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The development of metacognitive causal explanations

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Abstract

Metacognitive causal explanations reflect a child's understanding about how or why a strategy works. Two studies examined the growth of metacognitive causal explanations over time. Study 1 found an increase in the sophistication of early elementary school children's causal explanations over a 3-year period, although the mean intelligence score in the group was relatively high. Study 2 was conducted with children from a wider range of intelligence. Only those children with higher intelligence scores were likely to shift to more sophisticated metacognitive causal explanations over a 2-year period. Results from the two studies together suggest that the relationship between intelligence and metacognitive knowledge is much more than monotonic throughout development [Dev. Rev. 15 (1995) 1]. Indeed, higher levels of intelligence increase the likelihood that children will move from less sophisticated to more sophisticated levels of metacognitive understanding, possibly laying the foundation for more sophisticated later learning.

Keywords: Development; Metacognitive causal explanation; Intelligence

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1. Introduction

It has been argued that a circular relationship exists between metamnemonic competence and strategy use such that information gained during a strategic task feeds back into the metacognitive system and adds to the declarative knowledge we have about the effectiveness of a given strategy (Bjorklund, 2000). Finding the evidence to support this argument, however, has been elusive (Cavanaugh & Borkowski, 1980). While knowing the level of a child's metacognitive knowledge has not always allowed one to predict performance on a strategic task (Cavanaugh & Borkowski, 1980), research on specific metacognitive causal explanations suggests that knowing how a child believes a strategy will help them to remember can lead to fairly accurate predictions (Alexander & Schwanenflugel, 1994; Fabricius & Cavalier, 1989; Fabricius & Hagen, 1984).

Fabricius and Cavalier (1989) and Fabricius and Hagen (1984) have proposed that specific metacognitive explanations give us more information than simply that a child believes a strategy is useful. Instead, metacognitive explanations give us a window into a child's understanding of "why" a particular strategy works to promote recall. Fabricius and Cavalier found that only children who could verbalize how a strategy would aid in the processing of information were seen to use that strategy on a second, separate occasion. These explanations have also been found to lead to more sophisticated sorting strategy use (Fabricius & Hagen, 1984). The question remains, however, whether or not metacognitive causal explanations increase in sophistication over time.

If we believe that metacognitive causal explanations become more sophisticated with development as general declarative metacognitive knowledge has been shown to do (e.g., Kreutzer, Leonard, & Flavell, 1975), then the question becomes one of individual differences. Do all children progress through this "developmental continuum" at an equal speed or even in the same manner? Do individual differences in general intelligence predict differential growth? Alexander et al. (1995), in a review of the relationship between giftedness and metacognitive knowledge, noted that intelligence and declarative metacognitive knowledge have been shown to have a monotonic relationship throughout development. In other words, higher levels of intelligence are associated with more sophisticated levels of declarative metacognitive knowledge from kindergarten through junior high school. Unfortunately, little longitudinal research has followed children during this growth period to explicate the exact relationship between intelligence and metacognitive growth. The present paper, therefore, seeks to explore these issues.

Metacognition has been defined differently by different researchers. We adopt the broad definition offered by Alexander and Schwanenflugel (1996) which includes: (a) conceptual information about the mind (elaborated below); (b) cognitive monitoring (or the ability to read one's own mental states and accurately assess how that state will affect present and future performance on mental activity tasks; Wellman, 1983); and (c) strategy regulation (or the ability to use metacognitive knowledge strategically to achieve goals).

We believe that conceptual information about the mind can be further distinguished into three varieties of knowledge organized in terms of decreasing levels of generality: (a) knowledge of mental activity concepts, (b) general declarative metacognitive knowledge about these concepts, and (c) strategy-specific metacognitive causal explanations. The present study will concentrate on the last type of conceptual information about the mind only: strategy-specific metacognitive explanations. These explanations refer to justifications that children make regarding why specific strategies work the way they do.

Fabricius and Cavalier (1989) found that children's strategy-specific metacognitive explanations fell into two categories of causal theories: information processing (IP) and information acquisition (IA). Children with IP causal explanations understand that memory performance is affected by how information is mentally processed. Children who believe that their ability to remember is affected by how well information is first perceived or acquired are said to have an IA causal explanation theory.

Several research studies have shown that the possession of more sophisticated IP causal explanations does have an effect on increased strategy use and recall. Fabricius and Cavalier (1989) found that children who possessed an IP explanation for why a strategy worked—in other words, they were able to say that labeling would help them to "keep thinking about the pictures"—were more likely to use the labeling strategy again on a separate, more demanding task. Alexander and Schwanenflugel (1994) found that children who were classified at more sophisticated levels of metacognitive causal explanations were more likely to report using sophisticated memory strategies which eventually increased their recall relative to children with less sophisticated metacognitive causal explanations. IA explanations, on the other hand, have not been shown to be related to effective strategy use and have been argued to represent a less sophisticated level of metacognitive understanding about how a strategy works.

The present studies were designed as the first to examine the development of metacognitive causal explanations over time and the effects of general intelligence on the growth in sophistication of this knowledge. Our goals were twofold: (a) to determine if metacognitive explanations develop over time, particularly over the early elementary school years when previous research has shown relations between metacognitive causal explanations and strategy use; and (b) to determine the relative contribution of general intelligence to metacognitive explanation growth. The present studies used a method similar to Alexander and Schwanenflugel (1994) and Fabricius and Hagen (1984) so that metacognitive causal explanations could be examined at multiyear intervals in Study 1 from ages 6 to 9 and in Study 2 from ages 8 to 10.

2. Study 1

2.1. Method

2.1.1. Participants

There were 42 children who were given metamemory assessments at both ages 6 (6.0–7.1, $M=6.5$) and 9 (8.6–10.5, $M=9.4$). They were given a standardized intelligence test at age 10 (9.8–10.10, $M=10.2$). The children were originally obtained from two daycare centers and a private school in the Athens, Georgia area. Half were the 6-year-olds from a previous study (Fabricius & Cavalier, 1989). There were approximately equal number of boys and girls.

2.1.2. Materials

Materials used with half of the 6-year-olds were described by Fabricius and Cavalier (1989) but were similar to those described below. For the other half there were nine sets of eight black-and-white drawings each measuring 10 cm^2 mounted on card stock. Seven sets included four pairs of thematically related pictures, such as key and lock, hamburger and plate, finger and ring, and bed and pillow. Two sets included nonmatching pictures (e.g., yoyo, penny, heart, leaf, piano, suitcase, scissors, zipper). In addition, there were four moveable stands that held two pictures each. For the 9-year-olds, there were two sets of 20 colored pictures each on 76 × 102 cm cards. Both decks included four pictures from each of five categories. Set 1 included clothing, farm animals, food, fictional characters, and tools. Set 2 included toys, people, wild animals, buildings, and vehicles.

2.1.3. Procedure

Those 6-year-olds who were not part of the Fabricius and Cavalier (1989) study received a five-trial procedure (below) very similar to that study but with different materials. According to Fabricius and Cavalier, the emphasis was on children's understanding of how labeling worked to aid recall; for the remaining children the emphasis was on their understanding of how a conceptual relationship between items aids recall ("matching"). In both procedures, children were induced to spontaneously produce the target strategies (i.e., labeling and matching), were given experience recalling with and without them, and then were asked about what they thought helped them recall and how they believed that worked to help them. On the basis of their explanations of how the strategies worked, children in both procedures were classified in the same ways, as either offering IP explanations in which they referred to mental processes elicited by the target strategies, or IA explanations in which they were unaware that the strategies helped them recall or had no explanation for how they worked.

The experimenter and child sat facing each other at a table. Trials 1 to 4 each used a different set of matching pictures, and Trial 5 used a set of nonmatching pictures.

Trial 1 (no recall) was designed to encourage the child to put two thematically related pictures on each stand. The experimenter placed each picture on the table in a circle so that no matching pictures were adjacent, naming each picture in turn. He told the child, "I would like you to put these pictures on the stands for me." After the child finished, the experimenter turned the stands around to face him and asked, "Did you put the pictures up in any special way?" If the child did not report matching them, he asked, "Did you match any?"

Trial 2 (incidental recall) was identical to Trial 1, except that after the stands were turned around the experimenter asked the child to recall them.

Trial 3 (intentional recall) was identical to Trial 2, except that now the experimenter told the child, "I'm going to ask you to remember these pictures too, so do whatever you want to help yourself remember." It was important that children matched all four pairs of pictures so they would have experience recalling matched pairs.

Trial 4 (no recall) was identical to Trial 3 except that recall was omitted so that the following questions could be asked in close proximity to the child's strategic behaviors: (1) "You were trying to remember the pictures, right? So, what did you do that would help you remember?", "Did you do anything else that would help you remember them?"; (2) "How does (each thing the child mentioned) work to help you remember?"; (3) If the child did not mention matching the pictures, the experimenter asked, "Did you put the pictures up in any special way? Did you match any?". It was important that children matched all four pairs of pictures so they would have the opportunity to report matching as their strategy and explain how it worked.

Trial 5 (nonmatching recall) was identical to Trial 3, except that a set of nonmatching pictures was used. After recall, the experimenter asked, (1) "Was it harder, easier, or the same to remember the pictures this time?"; (2) Why was it harder (on the trial the child indicated)? Why was it easier (on the trial the child indicated)? Why was it the same (if that was what the child answered)?"; (3) "How does (whatever the child said in response to above) work to make it harder (easier, the same)?"; (4) If the child did not mention matching the experimenter asked, "When you put them on the stands you matched the others right? What about these? Which matched better?". Then the experimenter re-asked questions 2 and 3 to give the child a last chance to say that matching helped him recall and explain how he thought it worked. It was important that children said it was harder to recall on Trial 5 so they would have the opportunity to report that matching affected recall and explain how it worked.

In seven cases, children either failed to report that it was harder to recall on Trial 5 or they did not match all the pictures on Trial 3 or 4. In the former cases, children were given repeated Trials 3 and 5 with new pictures, after which they all did report that Trial 5 was harder. In the latter cases, children repeated the trials on which they failed to match and all subsequently matched.

Children were classified into causal explanation classifications according to their responses to question 2 in Trial 4 and question 3 in Trial 5 about how matching worked to help them remember. Children were considered to have an IP explanation if they responded that matching helped them because when they thought of one item, it made them think of the related item. Children who reported that matching helped them turn the recall task into a recognition task were also classified as having an IP explanation (e.g., "If I remembered plate I could just think 'What goes with plate?'"). Children were considered to have an IA if they realized that matching helped them to remember but had no explanation for how it worked, or were unable to make the attribution that matching had helped them to remember. An initial 94% agreement between two coders classifying children into these categories was obtained. Disagreements were resolved by discussion.

At age 9, children were shown the 20 stimuli in an array in front of them on the table and told, "You are going to be given some pictures to remember. Do whatever you want to help yourself remember. You can leave them where they are, move them (randomly exchanging two cards in the array), or just leave them where they are—whatever you think will help you remember". During the 2-min study period, the child's behaviors were observed and recorded at 15-s intervals. Behaviors of moving pictures, verbalizing, looking at the pictures, or being distracted were recorded. At the end of the study period, a screen was placed over the grid and the children were asked to recall, "Tell me as many of the pictures as you can remember." Recall was terminated only after the child had exhausted his/her memory and had been given 15 s to recall after being prompted for additional words. They were then asked, "What did you do to help yourself remember?" and "What else?" followed by the metacognitive causal attribution question, “How do you think X worked to make remembering easier?”. A second trial followed immediately using the same procedures with the second set of pictures.

Children were classified into causal explanations classifications according to their responses to the metacognitive causal explanation question. Children were considered to have an IP explanation if, in their explanation of *how* a strategy worked to improve recall, they understood that their memory performance was affected by how the information was mentally processed. If the child described using categories to aid recall, she would have to indicate that she was aware that first one thing was in her mind which made her think about another item. It could either be the category in mind (e.g., “I knew they were all toys”) or a related item (e.g., “Ball made me think of glove”). If the child said her strategy was either labeling or looking at the pictures, she would have to distinguish in her explanation between overt labeling or looking, and saying the words in her mind or mentally picturing the items (e.g., “Saying the names over and over again keeps it in my mind,” “I looked at them and said them in my mind”). Finally, children were also classified as having an IP explanation if they described monitoring and self-testing processes (e.g., “I kept going over them till I had them,” “I looked over them till I remembered”). If children gave an IP explanation on either or both trials, they were assigned to the IP group. Any children who gave explanations that did not appeal to mental processes or gave no explanation were included in the IA group. Interrater agreement between two coders on classification was initially 93% with all discrepancies resolved through discussion. The experimenter and coders were blind to the child’s metacognitive causal explanation classification from age 6.

At age 10 children were individually administered the Arithmetic, Vocabulary, Picture Arrangement, and Block Design subtests from the Wechsler Intelligence Scale for Children—Revised by a licensed school psychologist. Scores were standardized and combined to create a composite score.

2.1.4. Results

At age 6, 15 children had been classified as having an IP explanation and 27 children were classified as having IA explanations. At age 9, 29 children were classified as having IP explanations and 13 were classified as having IA explanations (see Table 1). Nine children were classified at the less sophisticated IA level at age 6 and did not gain a more complete understanding of the strategy at age 9. Eighteen children, however, became aware over the 2.5 years of the IP explanation of strategy effectiveness. Only four children were classified as less sophisticated at age 9 than at age 6. A McNemar’s test to examine change in a categorical variable with a related sample indicated that children were more likely to

Table 1
Shift from information acquisition to information processing causal explanation between ages 6 and 9 in Study 1

Age 6	Age 9	
	Information acquisition	Information processing
Information acquisition	9	18
Information processing	4	11

move to more sophisticated levels of metacognitive explanations than the reverse [$\chi^2(1) = 8.91$, $P < .01$].

At age 10, these children as a group were somewhat advanced intellectually, with a mean intelligence score (IQ) of 113.86. To examine for differences in IQ between children classified as IP and children classified as IA at age 9, a t test was computed. Results indicated no significant difference on IQ between the IP ($M = 115.38$) and IA ($M = 110.46$) children [$t(40) = 1.30$, $P = .20$].

2.1.5. Conclusion

Fabricius and Cavalier (1989) had proposed that children's early theories of metamemory are based on how information is perceived or acquired. With time, however, children should begin to develop an understanding that memory is based on how information is processed, not simply acquired. The significant shift in the group classifications from IA to IP explanations lends credence to this proposal. However, given that the current sample represented a restricted range of IQ for children in elementary school (37 out of the 42 were above the mean of 100), we were unsure whether the results could be applied to a more representative school-wide population. In addition, because the IQ scores were not obtained until age 10, we were unable to ascertain whether children with higher IQ at younger ages were likely to shift to more sophisticated metacognitive causal explanations than children with lower IQ scores. Among a relatively gifted group such as ours, many children did switch but there was little difference in IQ between those who had switched by age 9 and those who had not. Therefore, we designed Study 2 to reach a wider range of children. In addition, we were interested in whether the particular procedure we used made any difference in the results we obtained. We believed that obtaining the same results with a similar but slightly different procedure (aimed at a different strategy) would greatly enhance the external validity of our findings.

3. Study 2

3.1. Participants

Forty-eight children from an elementary school in southern Indiana were seen in second grade (7.7–9.9, $M = 8.4$) and again in fourth grade ($M = 9.11$). There were approximately equal numbers of girls and boys. One subject was subsequently dropped due to experimenter error.

3.2. Materials

For the second grade session, there were four decks consisting of 12 black and white line drawings each on 8.5 × 8.5 cm cards. Each deck included four pictures from each of three categories: (a) weather phenomena, animals, tools; (b) kitchen utensils, musical instruments, dogs; (c) parts of a building, birds, body parts; (d) buildings, toys, vegetables. A different deck of cards was used for each of four trials.

In addition, stimuli for two noncategorizable trials were developed consisting of two decks of 12 black and white pictures. The first set included: monkey, garbage can, balloon, book, paintbrush, train, ruler, peanut, tie, watermelon, spoon, moon. The second set included: bell, peacock, basket, envelope, star, key, mushroom, eye, telephone, cake, purse, and refrigerator. The only restrictions were that no two items are from the same category and all items are easily known to children of this age.

For the fourth grade session, fifteen 19-cm words individually printed on 76 × 102 cm cards served as stimuli. Three decks (used in the first three trials) included words from three different categories (Deck A: dogs, kitchen utensils, vegetables; Deck B: colors, toys, buildings; Deck C: tools, flowers, body parts), while the fourth deck (used in the fourth trial) contained noncategorizable words (poodle, carrot, guitar, bank, hand, canary, pistol, hammer, car, pan, sunny, dress, apple, chair, and football).

Three stands were constructed which would each hold four or five (depending on the grade level) pictures side by side. These were used for both the second and fourth grade sessions.

3.3. Procedure

The second grade session began with the assessment of children's ability from the Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1990), a measure of both expressive vocabulary and nonverbal intelligence. Split-half reliabilities between .89 and .98, along with correlations between .58 and .80 with the WISC-R, show the K-BIT to be a reasonable measure of verbal and nonverbal intelligence, hence, referred to as general intelligence.

At age 8, as in Study 1, we used a five-trial procedure to spontaneously produce the target strategy (in this case, sorting), gave the children experience recalling both with and without the target strategy, and then asked them for metacognitive causal explanations.

After Trial 4, all children were able to sort the stimuli into groups and labeled their strategy use as "grouping" or "putting them together." At the end of Trial 5, if the child actually remembered more items from the noncategorizable trial than from the categorizable one, another set of noncategorizable stimuli was used. Then, the metacognitive questions were asked only after the second trial. All but two children did worse or equally well (but were able to make the attribution that the noncategorizable trial was harder) by the second trial. Thus, the noncategorizable trial provided the opportunity for the children to experience a decline or greater difficulty in recall attributable directly to the nature of the stimuli with which they were working.

Children were classified into causal explanation classifications according to their responses to the same questions as Study 1. Children were considered to have an IP explanation if they responded that sorting helped them because when they thought of one item they could think of the other items in that group. Children who reported that sorting helped them turn the recall task into a recognition task were also classified as having a mental explanation. Some examples were: "They were the same—it was like a clue. An ear would go to a person, a toe would go to a person..." and "There were more things to think about than just one... You could go in some place and go through it in your mind and can look for the things you saw." Children were considered to have an IA if they said that sorting allowed other perceptual or behavioral things to occur, realized that sorting helped them to remember but had no clue as to how it worked, or were unable to make the attribution that sorting had helped them to remember. An initial 91% agreement between two authors classifying children into these categories was obtained at age 8. Disagreements were resolved by discussion. Again, the experimenter and coders at age 10 were blind to the causal attribution classification from age 8.

Procedures for the fourth grade session were identical, except that the K-BIT was not readministered. Children were shown 15 cards instead of 12 to make the task more realistically a challenge for the 10-year-olds. In addition, there were only four trials, as the first trial was deemed unnecessary as a way of familiarizing students with the procedure. An initial 94% agreement between one author and another trained coder on the metacognitive causal explanation classification was obtained at age 10. As before, disagreements were resolved through discussion.

3.4. Results

The K-BIT scores for the 8-year-olds ranged from 72 to 130 ($\bar{X}$=100.8, S.D.=11.73), so our goal of assessing a wider range of elementary school aged children had clearly been achieved. At age 8, 20 children were classified as having an IP explanation while 27 children were classified as having IA explanations. At age 10, 25 children were classified as having an IP while 22 professed an IA explanation. A majority of the sample kept the same explanation they had shown at age 8 over the 2 years ($n=30$). Eleven children moved to a more sophisticated level, six children were rated as having a less sophisticated causal explanation. A McNemar's test for related samples found no significant shift in causal explanation sophistication between ages 8 and 10 [$\chi^2(1)=1.47$, $P>.05$] for this more representative group (Table 2).

Given that the children in Study 1 had a higher mean IQ than in the present study, we were interested in whether IQ affected children's ability to shift to higher levels of metacognitive causal explanations in this sample. We divided the children into three groups approximating the normal curve (IQ <90; IQ=90–109; IQ ≥ 110) and ran separate McNemar's tests on the shift in metacognitive causal explanations for each group. Results paralleled those found in Study 1. Children in the low and moderate IQ groups did not exhibit significant shifts toward more sophisticated causal explanations over the 2 years

Table 2
Shift from information acquisition to information processing causal explanation between ages 8 and 10 in Study 2

Age 8	Age 10	
	Information acquisition	Information processing
Information acquisition	16	11
Information processing	6	14

[$\chi^2(1) = 3.0$ and 2.0, respectively, both P's>.05]. Children in the high IQ group ($n = 23$) did, however, exhibit the same shift in causal explanations we had seen in Study 1 [$\chi^2(1) = 6.0$, $P < .05$] with more children moving from IA explanations to IP explanations than staying static or moving backwards along the continuum from IP to IA. Sixty percent of the children in the high IQ group increased the sophistication of their metacognitive causal explanations, while none were rated as having a less sophisticated causal explanation at age 10 than at age 8.

As shown above, intelligence was related to the probability that a child would shift from IA to IP explanations between ages 8 and 10. Intelligence was not, however, related to the sophistication of a child's metacognitive causal explanation at age 8 [$F(1,43) = 1.3$, $P > .05$].

4. General discussion

Taken together, these studies begin to help us understand the relationship of metacognitive causal explanations and intelligence. Although children with higher IQ scores are not advantaged in the early grades in terms of their metacognitive understanding, children with higher IQ scores are more likely to shift to a more sophisticated understanding of how specific strategies work to enhance recall. By third grade, differences in metacognitive understanding about specific strategies parallel differences in intelligence.

Alexander et al. (1995) noted that developmental research in the area of declarative metacognitive knowledge seems necessary to tease apart the relationship between IQ and metacognitive understanding very early on. If we consider metacognitive causal explanations as a type of declarative metacognitive knowledge ~~about a~~ specific strategy, the present research suggests that the relationship between intelligence and metacognitive knowledge is one where intelligence lays the foundation for the development of sophisticated metacognitive knowledge about strategy effectiveness.

Longitudinal studies allow researchers to examine the ontology of variables during development. Although cross-sectional research on metacognition and intelligence suggests that there is a monotonic relationship between high levels of intelligence and high levels of metacognition throughout early childhood, the current findings make us pause. Although it is true that a group of children at each age had a sophisticated metacognitive explanation about strategies, that group of children was not necessarily the more intelligent one. Given that intelligence tests typically assess nonstrategic tasks, this should not be surprising. What a "domain-general form of intellectual functioning" (Schneider, Bjorklund, & Maier-Bruckner, 1996) measure does seem to facilitate is the growth of metacognitive understanding within a relatively short time period. The basis of this advantage could be working memory size, working vocabulary size (and likely correlated reading speed), or some other factor; but, the combination of these skills allows children to monitor more closely their strategic performance and reflect on that performance to gain later benefits.

Interestingly, this shift in the relationship between intelligence and metacognitive sophistication parallels the shift around third grade from learning to read to reading to learn (Bruning, Schraw, & Ronning, 1999). The context of school, where children must engage in deliberate memory and learning tasks for perhaps the very first time, may promote the acquisition of strategies and metacognitive knowledge about those strategies (Best & Ornstein, 1986; Morrison, 1987), particularly as the demands for more efficient reading and processing of information increase. More intelligent children may be more likely to notice changes in their performance based on strategy use and begin to incorporate that knowledge back into the knowledge they hold about strategies in general. Alexander et al. (1995) questioned whether high levels of intelligence were related to the ability to cognitively monitor strategy use. The data from the current study suggest that slightly above average intelligence may be all that is necessary to take advantage of this feedback loop.

Of course, an alternative interpretation is credible. It may be that strategies and monitoring techniques are taught differentially by teachers and parents based on the child's perceived level of competence. Borkowski and Peck (1986) hypothesized that parental observation of early IP efficiency might be responded to with more challenging tasks and games. These games may be settings in which children begin to practice and acquire metacognitive knowledge about effective strategies. Recent research by Stright, Neitzel, Sears, and Hoke-Sinex (2001) supports this interpretation. They found that parental interactions in the home including metacognitive content and emotional support during problem solving predicted the amount of monitoring and metacognitive talk children did in the classroom later that same year. Although IQ was not assessed, this study leaves open the possibility of differential support very early in the home. Future research may help explicate this relationship.

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