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Going Beyond the Facts: Young Children Extend Knowledge by Integrating Episodes

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Abstract

The major question posed in this research was whether 4- and 6-year-old children productively extend their knowledge by integrating information acquired in separate episodes. The vehicle was a read-aloud activity during which children were presented with a novel fact in each of two passages. In Experiment 1, both age groups showed evidence of integration between the passages. For 6-year-olds, the evidence came in the form of responses to open-ended questions. Four-year-olds recognized the correct answers, but did not generate them in the open-ended question format. The 6-year-olds who generated the correct answers also were likely to recall both of the individual facts presented in the passages. In Experiment 2, we tested whether 4-year-olds' integration performance would improve if their memory for the individual facts improved. Extra exposure to the individual facts resulted in higher levels of integration performance in both recall and recognition testing. The roles of memory and other potential sources of age-related differences in integration performance are discussed.

Going Beyond the Facts: Young Children Extend Knowledge by Integrating Episodes

Like most psychological phenomena, learning and memory are influenced by many factors and undergo pronounced changes with development. Moreover, they interact with one another: what a child has learned in the past influences (though does not determine) what she or he remembers, and what a child remembers from an experience constrains what she or he learns from it. Although learning and memory are intimately linked, the question of how children connect separate episodes so that they contribute to the development of a general knowledge base has gone largely unexplored. The question is especially relevant as children enter the school years and find themselves in settings that demand that they integrate information that has been acquired at different times and in different contexts. The purpose of the present research was to test whether information learned in different episodes becomes linked in memory, and whether the process is different for 4- and 6-year-old children.

The facts that learning and memory are related and interdependent are illustrated in numerous ways in the literature. An especially compelling example of the influence of prior

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learning on the formation of new memories is Chi's (1978) research on expertise in the domain of chess. Child chess experts and adult chess novices were required to remember chess positions and random strings of digits. In the domain of strings of digits, as expected, the adults outperformed the children. In contrast, in the domain of chess, the children outperformed the adults. These and similar results from other studies (e.g., Schneider, Gruber, Gold, & Opwis, 1993; see Bjorklund, 1987, for a review) clearly demonstrate that knowledge of a domain is an important determinant of memory performance. The converse also is true, as illustrated by relations between working memory and reading comprehension, for example: Children with greater memory spans have higher comprehension scores (e.g., Friedman & Miyake, 2004).

Although clearly related and interdependent, the interaction between what a child has learned (i.e., her/his general knowledge) and what a child remembers from a new experience typically has been studied from only one perspective. That is, researchers have been concerned with how children keep individual episodes or experiences from being subsumed by general knowledge. The converse question of how general knowledge is derived from individual episodes has gone largely unexplored. The one-sided focus likely stems from observations made early in the study of children's memory and "scripts" for everyday events and routines. In these investigations Nelson (1986) and her colleagues observed that whereas children readily reported on "what happen*s*" at a fast-food restaurant, for example, they had difficulty reporting "what happen*ed*" during a particular visit (e.g., Hudson & Nelson, 1983). Children also sometimes showed evidence of confusion of specific episodes in their lives with general event knowledge (e.g., Hudson & Nelson, 1986). For example, Myles-Worsley, Cromer, and Dodd (1986) found that with increased school experience, children confused episodes from elementary school with episodes from preschool.

The ability to keep distinct episodes separate shows age-related change over the preschool and early school years. An illustrative example is Farrar and Goodman (1992), in which 4- and 7-year-old children participated in an event four times over a 2-week period. The event consisted of a variety of animal games in which children and an adult engaged. Three of the experiences were identical in structure and content. For example, these so-called "script" experiences involved a frog puppet and a bunny puppet crawling under a bridge. The fourth experience featured "deviations" from the script experiences, such as two new puppets jumping over the bridge. Developmental differences in children's abilities to maintain distinct representations of the script and deviation experiences were observed. That is, the younger children confused the script and deviation experiences such that recall of both was impaired. In contrast, the older children accurately reported the details of the script and deviation experiences, indicating that they had maintained separate representations of them. Children's abilities to maintain the boundaries of episodes has been of special interest in the literature on children's reliability as eyewitnesses in legal cases (e.g., Cordon, Pipe, Sayfan, Melinder, & Goodman, 2004; Ghetti, Qin, & Goodman, 2002; Goodman & Aman, 1990). Concern that separate episodes might be confused with one another or generalized into a generic "script" led to focus on the processes and determinants of maintaining separate episodes of repeated events.

In light of the obvious importance of the course of development of the ability to recall separate episodes, it is understandable that a great deal of research has been devoted to the issue. However, there is another side to the coin: the question of how separate episodes become linked in memory also is significant. The question is important because it will provide information about the development of the knowledge base in children, an issue that, to date, has received relatively little attention in research. The question also is of practical significance because it will provide information about how children learn and make productive use of their knowledge in their daily lives. Children are regularly required to reorganize already learned material to meet new retrieval demands (Salatas & Flavell, 1976). Nowhere is this clearer than in the kinds of activities in which children engage in school settings, perhaps the most salient of which is testing. Certain types of exams, such as those that are cumulative and integrative, require children to spontaneously reorganize the information they have learned in novel ways. This in turn demands that they selectively retrieve bits of information from different learning episodes distributed in time.

The goal of the present research was to test young children's responses to retrieval demands that required them to combine information acquired in separate episodes. The episodes were passages of text presented at different times. The passages were read to the children by an adult. Listening to stories read by an adult is a common practice for most preschool children (e.g., DeBaryshe, 1993; Fletcher & Reese, 2005). Prior to formal schooling, it is one of the major modes of "instruction" young children receive. It is clear that children learn from book reading sessions. For example, in Reese (1995), 5½-year-old children were read an unfamiliar book (*A Perfect Father's Day*, Bunting, 1991) and immediately thereafter were asked questions about plot information and to make inferences that required them to make causal connections between events in the story. Children averaged roughly 10 of 15 possible points, thus demonstrating their ability to learn from book reading episodes.

Preschool children also show transfer of information from one situation to another (e.g., Brown, Kane, & Echols, 1986; Holyoak, Junn, & Billman, 1984). For example, Brown and Kane (1988) presented preschoolers with problem pairs that required them to invent a novel solution and then transfer that solution to a similar problem. In one study, they presented children with three problem sets, each consisting of two stories, (A_1, A_2; B_1, B_2; C_1, C_2). The solution to each set involved a different physical activity (i.e., stacking, pulling, and swinging). Success required understanding of the underlying principle of the physical activity that connected the two stories in each set. The 4- to 5-year-old participants not only recognized the underlying similarity in the problems but also transferred the solution. This work demonstrates that preschool-age children can use the solution to one problem to solve another structurally similar problem. This ability is related to—though not isomorphic with—integration of information over different episodes separated in time.

In the present research, in each of two experiments, children learned novel facts in two different passages, the presentation of which was separated by a 15-minute delay. Each child then was asked questions that could only be answered by appeal to both stories, thus requiring that the child integrate the episodes and extract the relevant information. In both experiments, the questions first were presented in a recall format, requiring that the child generate the integrative response. The questions then were presented in a recognition format, requiring that the child select the integrative response from an array of distracters. The recall format of testing was expected to place a greater demand on the children, relative to the recognition format (see Schneider & Pressley, 1997, for review and discussion). Consistent with this suggestion, age-related differences typically are more pronounced in recall relative to recognition (e.g., Ackerman, 1985; Mandler & Stein, 1974; Perlmutter, 1984).

In the first experiment, the children were 4 and 6 years of age. These ages were selected because in the later preschool and early school years, children increasingly find themselves in settings and situations that demand that they integrate information that has been acquired at different times and in different contexts. Thus, the task is developmentally appropriate for this age group. We expected both age groups to succeed at the task, with higher levels of performance by the 6-year-olds relative to the 4-year-olds. We expected age differences to be especially pronounced in the recall relative to the recognition format (e.g., Ackerman, 1985; Perlmutter, 1984). As will become apparent, these predictions were born out. The study also suggested a possible contributor to the age-related difference, namely, better memory among the older children for the information from each individual episode. We tested the contribution in Experiment 2, with 4-year-old children only.

Experiment 1

Method

Participants—The participants were 15 4-year-olds (*M* = 4 years, 4 months; range = 4;0-4;11) and 15 6-year-olds (*M* = 6 years, 5 months; range = 6;0-6;11). There were 8 girls in each age group. The children were recruited from an existing pool of volunteer parents who had expressed interest in participating in research on children's development. Seventeen percent of the children were African-American, 13% were bi- or multi-racial, and 70% were Caucasian. All of the participants were native English speakers. Although no specific socioeconomic information was collected, the pool from which the participants were recruited primarily includes families of middle to upper-middle socioeconomic status. At the end of the hour-long session, each child was given an age-appropriate toy and a $5 gift certificate to acknowledge their participation. No participants were lost to attrition.

Stimuli—The stimuli were six novel "stem" facts and three novel "integration" facts. All facts were accurate and, based on pilot testing, were determined to be novel to children in the 4- to 6-year-old age range (i.e., *N* = 6 children in the age range were tested for generation and recognition of the facts; the modal number of facts generated and recognized was 0 and no child successfully generated or recognized more than 1 fact). Two of the stem facts were about dolphins (dolphins live in groups called pods; dolphins communicate by squeaking and clicking), two of the stem facts were about kangaroos (a Blue Flyer is a type of kangaroo; a baby kangaroo is a joey), and two of the stem facts were about a volcano (Mauna Loa is the largest volcano in the world; the largest volcano in the world is in Hawaii). Each pair of stem facts could be combined to generate the novel integration fact: (a) pods communicate by clicking and squeaking, (b) baby Blue Flyers are called joeys, and (c) Mauna Loa is in Hawaii.

Each stem fact was presented in a short passage that was read aloud by an experimenter. A sample passage is provided in Appendix A. The passages were 82-89 words in length, distributed over 4 pages, with 13-27 words per page (the text did not appear on the page). On each page was a hand-drawn illustration depicting the main actions. The passages were similar in structure: in each, a character (e.g., a lady bug) learned a novel fact. Within a pair of passages, the character was the same; across pairs of passages, the characters were different. The novel fact always was presented on Page 2 or 3 of the passage; each passage ended with a restatement of the fact. Only the stem facts were presented in the passages; the integration facts were not presented.

Procedure—Children were tested individually in a laboratory room outfitted with a testing table, chairs, and a small couch. All children were tested by the same female experimenter (PS). Each session began with the experimenter describing the method and obtaining informed written consent from the parent and verbal assent from the child.

<u>**Phase I: Exposure to stem facts:**</u> Each child was exposed to four passages: two of the passages were from the same pair; each of the other two passages featured one of the stems from each of the other two pairs. Thus, each child was exposed to both stems necessary to generate one integration fact (the 2-Stem condition) and only one of the two stems necessary to generate each of the other two integration facts (the 1-Stem condition). We expected the children to generate the novel integration facts only in the 2-Stem condition (the only condition in which they were exposed to both stem facts). The 1-Stem condition was included as a control for spontaneous generation of the integration facts.

As depicted in Table 1, in Phase I of the procedure, the experimenter first read two passages: one member of the pair of passages from the 2-Stem condition (e.g., *The Traveling Lady Bug*), and one 1-Stem condition passage (e.g., *The Hungry Deer*). Each passage was read continuously, without interruption, consistent with a performance-oriented style of reading (e.g., Dickinson & Smith, 1994). Each passage was read twice, before presenting the next passage. After presentation of the two passages, the children were engaged in age-appropriate filler activities that were unrelated to the questions of interest. The filler activities consumed approximately 15 minutes.

After the filler activities, the experimenter presented two more passages: the second member of the pair of passages from the 2-Stem condition (i.e., *The Lonely Lady Bug*), and a 1-Stem condition passage that was unrelated to the first 1-Stem condition passage (e.g., *The Rainy Cloud*). Again, each passage was read twice, before presenting the next passage. The children then were engaged in approximately 15-minutes of age-appropriate filler activities.

Note that in each segment of Phase I, the passage from the 2-Stem condition was read first, followed by the passage from the 1-Stem condition. The filler activities ensured that there was a delay of roughly 15 minutes between presentation of the stem facts in the 2-Stem condition. Within each age group, each pair of passages was used in the 2-Stem condition approximately equally often, and each passage was used in the 1-Stem condition approximately equally often.

Phase II: Test for recall and recognition of integration and stem facts: Following the second set of filler activities (and thus, a delay of roughly 15 minutes), the children were tested for recall and recognition of the integration and stem facts. The experimenter recorded the children's responses as they made them. First, the experimenter asked each of three integration questions: "How does a pod talk?", "What is a baby Blue Flyer called?", and "Where is Mauna Loa located?" The integration questions were interspersed among 5 facts commonly known to 4- and 6-year-olds, including "What is a baby cow called?" and "Where does Mickey Mouse live?" (for a total of 8 questions) The known questions were provided so that children had a successful experience, even if they failed to generate the integration facts. As noted above, because children were provided both stems for only one pair of passages (those in the 2-Stem condition), they were expected to generate the integration fact only in the 2-Stem condition. The integration facts from the 1-Stem condition were included as controls for spontaneous generation of the integration facts.

Second, the experimenter asked eight fact recall questions, probing children's recall of the four stem facts to which they had been exposed via the passages. Example questions are "What is a joey?", "Where is the world's largest volcano?", and "How does a dolphin talk?" Children were asked about the four facts they had experienced in the passages, and about four additional facts to which they had not been exposed. Two of the four additional fact questions were from the 1-Stem passages that they had not experienced. Children could be expected to recall the four stem facts to which they had been exposed. The final two additional fact questions were commonly known, thereby providing the children with a successful experience, regardless of their ability to recall the stem facts.

Third, children were tested for recognition of the correct answers to the integration fact questions. A sample recognition question for an integration fact is provided in Appendix A. The integration recognition questions were interspersed among recognition questions to which children in the target age range were likely to know the answers. All recognition questions had three alternatives, one of which was correct. Children were asked the recognition questions only for the integration facts that they failed to generate in the recall phase of testing. That is, if the child generated the correct response to the integration fact question when it was posed in recall format, the recognition question for that integration fact was not presented. Thus, children received a different number of recognition questions, depending on the number of integration facts generated in the recall format.

Finally, children were tested for recognition of the correct answers to the stem fact questions; a sample stem fact recognition question is provided in Appendix A. Children were tested for recognition of the answers to the four stem facts to which they had been exposed in the passages, as well as for the two stem facts to which they had not been exposed, along with two other commonly known facts. All recognition questions had three alternatives, one of which was correct. As for the integration fact recognition questions, children were asked the stem fact recognition questions only for the stem facts that they failed to generate in the recall phase of testing. Thus, children received a different number of recognition questions, depending on the number of stem facts generated in the recall format.

Testing for the integration and stem facts was administered in the fixed order just described. Recall was the strongest test of children's ability to integrate the two stem facts into the novel integration fact. To be valid, the recall test had to be administered before the test of recognition. Within each phase (recall, recognition), the integration fact questions were asked before the stem fact questions, so that children were not reminded of the stem facts immediately prior to testing of the integration facts.

Results

We addressed three questions about children's performance. The first and second questions were whether the children generated the integration facts when the questions were posed in the recall format, and whether performance differed by age (respectively). Third, we examined performance in the 1- and 2-Stem conditions, to determine whether generation of the integration facts was dependent on provision of both stem facts and thus could be attributed to integration across the separate episodes (passages). Because of the dichotomous nature of the data (children either did or did not produce the integration facts), between-groups comparisons were conducted using chi-square tests. Within-groups comparisons were conducted using paired *t*-tests (2-tailed).

Descriptive statistics on children's recall and recognition of the integration facts are provided in Table 2, Panel a. Because the number of trials on which children were questioned about the integration fact differed in the 2-Stem and 1-Stem conditions (1 vs. 2, respectively; 2 responses were possible in the 1-Stem condition because each stem had an integration fact associated with it), all values are presented in percentages. In the 2-Stem condition, in which the children had both of the stem facts necessary to produce the novel integration fact, 13% of the 4-year-olds ($n = 2$) and 67% of the 6-year-olds ($n = 10$) generated the novel integration fact. The levels of performance differed by age: $X^2(1, N = 30) = 9.51$, $p < .01$.

Performance in the 1-Stem control condition makes clear that the 6-year-olds generated the novel integration facts as a result of exposure to the pair of related stem facts. In the 1-Stem condition, in which the children had been exposed to only half of the information required to generate the novel fact, the 6-year-olds generated only 17% of the novel integration facts (i.e., they generated 5 of the 30 possible integration facts). For the 6-year-olds, performance in the 2-Stem and 1-Stem conditions differed reliably: $t(14) = 3.09$, $p < .01$. The 4-year-olds did not generate the novel integration facts on any of the 1-Stem trials.

Although only two 4-year-olds generated the novel integration facts when tested in the recall format, an additional eight 4-year-olds (62% of the remaining 13) recognized the novel integration facts from among distracters (see Table 2, Panel a). Four of the five 6-year-olds

(80%) who failed to generate the novel integration fact in the recall format successfully recognized it. Based on recognition performance alone, the age groups did not differ in their levels of performance: $X^2(1, N = 18) = .59$, ns.

Performance in the 1-Stem condition makes clear that for the 4-year-olds, successful recognition of the integration fact was conditional on the children having been exposed to the pair of related stem facts. That is, within-subjects *t*-tests revealed that recognition performance in the 2-Stem and 1-Stem conditions differed reliably for the younger children: $t(12) = 2.31$, $p < .05$. For the 6-year-olds, recognition performance in the 2- and 1-Stem conditions did not differ reliably, likely due to the small number of observations ($n = 5$).

Across the recall and recognition formats, 10 of the 15 4-year-olds (67%) and 14 of the 15 6-year-olds (93%) showed evidence of having integrated the information from the stem facts in the 2-Stem condition. The age difference fell just below the conventional level of statistical significance: $X^2(1, N = 30) = 3.58$, $p < .06$. In the 1-Stem condition, the older children had significantly higher total performance (across the recall and recognition formats) than the younger children (63% and 33%, respectively): $X^2(1, N = 30) = 6.78$, $p < .05$. Both across age groups and for each age group separately, within-subjects *t*-tests revealed that total performance in the 2-Stem and 1-Stem conditions differed reliably: $t(29) =3.47$, $p < .01$, across age groups; *t*s(14) = 2.65 and 2.20, *p*s < .05, for the 4- and 6-year-olds, respectively.

Hints as to a contributor to the age-related difference in the 4- and 6-year-old children's recall and total production (across recall and recognition formats) of the novel integration facts are provided by examination of the children's recall and recognition of the individual stem facts. As reflected in Table 3, Panel a, across age groups, recall of the novel integration fact was associated with recall of both of the individual stem facts. That is, 10 of the 12 (83%) children who generated the novel integration fact in the recall format portion of the test also recalled both of the stem facts to which they had been exposed in the related pair of passages. The distribution of responses was reliably different from chance: $X^2(1, N = 12) = 5.33$, $p < .05$ (comparing the 1 and 2 stems recalled cells only, to provide minimum expected cell frequencies). Ten of the 12 children who generated the novel integration fact in the recall format portion of the test were 6-year-olds. Thus, this effect was carried by the older children. Across age groups, the children who did not generate the novel integration fact in the recall format portion of the test were equally likely to recall neither, one, or both of the stem facts: $X^2(2, N = 18) = 2.33$, ns.

The relation between total memory for both stem facts (across recall and recognition formats) and total integration performance (across recall and recognition formats) was parallel to that observed for recall alone. That is, across age groups, children who recalled or recognized both stem facts more frequently recalled or recognized the novel integration facts. The distribution was reliably different from chance: $X^2(2, N = 24) = 23.25$, $p < .001$. In the case of failure to either recall or recognize the novel integration fact ($n = 6$ children), the relation with recall of the stem facts could not be evaluated due to insufficient expected cell frequency. Interestingly, for the 6-year-olds, all of the children who recalled or recognized both stem facts also recalled or recognized the novel integration facts. For the 4year-olds, however, children who recalled or recognized both stem facts were equally likely to recall or recognize the integration facts, or to fail to do so.

Discussion

Experiment 1 was a test of whether 4- and 6-year-old children spontaneously generate novel facts by combining information learned in separate passages of text that is read to them. The older children showed an impressive ability to extend their knowledge in this way. They generated the novel fact on 67% of the recall format trials. Fully 93% of the 6-year-olds either spontaneously generated the novel fact or recognized it from among distracters. The younger children had a low rate of spontaneous generation of the novel fact. Yet the ability to integrate information across episodes was not absent even at this young age, as evidenced by a reasonably high rate of recognition of the novel fact among distracters. Overall, two-thirds of the 4-year-olds either recalled or recognized the novel integration fact.

The children's performance in the 1-Stem control condition made clear that exposure to both members of the pair of related stem facts was necessary to generate the answer to the integration questions in the recall format. When the children were exposed to only one of the stem facts, they rarely generated the novel integration facts. Although levels of recognition of the integration facts in the 1-Stem condition were higher than levels of spontaneous generation, they fell short of the levels of recognition in the 2-Stem condition. Overall, with recall and recognition combined, the children produced more integration facts in the 2-Stem than in the 1-Stem condition.

Finally, examination of children's recall of the stem facts provided insight into the ingredients of successful integration across episodes. The children who spontaneously generated the novel integration fact typically recalled both of the stem facts. In contrast, among the children who did not generate the integration fact, most recalled none or only one of the stem facts. In most cases, it was the older children who recalled both stem facts; the 6-year-olds had an overall higher level of performance than the 4-year-olds. The relation between recall of stem facts, generation of integration facts, and age, raises the possibility that younger children's spontaneous integration performance would improve if they recalled more of the stem facts. Improved performance as a function of recall of the stem facts would be consistent with findings from Bryant and Trabasso (1971). They found that young children's performance on transitive reasoning problems (if A is longer than B, and B is longer than C, is A longer than C?) improved when they were given extensive training on the individual premises (although see Brainerd & Kingma, 1984, for an alternative perspective). In Experiment 2 we tested whether 4-year-olds' spontaneous integration performance would improve if their recall of the stem facts improved.

Experiment 2

Method

Participants—The participants were 15 4-year-olds (*M* = 4 years, 6 months; range = 4;1-4;11); 8 of the children were girls. The children were recruited from the same source and represent the same population as in Experiment 1. Thirteen percent of the children were African-American, 20% were bi- or multi-racial, and 67% were Caucasian. None of the children had participated in Experiment 1. As in Experiment 1, at the end of the hour-long session, children were given an age-appropriate toy and a $5 gift certificate. No participants were lost to attrition.

Stimuli and Procedure—The stimuli were the same as in Experiment 1 and the children were tested by the same female experimenter as in Experiment 1. The procedure was the same as in Experiment 1, with minor exceptions designed to increase the likelihood that the children would remember the stem facts. First, in the stem-fact exposure phase (see Table 1, Phase I), after the second reading of each passage, the experimenter read the final sentence of the passage twice, rather than once. The final sentence contained the stem fact (see Appendix A). Thus, children received an additional exposure to the stem fact. Second, after repeating the final sentence of the passage, the experimenter asked the fact recall question of the child. For example, after the two readings of the final sentence of *The Traveling Lady Bug*, the experimenter asked the child "How do dolphins talk?" If the child answered correctly, the experimenter affirmed the child's answer, repeated it, and then moved on. If the child answered incorrectly, the question was repeated. If the child again answered incorrectly, the experimenter provided the correct answer and asked the question again. This procedure was repeated up to four times. The procedure for testing for recall and recognition of the integration and stem facts was identical to Experiment 1.

Results

The manipulation of stem-fact memory was a mixed success. Immediately after presentation of the stem passages, the children readily recalled the stem facts: 11 of the 15 children recalled both of the stem facts in the 2-Stem condition and 3 children recalled one of the two stem facts. Only one child failed to recall either stem fact. However, in the formal test for recall of the stem facts that occurred at the end of the session, 6 of the children recalled both of the stem facts in the 2-Stem condition, 7 children recalled one of the stem facts, and 2 children recalled none. Thus, although there was evidence that the children had encoded the stem facts (apparent from their recall of them immediately after the passages were read), the information did not remain fully accessible over the 15- to 30-minute delay until the formal test.

Although not all of the children retained the stem fact information, more of the children spontaneously generated the integration facts, relative to Experiment 1. As reflected in Table 2, Panel b, in the 2-Stem condition, in which the children had both of the stem facts necessary to produce the novel integration fact, 33% of the children ($n = 5$) generated the novel integration fact. This level of performance did not reach that achieved by the 6-year-olds in Experiment 1 (67%), yet was higher than the 13% achieved by the 4-year-olds in the first experiment. Performance in the 1-Stem control condition makes clear that the children generated the novel integration facts as a result of exposure to the pair of related stem facts. In the 1-Stem condition, only one 4-year-old generated one of the novel integration facts (3% of total). Within-subjects *t*-tests indicated that the levels of performance differed by condition: $t(14) = 2.55$, $p < .05$.

The 4-year-olds in the present experiment also achieved high levels of recognition of the novel integration fact. Specifically, 8 of the 10 children who had not spontaneously generated the novel integration in the recall format recognized the novel integration facts from among distracters (see Table 2, Panel b). Although performance in the 1-Stem condition was lower (52%), it did not differ from that in the 2-Stem condition.

Across the recall and recognition formats, 13 of the 15 4-year-olds (87%) showed evidence of having integrated the information from the stem facts in the 2-Stem condition. In the 1-Stem condition, across formats, the children generated 53% of the novel integration facts. Within-subjects *t*-tests indicated that total performance in the 2-Stem and 1-Stem conditions differed reliably: $t(14) = 2.20$, $p < .05$.

Examination of the 4-year-olds' recall of the individual stem facts provided no evidence of the link that was apparent among the 6-year-olds in Experiment 1, between recall of the stem facts and generation of the integration facts in the recall testing format. As reflected in Table 3, Panel b, the children who recalled the integration facts were equally likely to recall 1 or both of the stem facts; the children who recalled both of the stem facts were equally likely to generate the integration fact in recall testing and to fail to generate it (though the distributions could not be evaluated statistically because of insufficient expected cell frequencies). When total performance (across recall and recognition formats) was considered, however, there was a clear relation between the 4-year-olds' memory for the stem facts and successful integration. Specifically, among the 13 children who recalled or recognized the integration facts, 11 recalled or recognized both stem facts. The distribution was reliably different from chance: $X^2(1, N = 13) = 6.23$, $p < .05$ (comparing the 1 and 2 stems recalled cells only, to provide minimum expected cell frequencies). Finally, all of the children who recalled or recognized both stem facts also recalled or recognized the novel integration facts. Overall, this pattern supports the hypothesis that memory for the individual stem facts is an important ingredient of successful integration.

Discussion

Experiment 2 was a test of the possibility that 4-year-old children's integration performance would improve with better memory for the stem facts. The manipulation to increase memory for the stem facts was a mixed success. Although the children recalled the stem facts immediately after the passages were read to them, when tested 15- to 30-minutes later, their memories of the stem facts were less accessible. Lower levels of accessibility are not surprising given the passage of time and the fact that the delay interval was filled with potentially distracting activities and material that may have interfered with consolidation of the newly acquired memory traces for the stem facts (see Bauer, 2009, for discussion).

Although the manipulation of memory for the stem facts was not entirely successful, children who recalled or recognized both of the stem facts in the 2-Stem condition were more likely to recall or recognize the integration facts than were children who did not demonstrate memory for both stem facts. Interestingly, although approximately the same number of 4-year-olds recalled or recognized both of the stem facts in the 2-Stem condition in Experiments 1 and 2 (10 and 11, respectively), a relation between memory for the stem facts and successful integration was observed only in the present experiment. A tighter relation between memory for the stem facts and integration of them might help explain the higher level of integration observed in the present experiment relative to that achieved by the children's same-age peers in Experiment 1: both recall performance and total performance (across recall and recognition formats) were higher in the present experiment, relative to Experiment 1. In fact, whereas production of the integration facts in recall format testing by the 4-years-olds in the present experiment was lower than that of the 6-year-olds in Experiment 1 (33% vs. 67%, respectively), levels of total integration performance (across recall and recognition formats) were roughly comparable (87% vs. 93%, respectively).

General Discussion

The purpose of the present research was to test whether information learned in different episodes becomes linked in memory, and whether the process is different for 4- and 6-year-old children. The vehicle for the investigation was a read-aloud activity. In the course of a pair of related passages read by an adult, children learned two novel facts (stem facts) that could be integrated to generate a third novel fact (integration fact). For example, they learned that the largest volcano is the world is located in Hawaii, and in a separate passage, that Mauna Loa is the largest volcano in the world. They then were presented with the question of where Mauna Loa is located. The answer to the question had not been given in either of the passages, yet could be generated by combining the individual stem facts. Performance in this condition was compared with performance when children had been exposed to only one of the two stem facts necessary for the integration. Higher performance in the 2-Stem relative to the 1-Stem condition would be consistent with the interpretation that children generated their responses to the questions by integrating the information presented in the separate passages.

In the first experiment, both 4-year-olds and 6-year-olds showed evidence of integration. In the case of 6-year-olds, evidence came in the phase of testing that required the children to generate the information in response to open-ended questions, such as "Where is Mauna Loa located?" In this condition, two-thirds of the 6-years-olds generated the novel integration facts. In the case of the 4-year-olds, evidence of integration between separate episodes came in the phase of testing that required that children recognize information in an array of distracters. Sixty-two percent of the 4-year-olds recognized the correct answers, even though only 13% of them had generated the answers spontaneously. Considering recall and recognition opportunities combined, 6-years had higher performance than 4-year-olds (93% vs. 67%, respectively).

The performance of children in Experiment 1 suggested an association between recall of the information presented in the passages (the stem facts) and successful integration. That is, children who generated the integration facts in the recall format also were likely to recall both of the stem facts. The relation was especially apparent among the 6-year-olds: 9 of the 10 children who generated the integration facts in the recall format also recalled both of the stem facts that contributed to the integration; only one 6-year-old recalled both stem facts yet failed to integrate them. In contrast, only three 4-year-olds recalled both of the stem facts, and two of the three failed to integrate them. Experiment 2 was a test of whether 4-year-olds' integration performance would improve if their memory for the stem facts improved. The answer was a qualified "yes." More of the 4-year-olds in Experiment 2 spontaneously generated the novel integration facts relative to their peers in Experiment 1: 33% compared with 13%, respectively. They also had higher levels of recall of the stem facts: 6 children recalled both of the stem facts in Experiment 2 compared with only 3 children in Experiment 1. However, the association between recall of the stem facts and integration was not perfect: half of the children who recalled both of the stem facts failed to generate the integration facts in the recall testing format. From the manipulation we may conclude that recall of the stem facts facilitates integration, but it is not sufficient to ensure it.

For the 4-year-olds in Experiment 2, consideration of recognition as well as recall performance provided stronger evidence of a link between memory for the stem facts and successful integration. Thirteen of the 15 children in the study either recalled or recognized the integration facts from among distracters; 11 of the 13 either recalled or recognized both of the stem facts from which the integration facts were derived. In fact, the relation between memory for both stem facts and recall or recognition of the integration fact was perfect: all of the children who remembered both stem facts also recalled or recognized the integration facts. Thus, across experiments, a relation between memory for stem facts and successful integration was established. For 4-year-olds, the relation was apparent only when the burden of generating the correct answers was lessened by allowing the children to recognize them. For 6-year-olds, the relation was apparent in the more demanding recall format.

The present experiments are important steps in understanding how children extend knowledge beyond the information they are given, and some of the factors that influence the likelihood of successful extension. Many more questions remain to be addressed. One of the most salient open questions is whether the abilities demonstrated in the present research would be apparent in circumstances that more closely approximate those outside the laboratory, such as in educational settings. In the classroom, children are challenged to integrate information presented in different episodes that are separated in time by days, weeks, semesters, and even years. Moreover, they may be challenged to integrate the information long after having studied it, such as at the end of a semester, in a cumulative examination. Children's performance under conditions of delay between the presentation of each of the items (e.g., passages of text), and under conditions of delay between presentation of the items and demand to integrate them, is a subject for future research.

Another important question is the role of support for integration provided in the present research. One source of support was the form of the integration test questions. Children showed more evidence of integration when they were required only to recognize the correct answers in an array of choices, as opposed to when they were required to generate them on their own. The advantage was especially apparent for the younger children. Better performance in recognition relative to recall tests is not a novel finding (e.g., see Schneider & Pressley, 1997, for a review). Nor is it a novel finding that recognition formats minimize age differences, relative to recall formats (Ackerman, 1985; Mandler & Stein, 1974; Perlmutter, 1984). The demands of the two situations make it easy to appreciate the source of the advantage of recognition over recall. Whereas recognition formats permit the child to match a memory representation to an external stimulus, recall formats require retrieval of the representation from memory, in the absence of external support. Retrieval makes heavy demands on young children in particular, owing in no small part to the fact that the neural structures and processes implicated in retrieval undergo substantial development throughout childhood and beyond (see Bauer, 2006, 2007, for reviews).

The present research also raises the question of the basis of the relation between memory for the stem facts and integration. That is, children showed higher levels of integration when they had better memory for the stem facts. The relation was apparent for the 6-year-olds in Experiment 1 and for the 4-year-olds in Experiment 2, in which the stem facts were presented more times, relative to Experiment 1, and the children were encouraged to repeat them after the experimenter. For the 4-year-olds, these features of the design were associated with a more than a two-fold increase in the number of children who produced the integration facts in recall format testing, relative to that observed in Experiment 1. The design also revealed the relation between successful integration and memory for the stem facts among the younger children; the relation was not apparent in Experiment 1. Approximately the same number of 4-year-olds remembered both stem facts in Experiments 1 and 2 (10 and 11, respectively). Yet only in Experiment 2 did this high level of memory for the stem facts translate into successful integration. We may speculate that the additional support for memory for the stem facts provided to the 4-year-olds in Experiment 2 made the relation between them more apparent, perhaps through overt production of the element that the stem facts had in common: dolphins, kangaroos, or volcanoes. Akin to cumulative rehearsal (see Bjorklund, Dukes, & Brown, 2009, for discussion of rehearsal strategies), the act of repeating sentences with shared elements may have made it easier to see the relation between them.

In contrast to the 4-year-olds, the 6-year-olds needed less support for integration and they generated the integration facts more often than younger children. Two-thirds of the older children spontaneously generated the answers to the integration questions in the recall format. Across the recall and recognition formats, 14 of the 15 6-year-olds successfully integrated the two related stem facts. They did so even though they were not asked to repeat the stem facts as the 4-year-olds were in Experiment 2. Thus, the 6-year-olds were less dependent on repetition and external support in order to remember the stem facts, and they more readily appreciated the relation between them. The higher levels and more autonomous performance by the 6-year-olds relative to the 4-year-olds may be attributable to any number of factors, including faster speed of processing (e.g., Kail & Miller, 2006), a greater knowledge base that makes connections more apparent (e.g., Chi, Hutchinson, & Robin, 1989; see Bjorklund, 1985, for discussion), and more deliberate or strategic use of prior knowledge and new information (see Bjorklund et al., 2009, for a review). As an example of the latter, after successfully recognizing the integration fact that Mauna Loa is in Hawaii, one child commented that she was able to guess the right answer because she knew that Hawaii has a lot of volcanoes. Domain-specific knowledge also can help explain how older children, in particular, were able to achieve a relatively high level of recognition of the integration facts in the 1-Stem condition. For example, a child who already knows that a baby kangaroo is a joey, and who hears that some kangaroos are called Blue Flyers, may find it relatively easy to select the correct answer to the question "What is a baby Blue Flyer called?—(a) joey, (b) fawn, (c) chick." The role of individual differences in, for example, speed of processing and domain-specific knowledge, in promoting integration cannot be assessed in the present study and thus is a subject for future research.

In conclusion, in the present research we took important steps towards constructing a better understanding of how children extend their knowledge beyond the information they are given. We found high rates of spontaneous integration of information among 6-year-olds (Experiment 1) and almost equally high rates of total performance (across recall and recognition formats) by 4-year-olds who had been encouraged to remember the individual stem facts (Experiment 2). The research is a productive starting point for further investigations of the factors that interfere with and support productive extension of knowledge through integration.

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Appendix A

Sample Passage with Stem Facts (in italics) and Sample Recognition Questions

Sample Passage: *The Traveling Lady Bug*

Page 1: As a ladybug slept one night a strong wind came and blew her out of bed.

Page 2: She woke up and found she was at sea. A friendly dolphin came up and *said "hello" to her by clicking and squeaking*.

Page 3: Before the ladybug could say much more than "hello," the very strong wind blew again and she was swept back home.

Page 4: The ladybug was sad she didn't get to play with the friendly dolphin. But now the ladybug knew how all *dolphins talk—by clicking and squeaking*.

Sample Recognition Questions

Integration fact: How does a pod talk?—(a) by rubbing noses, (b) by clicking and squeaking, (c) by cell phone.

Stem fact: Which of these animals talks by clicking and squeaking?—(a) dolphins, (b) goldfish, (c) sharks.

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Table 1

Schematic Representation of the Procedure

Phase and Activity	Example
Phase I: Exposure to stem facts	
Passage 1 for 2-Stem condition	" *The Traveling Lady Bug* "
One passage for 1-Stem condition	" *The Hungry Deer* "
15 minutes of Filler Activities	
Passage 2 for 2-Stem condition	" *The Lonely Lady Bug* "
One passage for 1-Stem condition	" *The Rainy Cloud* "
15 minutes of Filler Activities	
Phase II: Test for recall and recognition of integration and stem facts	
Integration fact questions: recall format	
Stem fact questions: recall format	
Integration fact questions: recognition format	
Stem fact questions: recognition format	

Note: Only one example passage is provided for each activity. Passages were counterbalanced so that each served equally often in the 1- and 2-Stem conditions.

Table 2

Percentage of Children Who Recalled and/or Recognized the Integration Facts in Experiment 1 (Panel a) and Experiment 2 (Panel b)

		Condition	
Phase of Testing	**Age Group**	**2-Stem**	**1-Stem**
Panel a: Experiment 1			
Recall	4-year-olds	13%	0%
	6-year-olds	67%	17%
Recognition	4-year-olds	62%	33%
	6-year-olds	80%	56%
Total (recall plus recognition)	4-year-olds	67%	33%
	6-year-olds	93%	63%
Panel b: Experiment 2			
Recall	4-year-olds	33%	3%
Recognition	4-year-olds	80%	52%
Total (recall plus recognition)	4-year-olds	87%	53%

Note: Children were asked the recognition questions only for the integration facts that they failed to generate in the recall phase of testing. Thus, children received a different number of recognition questions, depending on the number of questions answered in the recall format. Reported percentages are based on the number of questions posed.

Table 3

Relation between Recall of Stem Facts and Recall of Integration Facts and between Recall or Recognition of Stem Facts and Recall or Recognition of Integration Facts in Experiment 1 (Panel a) and Experiment 2 (Panel b)

Age	No. stem facts recalled and recalled or recognized	Integration Fact: Recalled		Integration Fact: Recalled or Recognized	
		Yes	No	Yes	No
Panel a: Experiment 1					
Across ages		n = 12	n = 18	n = 24	n = 6
	0	0	7	1	0
	1	2	8	4	1
	2	10	3	19	5
4-year-olds		n = 2	n = 13	n = 10	n = 5
	0	0	5	1	0
	1	1	6	4	0
	2	1	2	5	5
6-year-olds		n = 10	n = 5	n = 14	n = 1
	0	0	2	0	0
	1	1	2	0	1
	2	9	1	14	0
Panel b: Experiment 2					
4-year-olds		n = 5	n = 10	n = 13	n = 2
	0	0	2	0	1
	1	2	5	2	1
	2	3	3	11	0