there are likely to be frequent temporal gaps between encountering a new object and subsequently encountering a second object of the same category. A memory bias for shape information may prevent learners from forgetting the shape of objects during these temporal gaps and allow learners more readily retrieve shape information than other types of information, such as other perceptual features of objects. Consequently, when encountering new category exemplars, learners are more likely to retrieve their prior experiences with an object category, but retrieve them in such a way that supports categorization and generalization. That is, learners will more readily retrieve shape information, supporting object category generalization. Indeed, a relevant and defining feature of the majority of object categories is the shape of an object (see Samuelson & Smith, 1999, for a discussion). Thus, remembering the shape of previous objects may support categorization and generalization of exemplars across time.

Evidence for this proposal comes from recent research suggesting that memory processes, such as forgetting and retrieval dynamics, may be critical in supporting children's categorization and generalization (Vlach et al., 2008, 2012, 2014). For example, according to forgetting-as-abstraction account (see Vlach, 2014, for a review), children's forgetting during the temporal gaps between category exemplar presentations promotes categorization and generalization. Across experiences with category exemplars, relevant features are likely to be present in multiple exemplars, reactivating this feature in memory. Conversely, irrelevant features of categories are not likely to be present across all of the exemplars and not reactivated in memory, which means they continue to be forgotten and are forgotten at a faster rate than the relevant features. Thus, across category exemplar presentations, learners acquire stronger memory and slower forgetting for relevant features of the category.

It may be that acquisition of the shape bias and memory bias for shape information slows forgetting for shape information across several object categories, including novel categories in which young children have no experience. Rather than engender differential forgetting rates for features of objects across experiences with category exemplar presentations, such as in the account described above, the onset of a strong shape bias may engender a slower forgetting curve for shape information after the first experience with a novel category. That

is, after a first experience with a novel object, learners may have slower forgetting for the shape of an object than other perceptual features of the object. Indeed, this proposal is supported by the data from the 4-year-old and adult participants who demonstrated both better memory performance for shape than other features and a persistent shape bias. Future research should examine this possibility to understand how a memory bias for shape information promotes categorization and generalization across categories and extended timescales.

Moving Beyond One Moment in Time: Future Directions for Theories of the Shape Bias

The shape bias literature consists primarily of debates regarding which types of information children attend to when generalizing across multiple objects in one moment in time (i.e., perceptual vs. linguistic/conceptual information; for a review, see Samuelson & Bloom, 2008). However, 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 their learning history.

Critically, the results of the current experiments bridge a gap in our understanding of how performance on an in-the-moment task, such as simultaneously comparing multiple objects in the shape bias task, relates to developmental outcomes in language and cognitive development (Gershkoff-Stowe & Smith, 2004; Jones, 2003; Perry et al., 2010; Samuelson, 2002; Smith et al., 2002). This work identifies one potential mechanism to explain this relation: enhanced memory for shape over other perceptual features of objects. For example, it may be the case that an early onset of the shape bias is the beginning of the interaction between memory and categorization abilities, and the earlier this process starts, the more readily children will acquire new words and categories across early childhood.

In conclusion, what we remember may influence how we categorize the world and our developing organization of our experiences may change how we remember information. Multidirectional relations among memory and categorization processes may result in the development of a memory system that mirrors the ways in which we categorize information, supporting our ability to generalize knowledge across moments in time. Future research should continue to examine how categorical biases affect memory in order to understand how the developing, lower-level processes of attention and memory support the acquisition and formation of higher level categorical structures of the world.

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Research Highlights

- The “shape bias” describes the phenomenon that, after a certain point in development, children and adults generalize object categories based upon shape to a greater degree than other perceptual features.
- Previous research has focused on how attentional processes give rise to the shape bias. The current research take a different direction by examining whether the shape bias is related to other cognitive processes, such as the ability to retain and retrieve knowledge of objects over time.
- The results of three experiments revealed that participants with a shape bias demonstrated better memory for shape than other perceptual features, such as color and size. Participants without a shape bias did not show better memory for shape.
- This work suggests that the development of a shape bias may result in a memory bias for shape information. A memory bias for shape may prevent learners from forgetting the shape of objects across time and allow learners more readily retrieve shape information when categorizing the world.

Figure 1.

Examples of tasks and stimuli used in Experiments 1, 2, and 3. All participants completed the shape bias task and feature memory task. The ordering of the tasks was counterbalanced across participants. In Experiment 3, the testing prompt used during the feature memory task was manipulated.

Memory Performance by Age Group – Exp. 1

Children's Memory Performance by Categorical Bias – Exp. 1

Figure 2.

Percentage of correct responses on the feature memory task trials from Experiment 1. In the top row, participants are grouped by age (2-year-olds vs. adults). In the bottom row, 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. However, when grouped by categorical bias, children demonstrated significantly different memory performance for the three features of objects. The dashed line indicates chance performance.

Figure 3.

Percentage of correct responses on the feature memory task trials from Experiment 2. The data is displayed by age group: 2-year-olds, 3-year-olds, 4-year-olds, and adults. On the group level, the 2- and 3-year-old children did not demonstrate differences in memory performance for the three features. However, the 4-year-old children and adults demonstrated significantly higher memory performance for shape than color and size. The dashed line indicates chance performance.

Children's Memory Performance by Categorical Bias – Exp. 2

Figure 4.

Percentage of correct responses on the feature memory task trials from Experiment 2 for 2- and 3-year-old children. In both rows, children are grouped by categorical bias (shape vs. no/other bias). Both 2- and 3-year-old children demonstrated significantly different memory performance for the three features of objects when grouped by categorical bias. The dashed line indicates chance performance.

Table 1
Number of Participants with Categorical Biases by Age Group/Condition and Experiment

EXPERIMENT 1					
	Shape Bias (N)	Color Bias (N)	Size Bias (N)	No Bias (N)	Total (N)
2-year-olds	8	3	1	6	18
Adults	38	0	0	2	40
EXPERIMENT 2					
	Shape Bias (N)	Color Bias (N)	Size Bias (N)	No Bias (N)	Total (N)
2-year-olds	7	4	1	6	18
3-year-olds	9	4	0	5	18
4-year-olds	14	1	0	3	18
Adults	37	0	0	3	40
EXPERIMENT 3					
	Shape Bias (N)	Color Bias (N)	Size Bias (N)	No Bias (N)	Total (N)
Prompt #1	40	0	0	0	40
Prompt #2	39	0	0	1	40
Prompt #3	39	0	0	1	40
Prompt #4	40	0	0	0	40

Note. To be classified as having a categorical bias (e.g., shape bias), participants must have selected the same feature match 6 or more times (out of 9) at test during the shape bias task.

Table 2
Number of Participants in Experiment 3 Responding Correctly at Test by Feature, Testing Timescale, and Testing Prompt Condition

	Shape			Color			Size		
	Immediate	2min	5min	Immediate	2min	5min	Immediate	2min	5min
Prompt #1	40	39	38	37	34	31	32	21	23
Prompt #2	40	40	38	38	32	28	35	27	27
Prompt #3	40	40	39	36	34	33	31	29	28
Prompt #4	39	40	40	36	35	30	31	30	28

Binary Logistic Regressions Predicting Memory Performance, by Feature and Testing Delay

Table 3

<i>Model 1: Shape Memory at Immediate Test</i>						
Model χ^2	Nagelkerke R^2	Predictor	Wald	β	S.E.	e^{β}
26.089 *	.527	Constant	1.135	-1.809	1.698	.164
		Age (in months)	.036	-.008	.045	.992
		Number of shape choices	14.414	.605 *	.159	1.832
<i>Model 2: Shape Memory at 2-Minute Delayed Test</i>						
Model χ^2	Nagelkerke R^2	Predictor	Wald	β	S.E.	e^{β}
20.037 *	.416	Constant	5.471	-3.716 *	1.588	.024
		Age (in months)	1.725	.052	.039	1.053
		Number of shape choices	9.171	.379 *	.125	1.461
<i>Model 3: Shape Memory at 5-Minute Delayed Test</i>						
Model χ^2	Nagelkerke R^2	Predictor	Wald	β	S.E.	e^{β}
8.152 *	.187	Constant	1.292	-1.467	1.290	.231
		Age (in months)	.043	.007	.034	1.007
		Number of shape choices	5.223	.253 *	.111	1.288
<i>Model 4: Color Memory at Immediate Test</i>						
Model χ^2	Nagelkerke R^2	Predictor	Wald	B	S.E.	e^{β}
2.546	.062	Constant	.874	-1.292	1.381	.275
		Age (in months)	1.035	.030	.030	1.031
		Number of color choices	1.977	.173	.123	1.189
<i>Model 5: Color Memory at 2-Minute Delayed Test</i>						
Model χ^2	Nagelkerke R^2	Predictor	Wald	B	S.E.	e^{β}
11.704 *	.260	Constant	6.454	-4.043 *	1.591	.018
		Age (in months)	5.596	.078 *	.033	1.081
		Number of color choices	6.618	.398 *	.155	1.490
<i>Model 6: Color Memory at 5-Minute Delayed Test</i>						
Model χ^2	Nagelkerke R^2	Predictor	Wald	B	S.E.	e^{β}
1.827	.044	Constant	1.934	-1.932	1.390	.145

Age (in months)	1.574	.037	.029	1.038
Number of color choices	.650	.089	.111	1.093

Note.
* indicates that p-value is less than .05.