The use of questions as problem-solving strategies during early childhood

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\textbf{A B S T R A C T}

This study examined the strategic use of questions to solve problems across early childhood. Participants (N = 54; 4-, 5-, and 6-year-olds) engaged in two tasks: a novel problem-solving question task that required asking questions to an informant to determine which card in an array was located in a box and a cognitive flexibility task that required classifying stimuli by multiple dimensions. The results from the question task indicated that there were age differences in the types of questions asked, with 6-year-olds asking more constraint-seeking questions than 4- and 5-year-olds. The number of constraint-seeking questions asked was the only significant predictor of accuracy. Performance on the cognitive flexibility task correlated with both constraint-seeking strategy use and accuracy in the question task. In sum, our results provide evidence that the capacity to use questions to generate relevant information develops before the capacity to apply this information successfully and consistently to solve complex problems. We propose that the process of using questions as strategic tools is an ideal context for examining how children come to gain active and intentional control over problem solving.

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\textbf{Introduction}

Few topics in the field of cognitive development have been as widely studied and relevant to understanding children’s learning as the development of strategies (Bjorklund, Dukes, & Brown,}
Strategies are typically defined as goal-directed activities that facilitate task performance and are potentially available to conscious awareness (Schwenk et al., 2009). The study of strategy development addresses one of the primary concerns of cognitive development: How do children come to gain intentional control over their problem-solving behavior (Bjorklund, 2010; Harnishfeger & Bjorklund, 1990; Klahr, 1985; Siegler, 1996)? Although an important and influential body of research has investigated the use of strategies to improve memory (DeMarie & Ferron, 2003; Kron-Sperl, Schneider, & Hasselhorn, 2008; Lehmann & Hasselhorn, 2007; Schwenk et al., 2009; Sodian & Schneider, 1999) and academic performance (Lemaire & Siegler, 1995; Waters & Schneider, 2009), little is known about how children apply the capacity to ask questions strategically to the task of problem solving. We propose that the process of using questions as strategic tools of inquiry is an ideal context for examining how children come to gain active and intentional control over the problem-solving process.

The complex cognitive process of actively seeking information from others by asking questions is a fundamental developmental task (Heyman & Legare, in press). Indeed, young children frequently ask questions of many different forms and for many different purposes (Callanan & Oakes, 1992; Kemler Nelson & O’Neil, 2005; Wellman, Hickling, & Schult, 1997). For example, preschoolers can tailor their questions to inquire about different conceptual categories (Greif, Kemler Nelson, Keil, & Gutierrez, 2006) and can ask questions to gather new information (Chouinard, 2007). The objective of the current research was to examine the process by which children integrate the ability to use questions to gather information with the task of solving problems.

The capacity to use questions flexibly and efficiently allows children to acquire new information, increase their understanding, and solve problems (Courage, 1989). Yet using questions strategically and effectively is not a simple process: to do so, one must understand the demands of the particular task at hand, identify the information necessary to solve the problem, formulate questions to acquire relevant information, and determine how to apply the information received to the problem-solving task. Using questions successfully to facilitate problem solving requires the coordination of all steps in this process (Mills, Legare, Bills, & Mejias, 2010; Mills, Legare, Grant, & Landrum, 2011).

Once the goal of the task is identified, children must determine the kinds of questions to ask and articulate in order to obtain the information they need to solve the problem at hand. There are important developmental improvements in this ability. Previous research examining preschool children’s questions has demonstrated that with age, preschoolers ask a greater proportion of questions that would be classified as constraint-seeking (i.e., appropriately worded to obtain the information needed to solve problems) as opposed to ineffective (i.e., vague, irrelevant, or otherwise inappropriate) (Mills et al., 2010). Children also seem to improve with training; modeling questions increases the number of questions children ask (Zimmerman & Pike, 1972).

However, the capacity to ask a question that will elicit relevant information does not ensure successful problem solving. Many complex problems require a substantial amount of information to solve; thus, it is plausible to ask some questions but fail to ask enough of them to obtain sufficient information to solve a problem. It is also possible to ask a sufficient number of questions but fail to remember relevant information during the process of acquiring information.

Generating sufficient information and organizing it effectively for problem-solving purposes poses a considerable cognitive challenge. Children, like adults, often manipulate too many variables to sufficiently test their hypotheses (Schauble, 1996), failing to recognize how to appropriately narrow the options to solve a problem (Chen & Klahr, 1999). For example, in a study using the Twenty Questions paradigm, most 5- to 7-year-olds did not spontaneously ask enough questions to solve each problem (Courage, 1989). Although there is some evidence that with fewer task demands, preschoolers can determine when they have gathered sufficient information to address their questions (e.g., Frazier, Gelman, & Wellman, 2009; Kemler Nelson, Egan, & Holt, 2004), we propose that the capacity to use questions strategically to generate relevant information develops before the capacity to apply this information successfully and consistently to solve complex problems.

Previous studies on preschool children’s questions have focused on question asking (i.e., number of questions asked) rather than questions as strategies, using simple problems that require only a couple of constraint-seeking questions to determine the correct answer (Chouinard, 2007). A key contribution
of the current research is that the question task used with preschoolers is considerably more complex than tasks used in previous research (Chouinard, 2007; Mills et al., 2011), with more dimensions and more items, across a broader age range (i.e., 4- to 6-year-olds participated). This allowed us to examine more complex strategies and, thus, the development of more complex problem-solving skills.

The novel question task we have developed is modeled on the Twenty Questions task and was designed to examine the development of “constraint-seeking strategies” during early childhood. In a classic study with elementary school-aged children, Mosher and Hornsby (1966) used a similar task to examine the kinds of strategies children employ when they use questions for problem-solving purposes and documented both developmental and individual differences during this process. For example, children played a game that required asking questions to determine which picture from an array of 42 pictures was the target picture, and their questioning patterns were classified into two main strategies. Children using the “constraint-seeking” strategy would ask questions in order to eliminate as many alternatives as possible with each question, slowly narrowing options down to the right answer. In contrast, children using the “hypothesis-scanning” strategy would ask questions bearing no clear relation to the knowledge obtained up to that point. Older children were more likely than younger children to use the constraint-seeking strategy. Presumably, the constraint-seeking strategy requires greater cognitive skills; children need to keep track of what they have asked so far, recognize what they do not yet know, and generate questions to fill gaps in their knowledge. It may also lead to greater cognitive load. Yet there is a clear benefit to this strategy; after successfully asking multiple questions to eliminate potential alternative solutions, children have the information necessary to obtain the correct answer.

Although recent research indicates that even preschool children can sometimes use sophisticated constraint-seeking strategies when asking questions for problem-solving purposes (Mills et al., 2010), due to the cognitive demands of using this strategy, there is little evidence that preschoolers apply this strategy consistently and effectively. There also seems to be considerable variation in the use of the constraint-seeking strategy; one study found that only 38% of 5-year-olds were able to successfully employ a constraint-seeking strategy (Mills et al., 2010). Thus, additional research is needed with children across a range of age groups to better understand age differences in the capacity to use questions efficiently in order to implement this strategy effectively.

Another key contribution of this study is that it examined the relationship between cognitive flexibility and the strategic use of questions. Cognitive flexibility is required to adapt questions based on additional evidence. For example, a child with a superior capacity to reason flexibly about multiple different kinds of information would presumably perform better on a question task that requires isolating and switching flexibly between information about animal kind, size, color, and pattern. There are substantial developmental differences in cognitive flexibility during early childhood (Brooks, Hanner, Padowski, & Rosman, 2003; Deák, 2000; Deák & Narasimham, 2003; Diamond, Carlson, & Beck, 2005; Kirkham, Cruess, & Diamond, 2003; Kloó & Perner, 2005; Zelazo, 2004; Zelazo, Frye, & Rapus, 1996). We examined age differences in the capacity to use questions effectively as problem-solving tools by examining the relationship between performance on a novel question task that required children to use questions strategically and a cognitive flexibility task.

The current study

The current study examined (a) age differences in the use of strategic (i.e., constraint-seeking) questions as problem-solving strategies and (b) one of the core cognitive capacities (i.e., cognitive flexibility) that facilitate the complex process of using questions as problem-solving tools across early childhood. Children (4- to 6-year-olds) were presented with two tasks: a novel question task and a cognitive flexibility task. In the question task, children asked an informant questions to determine which target card of the 16 (simple trials) or 24 (complex trials) possible cards was inside a special box. Given the complexity of this task, we were interested in multiple measures of performance, including question efficacy, evidence of constraint-seeking strategy use, information acquired, and accuracy. In the cognitive flexibility task (previously used to investigate multiple classification skills), children were asked to sort cards along two different dimensions individually and then along both
dimensions simultaneously. Previous research using this task has demonstrated improvements in performance on multiple classifications with age (Bigler & Liben, 1992).

There were two primary research questions in the current study. The first question concerns to what extent age differences contribute to variation in the use of strategic questions, and the second question explores how cognitive flexibility facilitates this process. Given developmental changes in cognitive flexibility and experience with problem solving across early childhood, age differences were anticipated in performance on the question task (i.e., question efficacy, evidence of constraint-seeking strategy use, information acquired, and accuracy). Older children generally have more experience than younger children both in problem solving and in asking questions. In addition, due to increases in working memory capacity and processing speed over development (Kail, 1991, 2007), older children generally have more information processing capacity.

Although little is known about individual variation in the strategic use of questions during early childhood, we anticipated that the successful implementation of constraint-seeking strategies and problem-solving skills would vary between individuals in the same age group. Previous research on the development of inquiry in young children has demonstrated that the capacity to ask a sufficient number of constraint-seeking questions is more predictive of problem-solving success than age (Mills et al., 2010, 2011). Thus, we predicted that the most important factor in the ability to accurately solve problems in our question task would be children's capacity to use constraint-seeking questions efficiently (i.e., as constraint-seeking strategies) in order to gather sufficient information.

Method

Participants

The final sample consisted of 17 4-year-olds (M = 4 years 4 months [4;4], range = 4;0–4;11), 18 5-year-olds (M = 5;4, range = 5;0–5;11), and 19 6-year-olds (M = 6;3, range = 6;0–6;11) recruited from a participant recruitment database in a major metropolitan area in the American Southwest. Participants were primarily Euro-American and from middle-class families. Approximately equal numbers of boys and girls participated in the study. Children were interviewed individually in a quiet room in a participating preschool or research laboratory; each session took 30 to 45 min. An additional 5 children participated but were dropped from the final sample due to either inability to engage with the tasks or experimenter error (2 4-year-olds, 2 5-year-olds, and 1 6-year-old).

Overview

Each child participated in two tasks. The objective of the question task was to investigate the use of questions in order to gather the information required to solve novel problems. The problems the children were presented with were to select which candidate card in an array was hidden in a special box (one card per trial; six trials total). The cognitive flexibility task was designed to assess children's capacity to classify or categorize items using information about multiple dimensions (e.g., color, animal kind, artifact kind).

Question task

Materials

Two sets of laminated cards with pictures of animals of different sizes, colors, and patterns were created for this study. One set of cards was created for the simple trials, and another set was created for the complex trials. The simple trials set contained 16 cards. These cards differed by type of animal (i.e., dog or bird), size (i.e., large or small), and color (i.e., red or yellow) as well as by whether there was a pattern on the animal (i.e., with spots or without spots) (Fig. 1). The complex trials contained 24 cards. These cards were identical to those in the simple trials except that one of the dimensions (type of animal) included an additional animal (i.e., fish) (Fig. 2). For each trial, there was an additional card that was a duplicate of a card from each set. These cards served as the special hidden cards that
Fig. 1. Question task: Stimuli used for simple trials.

Fig. 2. Question task: Additional stimuli used for complex trials.
children needed to discover (one per trial; three total for simple trials and three total for complex trials). All cards were identical in overall size (2 \times 2 inches) and were presented to children in random order.

**Procedure**

The experimenter began with several minutes of rapport building and then told the participants that they would be playing a game. Each child participated in three simple trials followed by three complex trials.

**Simple trials.** The experimenter laid out 16 different test cards randomly with the pictures facing up on a table between the experimenter and the children. For each trial, the experimenter had an additional hidden card that was a duplicate of one of the 16 test cards laid out facing the children. Children were instructed to determine which animal card was hidden in the experimenter’s special box by asking the experimenter only “yes-or-no” questions. Children were told, “To win this game, you have to figure out which of these animals is in the special box. You can ask me any questions you want, but I can only say ‘yes’ or ‘no’. You can only choose one time, so make sure you’ve asked all the questions you want to ask so you’re ready to pick the right one”. Children could ask an unlimited number of questions but could choose which animal they thought was in the box only once. The total number of questions asked and the accuracy of the children’s response were recorded for each trial. The accuracy score was calculated by summing the total number of correct responses across the six trials. The total number of questions was calculated as the sum of the questions asked per trial. If the children seemed unsure as to how to ask a yes-or-no question, the experimenter presented an example question that did not relate to the cards used in the experiment in any way (e.g., “Do you like ice cream?”). Once the children chose which animal they thought was hidden in the special box by pointing at the test card, the experimenter revealed the hidden card and showed the children whether they were correct. The simple trial was repeated two more times (three trials total) with a different animal in the special box each time.

**Complex trials.** The procedure for the complex trials was identical to that for the simple trials. However, to increase the complexity of the task, children were presented with 24 cards instead of 16 and the cards differed in three dimensions for each type of animal instead of two.

**Coding**

Each question the children asked was fully transcribed and analyzed for the type of information acquired. Questions were coded as constraint-seeking, confirmatory, or ineffective. Constraint-seeking questions demonstrated the use of an effective and efficient strategy. Constraint-seeking questions generated new and relevant information that could be used to solve the task. Notably, constraint-seeking questions led to the elimination or isolation of a group of cards based on knowledge of a particular dimension or dimensions (similar to the constraint-seeking strategy identified by Mosher & Hornsby, 1966). Questions that asked directly about a single dimension were coded as effective–simple (e.g., “Is it red?”), whereas those that asked about more than one dimension were coded as effective–multiple (e.g., “Is it red with spots?”). Queries about a dimension other than animal, size, color, or spots were coded as creative dimension questions. For example, creative dimension questions inquired about a nonphysical feature of the animal such as whether it swims or flies (e.g., “Does it have wings?”).

Questions asked with the intention to confirm or reiterate previously obtained information were categorized as confirmatory questions. Questions that were repetitive (e.g., asking “Is it red?” a second time) and redundant (e.g., asking “Is it red?” after receiving a negative response to asking, “Is it yellow?” when all animals were either yellow or red) were also coded as confirmatory questions (Table 1).

Ineffective questions did not yield systematically useful or relevant information. Questions that were indiscriminate were coded as ineffective. For example, asking whether the animal had a tail was coded as ineffective because, although it was a relevant feature of the stimulus, it did not elicit useful information or demonstrate constraint-seeking strategy use because all animals had tails. Questions that
were not asked in the specified yes-or-no format (e.g., “What color is it?”) were also coded as ineffective (Table 1).

To analyze the amount of information acquired through questioning, we counted the number of dimensions children had information about based on the questions they asked (out of four possible per trial). Thus, information obtained was assessed by counting the number of dimensions known. For example, whereas only one question was required to determine whether the animal on the target card had spots, up to two questions may have been required in order to verify the kind of animal (i.e., there were fish, dogs, and birds in the complex stimuli set). If children knew from the questions asked that the stimulus was a red fish, two dimensions were known; if they knew that the stimulus was a red spotted fish, three dimensions were known; and if they knew that the stimulus was a small, red spotted fish, four dimensions were known.

**Cognitive flexibility task**

Children were given a set of 12 cards with pictures of objects from two different categories and consisting of two colors. From this set, they were asked to group together cards that were like one another. The first part of the task involved differentiating cards along a single dimension, and the second part required the participants to sort along two dimensions simultaneously.

**Materials**

The card set contained 12 pictures with 3 of each of the following: purple hats, orange hats, purple shoes, and orange shoes (Fig. 3A). The tasks were modeled after the multiple classification task used by Bigler and Liben (1992). During the multiple classification part of the task, the interviewer introduced a $2 \times 2$ matrix that was drawn on a sheet of paper. Then the interviewer showed how to sort an example set of cards. This set contained 12 pictures with 3 each of the following: brown monkeys, gray monkeys, brown elephants, and gray elephants (Fig. 3B). No 2 cards in either set were identical.

**Procedure**

In the first part of the task (single classification sort), participants were asked to sort 12 cards into two separate groups so that each group contained cards that were alike in some way but collectively different from the other along some dimension (e.g., purple items vs. orange items). Then the cards were shuffled and the children were asked to make two new groups based on a different dimension (e.g., shoes vs. hats). On completion of this task, the interviewer brought out a matrix and a set of

<table>
<thead>
<tr>
<th>Question type</th>
<th>Question subtype</th>
<th>Description</th>
<th>Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraint-seeking</td>
<td>Effective–simple</td>
<td>Questions about one dimension; provides new relevant information</td>
<td>“Is it red?” “Does it have spots?”</td>
</tr>
<tr>
<td></td>
<td>Effective–multiple</td>
<td>Questions about multiple dimensions; provides new relevant information</td>
<td>“Is it a red dog with spots?”</td>
</tr>
<tr>
<td></td>
<td>Creative dimension</td>
<td>Questions about dimensions other than color, size, spots, or animal</td>
<td>“Does it walk on land?” “Does it have wings?”</td>
</tr>
<tr>
<td>Confirmatory</td>
<td>Repetitive or redundant</td>
<td>Questions that are exactly the same as those asked previously; follow effective–simple questions (ask about the same dimension); provide relevant (but not new) information</td>
<td>“Is it red?” “Is it red?” “Is it red?” “Is it yellow?”</td>
</tr>
<tr>
<td>Ineffective</td>
<td>Indiscriminate or different form</td>
<td>Questions that demonstrate effort on the part of the children but are not asked effectively to capture useful information (e.g., not yes-or-no format)</td>
<td>“Does it have a mouth?” “Does it have a tail?” “What color is it?”</td>
</tr>
</tbody>
</table>
example cards. Participants were shown how the example cards could be cross-classified along the two axes (left and right sides matching on one dimension and the top matching the bottom on another). Children were then asked to sort their cards in the same way using the matrix (multiple classification sort). Children were tested for their understanding of this kind of classification by being asked which line separated the groups by color or type.

**Coding**

For successful sorting along a single classification (including those off by just one card), children were credited with one point (e.g., color). Incomplete or incorrect sorting was scored a zero. In addition, children were given another point for being able to justify the basis for sorting. Even if sorting was not accomplished successfully (score of zero for that component), it was possible to receive a point for explanation once the interviewer showed a correct solution. The scoring applied to both tri-
als, and children were given the opportunity to sort along two different dimensions (two points per trial for up to four points). For the multiple classification part of the task, children received one point per dimension completed, incomplete or incorrect sorting was scored a zero, and one point was given for explaining the basis of a classification along a particular dimension. As with the first part of the task, the maximum possible score was four points. A total score of eight points was calculated.

Results

Due to the challenging cognitive demands of the question task, age differences in performance were analyzed by examining three measures: question efficacy (evidence of constraint-seeking question use), accuracy, and information acquired (dimensions known). We were also interested in the relationship among these measures of performance on the question task and performance on the cognitive flexibility task.

Our first analyses examined the kinds of questions children asked (constraint-seeking, confirmatory, and ineffective). Constraint-seeking questions provide evidence of the use of constraint-seeking strategies. Data were collapsed across all six experimental trials to create summary scores. To investigate potential age differences in the number of questions of each type children asked, we conducted three separate one-way analyses of variance (ANOVAs), one for each question type (constraint-seeking, confirmatory, and ineffective), with age (4-, 5-, or 6-year-olds) as a between-participants variable. We predicted that older children would ask more constraint-seeking questions than younger children, demonstrating increased use of constraint-seeking strategies with age. The first ANOVA compared the proportion of constraint-seeking questions per age group, revealing a significant effect of age, $F(2,51) = 4.92, p < .05, \eta^2 = .16$. Post hoc analyses showed that 6-year-olds asked significantly more constraint-seeking questions than both 4-year-olds ($p < .05$) and 5-year-olds ($p < .05$). The second ANOVA—comparing the proportion of confirmatory questions per age group—revealed no significant effect, $F(2,51) = 1.90, ns$. The third ANOVA compared the proportion of ineffective questions per age group and found no reliable effect, $F(2,51) = 1.71, ns$ (see Fig. 4). Additional descriptive data about the subtypes of questions asked by age are provided in Table 2 but were not analyzed inferentially due to infrequent use of some of the question subtypes.

![Fig. 4. Question task: Proportions of types of questions by age group. Error bars are 95% CI.](image_url)
We examined age differences in accuracy on the question task by comparing the number of correct choices across the six trials per age group. A one-way ANOVA compared the number of correct answers across age groups. Consistent with previous research (Mills et al., 2011), we found no reliable main effect of age (4-year-olds: $M = 1.94$ out of 6, $SD = 1.67$; 5-year-olds: $M = 2.83$, $SD = 1.65$; 6-year-olds: $M = 2.68$, $SD = 1.49$). To investigate the relationship between the frequency of each kind of question and accuracy, we conducted a regression analysis with the number of constraint-seeking questions, number of confirmatory questions, number of ineffective questions, and number of total questions as predictor variables and accuracy as the outcome variable. Given that, by definition, the total number of questions was highly correlated with the number of constraint-seeking, confirmatory, and ineffective questions, we orthogonalized this variable to address issues of collinearity. Results revealed that the number of constraint-seeking questions was the only statistically reliable predictor of accuracy in the question task, $b = 0.16$, $t(52) = 6.54$, $p < .001$. There were no statistically significant interactions between specific types of questions. The total variance accounted for by the model was $R^2 = .45$.

Notably, overall accuracy on this task was not high because children needed to have information about all of the dimensions correct in order to make a correct choice on this task (i.e., animal kind, color, size, and pattern). For both trial types, four dimensions were involved with 16 cards in the simple trials and with 24 cards in the complex trials. This made the task challenging from a working memory perspective. Thus, in addition to overall accuracy, we also analyzed information acquired or dimensions obtained (i.e., the number of dimensions children obtained through questioning per trial out of four possible averaged together across six trials). There were a number of dimensions that children needed to know in order to obtain a correct answer (i.e., color, animal, size, and pattern; four dimensions total), and children who selected incorrect cards varied in how much information they had obtained (e.g., some children obtained information about only one dimension [e.g., color], whereas others obtained information about three dimensions [e.g., color, animal, and size]). A one-way ANOVA with information acquired (average number of dimensions obtained through questioning) as the dependent measure indicated that there were statistically significant age differences (4-year-olds: $M = 1.96$ out of 4, $SD = 1.24$; 5-year-olds: $M = 2.99$, $SD = 0.84$; 6-year-olds: $M = 2.71$, $SD = 0.83$), $F(2,51) = 5.08$, $p < .001$, $\eta^2 = .17$. Post hoc tests (Bonferroni-corrected) revealed that the number of dimensions obtained was significantly fewer for 4-year-olds as compared with both 5-year-olds, $t(33) = 2.88$, $p < .001$, and 6-year-olds, $t(34) = 2.14$, $p < .001$. The 5- and 6-year-olds did not differ from each other in terms of information acquired (average number of dimensions obtained through questioning), $t(35) = 1.01$, ns.

Similar to the analyses performed for question task accuracy, to examine the extent to which information acquired (average number of dimensions obtained through questioning) could be predicted by the types of questions asked, we conducted a regression analysis with the number of constraint-seeking questions, number of confirmatory questions, number of ineffective questions, and number of total questions as predictor variables and information acquired as the average number of dimensions obtained through questioning. Results revealed that both the number of constraint-seeking questions, $\beta = 0.14$, $t(51) = 17.60$, $p < .001$, and the number of confirmatory questions, $\beta = 0.02$, $t(51) = 3.26$, $p < .005$, significantly predicted the average number of dimensions obtained through questioning. Both kinds of questions asked (constraint-seeking and confirmatory) accounted for 89% of the total variance in the amount of information acquired. No significant interaction term was found.

<table>
<thead>
<tr>
<th></th>
<th>Constraint-seeking</th>
<th>Confirmary</th>
<th>Ineffective</th>
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<tbody>
<tr>
<td></td>
<td>Effective–</td>
<td>Repetitive or</td>
<td>Indiscriminate or different</td>
</tr>
<tr>
<td></td>
<td>simple</td>
<td>redundant</td>
<td>form</td>
</tr>
<tr>
<td>4 years</td>
<td>41</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>5 years</td>
<td>50</td>
<td>33</td>
<td>10</td>
</tr>
<tr>
<td>6 years</td>
<td>62</td>
<td>23</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2

Question task: Percentages (%) of subtypes of questions by age (totals across age).
To examine group-level differences in the kinds of questions asked by performance, we compared children who performed at the top of the distribution to children who performed at the bottom of the distribution out of six possible trials. To divide children into two groups, we performed a median split on accuracy. This resulted in 24 higher performing children and 30 lower performing children. Children in the higher performing group asked significantly more constraint-seeking questions ($M = 22.1, SD = 3.03$) than children in the lower performing group ($M = 12.9, SD = 5.41$), $t(52) = 7.43, p < .001$. Children in the higher performing group asked marginally more confirmatory questions ($M = 9.58, SD = 6.22$) than children in the lower performing group ($M = 6.03, SD = 7.15$), $t(52) = 1.92, p = .061$. There was no difference in the number of ineffective questions asked per group (higher performing: $M = 2.45, SD = 3.32$; lower performing: $M = 2.63, SD = 2.45$), $t(52) = -0.21, ns.$

### Cognitive flexibility task

A one-way ANOVA revealed a reliable main effect of age on performance on the cognitive flexibility task, $F(2,51) = 7.93, p < .001, \eta^2 = .24$ (4-year-olds: $M = 5.88$ out of 8, $SD = 1.40$; 5-year-olds: $M = 6.72, SD = 1.07$; 6-year-olds: $M = 7.36, SD = 0.83$). Age differences in each of the subcomponent tasks (single and multiple classification) of the cognitive flexibility measure are included in Table 3. There were significant improvements by age on both the single classification score, $F(2,51) = 7.93, p < .001$, and the multiple classification score, $F(2,51) = 3.45, p < .05$. Post hoc tests revealed that for both subtasks, 6-year-olds performed significantly better than 4-year-olds ($ps < .05$).

Table 4 shows that performance on the cognitive flexibility task was significantly correlated with accuracy on the question task ($r = .37, p < .01$) and shows a marginally significant correlation with information acquired on the question task (average number of dimensions known) ($r = .26, p < .06$). The significant correlation between accuracy on the question task and cognitive flexibility performance was driven by the multiple classification component of the cognitive flexibility task ($r = .29, p < .05$); the correlation with the single classification score was not significant.

We also compared the performance on the cognitive flexibility task and the specific types of questions asked between children in the higher performing group and children in the lower performing group. Results revealed that the higher performing group performed marginally better ($M = 7.04,$

### Table 3

Cognitive flexibility task: Mean scores by age.

<table>
<thead>
<tr>
<th>Age</th>
<th>Single classification score</th>
<th>Multiple classification score</th>
<th>Total score</th>
</tr>
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<tbody>
<tr>
<td>4 years</td>
<td>2.88 (0.85)</td>
<td>3.00 (0.79)</td>
<td>5.88 (1.40)</td>
</tr>
<tr>
<td>5 years</td>
<td>3.38 (0.60)</td>
<td>3.33 (0.76)</td>
<td>6.72 (1.07)</td>
</tr>
<tr>
<td>6 years</td>
<td>3.74 (0.45)</td>
<td>3.63 (0.59)</td>
<td>7.36 (0.83)</td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses.

### Table 4

Correlations across age and dependent measures across tasks.

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<td>1. Age</td>
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<td>2. Question task: Accuracy</td>
<td>.19</td>
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<td>3. Question task: Information acquired</td>
<td>.31*</td>
<td>.72**</td>
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<td>4. Question task: Total number of questions</td>
<td>.00</td>
<td>.50*</td>
<td>.81**</td>
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<td>5. Question task: Constraint-seeking questions</td>
<td>.22</td>
<td>.67**</td>
<td>.94**</td>
<td>.78**</td>
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<td>6. Question task: Confirmatory questions</td>
<td>-.12</td>
<td>-.28</td>
<td>-.52**</td>
<td>.85**</td>
<td>.41**</td>
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<td>7. Question task: Ineffective questions</td>
<td>-.21</td>
<td>-.05</td>
<td>.06</td>
<td>.43**</td>
<td>.05</td>
<td>.28**</td>
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<td>8. Cognitive flexibility task</td>
<td>.52*</td>
<td>.29</td>
<td>.26*</td>
<td>-.04</td>
<td>.20</td>
<td>-.20</td>
<td>-.13</td>
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* $p < .10$.
** $p < .05$.
*** $p < .01$. 
SD = 0.95) than the lower performing group \((M = 6.40, SD = 1.40)\) in the cognitive flexibility task, \(t(52) = 1.92, p = .061\).

**Discussion**

Despite evidence that young children are motivated to ask questions to learn about the world around them (Frazier et al., 2009), little is known about how children apply this capacity to solve complex problems. The current experiment examined age differences in the capacity to use questions as problem-solving strategies across early childhood in addition to the role of cognitive flexibility in facilitating this complex cognitive process.

Given the intentional complexity of the question task, we were interested in multiple measures of performance: question efficacy (evidence of constraint-seeking strategy use), information acquired, and accuracy. Although there were no significant age differences for one of the measures of performance (i.e., accuracy), there were significant age differences in others (i.e., the use of a constraint-seeking strategy and the amount of information acquired per trial). Notably, overall accuracy was low across age groups and required acquiring, remembering, and coordinating information about four different dimensions (animal, color, size, and pattern) in order to select the correct card. Our data demonstrate that children have the capacity to acquire relevant information through the strategic use of constraint-seeking questions before they have the capacity to successfully coordinate and maintain the information in working memory. Thus, we propose that the number of constraint-seeking questions asked and information acquired through questioning (i.e., average number of dimensions known) are more sensitive measures of performance and better suited to examining age improvements. Notably, despite improvements in the capacity to implement these strategies effectively with age, our data indicate that even 4-year-olds were able to spontaneously generate constraint-seeking questions without always selecting the final correct card.

The results also indicate that the strongest predictor of accuracy was the number of constraint-seeking questions asked. This is consistent with previous research (Mills et al., 2010). However, the number of confirmatory questions asked and question task accuracy were correlated, and higher performing children asked marginally more confirmatory questions than lower performing children, suggesting that children may have been using confirmatory questions strategically to facilitate memory. An important direction for future research will be to examine individual differences in how confirmatory questions are used to improve performance on problem-solving tasks.

We were also interested in the relationship between cognitive flexibility and the ability to ask constraint-seeking questions for problem-solving purposes. Using a multiple classification task, we replicated previous research demonstrating age improvements in cognitive flexibility (Deák, 2000) and multiple classification (Bigler & Liben, 1992). We also found that performance on the cognitive flexibility task significantly correlated with both the overall accuracy and information acquired through questioning. This result was driven primarily by performance on the multiple classification component of the cognitive flexibility task, suggesting that this capacity may facilitate the ability to generate and apply constraint-seeking strategies, the strongest predictor of accuracy on the question task.

However, there are a number of additional potential contributors to children’s success at asking a constraint-seeking question, including linguistic skills, working memory capacity, and information processing speed. Improvements in these skills across early childhood (e.g., Kail, 1991, 2007) may relate to improvements in the ability to generate a constraint-seeking question. Although this study provides evidence for age differences in the strategic use of questions during early childhood, investigating the origins of individual differences in the cognitive capacities underlying performance on these tasks would also provide substantial additional insight. For example, examining how the capacity to generate relevant information relates to a child’s general level of intelligence and to metacognitive awareness would be an especially informative topic of future research.

Other open questions concern what changes over development and the extent to which these skills can be improved through education. Specifically, how do cognitively flexibility and problem-solving capacities contribute to children’s ability to successfully implement constraint-seeking strategies?
To examine this, one possible direction for future research would be training studies examining the extent to which these skills can be developed through instruction and practice.

The complex cognitive process of actively seeking information from others by asking questions is a fundamental developmental task. We propose that the process of using questions as strategic tools is an ideal context for examining how children come to gain active and intentional control over problem solving across early childhood. Our data demonstrate some age differences in the strategic use of questions as problem-solving tools (e.g., increasing use of constraint-seeking strategies and increase in information acquired with age) as well as providing evidence that cognitive flexibility facilitates this complex ability. We propose that our results have implications for research on the development of children’s questions as information acquisition and problem-solving strategies.

References


