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Characters and clues: Factors affecting children's extension of knowledge through integration of separate episodes

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Abstract

Children build up knowledge about the world and also remember individual episodes. How individual episodes during which children learn new things become integrated with one another to form general knowledge is only beginning to be explored. Integration between separate episodes is called on in educational contexts and in everyday life as a major means of extending knowledge and organizing information. Bauer and San Souci (2010) provided an initial demonstration that 6-year-olds extend their knowledge by integrating between separate but related episodes; the episodes shared a high level of surface similarity. Experiments 1A and 1B of the current research were tests of integration under low and high levels of surface similarity, respectively. In Experiment 1A, when surface similarity of the episodes was low, 6-year-olds integrated between passages of text, yet their performance was not as robust as observed previously. In Experiment 1B, when surface similarity of the episodes was high, a replication of Bauer and San Souci's results was observed. In Experiment 2, we tested whether a "hint" to consult the information learned in the passages improved performance even when surface level similarity was low. The hint had a strong facilitating effect. Possible mechanisms of integration between separate yet related episodes are discussed.

Keywords

Episodic memory; Facilitating factors; Integration; Learning; Semantic memory; Surface similarity

Introduction

Like language, semantic memory is productive. It permits novel combinations through deduction (reasoning from the general to the specific), induction (reasoning from the specific to the general), and inference (reasoning to the next logical step in a pattern), for example. Each new product enriches the semantic memory network. Semantic memory also can be enriched by integrating information acquired in two (or more) separate yet related learning episodes. For instance, the lesson of one episode may be that dolphins live in groups called pods, and the lesson of another episode about dolphins may be that they communicate by clicking and squeaking. Integration of the separate episodes yields the knowledge that pods communicate by clicking and squeaking. Although this manner of extension is common in educational and other contexts, it has gone largely unstudied. As a result, we know little about children's integration of separate episodes or about conditions that may promote it. The purpose of the current research was to begin to fill this void in the literature by testing integration of information between episodes that, on the surface, are

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either dissimilar or similar to one another (Experiments 1A and 1B, respectively) and providing “hints” to help children see the relevance of the episodes to one another, thereby promoting integration (Experiment 2).

Semantic or factual knowledge begins to accrue early in development. For example, as early as the first half of the first year of life, infants perform as if they “know” many of the rules that govern the behavior of objects (e.g., gravity and force: Spelke, 1994). By the second half of the first year, infants demonstrate knowledge of the typical behavior of animals and vehicles (e.g., that animals drink and vehicles start with keys: Mandler & McDonough, 1996). By the second year, children have formed superordinate categories with basic-level categories nested within (e.g., Mandler, Bauer, & McDonough, 1991). Over the preschool years, children acquire more information and freely use it to make inferences and predictions about the behavior of more and less familiar entities (Wellman & Gelman, 1998).

The ability to remember individual episodes of experience also makes its emergence early in development. Infants as young as 6 months show nonverbal evidence of recall of events over brief delays (i.e., deferred imitation of action sequences; e.g., Barr, Dowden, & Hayne, 1996). As reviewed in Bauer (2006, in press), over the first 2 years of life, there are developmental differences in the amount of information children remember, the length of time over which they recall, and in both the robustness and reliability of recall. Throughout the preschool and early school years, there are further developments in the amount children remember, the level of support they require for recall, and the length of time over which memory is apparent (reviewed in Bauer, 2006 in press).

It is clear that children build up knowledge about the world and that they remember individual episodes. Yet, we know little about how the individual episodes during which children learn new things are combined to extend semantic knowledge. Rather than study how information distributed across different episodes is combined, researchers have been concerned with how children keep episodes separate in memory. As noted in Bauer and San Souci (2010), the one-sided focus likely stems from concern that separate episodes might be confused with one another or generalized into a generic “script.” This concern led to a focus on the processes and determinants of maintaining separate episodes of repeated events (e.g., Farrar & Goodman, 1992; Price & Goodman, 1990). Children’s abilities to maintain the boundaries of episodes was of particular 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).

In light of the obvious importance of development of the ability to recall separate episodes, it is understandable that a great deal of research has been devoted to the issue. Yet, the complementary question of how separate episodes become linked or integrated such that information can be extracted and used productively also is significant. Research investigating relations between memory and reasoning makes clear that children falsely recognize unpresented yet true inferences (e.g., Paris & Carter, 1973; see Brainerd & Reyna, 1993, for a review). For example, given the premises that “The bird is inside the cage” and “The cage is under the table,” children will recognize as “old” the true inference that “The bird is under the table” (e.g., Reyna & Kiernan, 1994). Children also regularly are required to extend and reorganize already learned material to meet new retrieval demands (Salatas & Flavell, 1976). This is especially clear 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 and integrate the information they have learned in novel ways. This in turn demands that they selectively retrieve bits of information from different learning episodes.

The current research builds on an initial examination of preschool children's integration of information between separate episodes conducted by Bauer and San Souci (2010). In each of two passages of text, 4- and 6-year-olds learned a novel fact (i.e., a "stem" fact) such as how dolphins communicate (by clicking and squeaking) and the name of the groups in which they live (pods). Children then were asked questions that could be answered only by appealing to both passages, thereby requiring that they integrate the episodes and extract the relevant information (i.e., "integration" facts). The questions first were presented in an open-ended format, requiring that children generate the integrative fact. In the case of the dolphin example, the question was "How does a pod communicate?" On trials where children failed to generate the integration fact (by clicking and squeaking), the question then was presented in a recognition format, requiring that children select the integrative fact from an array of distracters. The 4-year-olds generated the integration facts on only 13% of the trials. Their levels of recognition of the integration facts were higher (62%). In a control condition, children were presented only one of the two passages necessary to generate the integration fact. Under this condition, the 4-year-olds generated the integration facts on none of the trials and recognized them from arrays of distractors on only 33% of the trials. The 6-year-olds generated the integration facts on 67% of the trials, compared with only 17% of the trials in the control condition. Thus, both the 4-and 6-year-olds evidenced productive extension of semantic knowledge. The 4-year-olds showed the ability in a recognition format only, and the 6-year-olds generated the new information in the open-ended format.

Relative to the conditions that children encounter in the world outside the laboratory, in Bauer and San Souci (2010), integration was strongly supported by a high degree of surface similarity between the members of the pairs of related passages. That is, in both passages in a pair, the same character (e.g., a ladybug) learned something new. High surface level similarity facilitates other means of extension of semantic knowledge such as analogical problem solving (e.g., Brown & Kane, 1988; Brown, Kane, & Echols, 1986; Gentner & Toupin, 1986; Holyoak, Junn, & Billman, 1984). High surface level similarity likely facilitates integration between episodes as well given that memory representations are reactivated to the extent that they share features with one another. Yet, separate episodes over which children are challenged to integrate often do not have high levels of surface similarity. It is important to know whether children nevertheless can integrate between them. Accordingly, in Experiment 1A of the current research, we conducted a test for conceptual replication of the results of Bauer and San Souci (2010) under conditions of a lower degree of surface similarity between the to-be-integrated passages. The question was not whether performance under high (Bauer & San Souci, 2010) and low (current research) surface similarity conditions would differ; everything we know about cognition predicts that it would. Rather, the question was whether children faced with passages that, on the surface, appeared to be about different things would nevertheless be able to integrate the passages with one another to generate new knowledge. We expected that children would still show the ability to integrate but that it would not be especially robust.

To anticipate the results of Experiment 1A, we found that children showed evidence of integration even under low surface similarity conditions. As predicted, performance was not as strong as that observed in Bauer and San Souci (2010). To test the competing hypotheses that less robust integration was due to the surface similarity manipulation vs. an alternative possibility that Bauer and San Souci overestimated 6-year-olds' propensity to integrate, in Experiment 1B we tested a new group of 6-year-olds under high surface similarity conditions. The level of integration replicated that observed in Bauer and San Souci's study, thereby supporting the interpretation that integration is less readily observed when surface similarity is low. In Experiment 2 of the current research, we tested whether lower levels of integration could be overcome by providing children with prompts that the information in separate low surface similarity passages could be integrated into a novel fact. It is well established in the memory literature that more information is retrieved when prompts or reminders are provided (see Bauer, 2007, for a review). Similarly, in other knowledge extension paradigms such as analogical problem solving, transfer is facilitated by explicit hints or suggestions to use the solutions in the problems experienced previously (e.g., Brown et al., 1986; Crisafi & Brown, 1986). By extension, integration between episodes should be facilitated by suggestions to children that they "Think about the stories we read to help answer this question." Experiment 2 was a test of whether an explicit suggestion to draw from prior episodes was useful in promoting integration.

In both experiments of the current research, the children were 6 years of age. This age was selected because during the early school years children increasingly find themselves in settings and situations demanding that they integrate information acquired at different times and in different contexts. Thus, the task is developmentally appropriate. We focused on 6-year-olds only because the 4-year-olds in Bauer and San Souci (2010) had low levels of integration in the open-ended testing format. We expected that reductions in surface level similarity might result in even lower (i.e., floor) levels of performance.

Experiment 1A

Method

Participants—The participants were 19 6-year-olds (9 girls and 10 boys, *M*=6 years 6 months, range = 6;0–6;11). The children were recruited from an existing pool of volunteer parents who had expressed interest in participating in child development research. In this sample, 21% of the children were African American, 5% were bi- or multi-racial, and 74% were Caucasian. All of the participants were native English speakers. 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, children were given an age-appropriate toy and a $5 gift certificate to acknowledge their participation. An additional 1 participant was tested but was not included in data analysis due to parental concern of possible developmental delay. For this and the subsequent experiments, the Emory University institutional review board approved the protocols and procedures.

Stimuli—The stimuli were the same six novel "stem" facts (three pairs of related facts) and three novel "integration" facts used in Bauer and San Souci (2010). All facts were accurate and, based on pilot testing and the results of Bauer and San Souci, were determined to be novel to 6-year-olds. Two of the stem facts were about dolphins (dolphins live in groups called pods; dolphins communicate by clicking and squeaking), 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 a novel integration fact, namely that (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 read aloud by an experimenter. A sample passage is provided in the Appendix. The passages were 82–89 words in length, distributed over four pages, with 13–27 words per page. The words were read aloud by the experimenter, but the text did not appear on the page. Each page was accompanied by a hand-drawn illustration depicting the main actions. In each passage, a character learned a novel fact. As depicted in Table 1, all passages featured different characters. The novel fact always was presented on the second or third page of the passage, and 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—The procedure was identical that that used in Bauer and San Souci (2010). Children were tested individually in a laboratory room. Each session began with an experimenter describing the method and obtaining informed written consent from the parents and verbal assent from the children. Sessions were video-recorded. All testing was conducted by one of two female experimenters (J.E. King and E.A. White). Task procedures were outlined in a written protocol, and the experimenters regularly reviewed and discussed video-recorded sessions to ensure protocol fidelity.

Phase 1: Exposure to stem facts: Each child was exposed to four passages; two of the passages were from the same pair, and each of the other two passages featured one of the stem facts from each of the other two pairs. Thus, each child was exposed to both stems necessary to generate one integration fact (the Two-Stem condition) and only one of the two stems necessary to generate each of the other two integration facts (the One-Stem condition). Children were expected to generate the novel integration facts only in the Two-Stem condition. The One-Stem condition was included as a control for spontaneous generation of the integration facts.

As depicted in Table 2, during Phase 1 of the procedure, the experimenter first read two passages: one member of the pair of passages from the Two-Stem condition (e.g., *The Hungry Deer*) and one One-Stem condition passage (e.g., *The Traveling Ladybug*). 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, children were engaged in approximately 15 min of age-appropriate filler activities that were unrelated to the questions of interest.

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

Note that in each segment of Phase 1, the passage from the Two-Stem condition was read first, followed by the passage from the One-Stem condition. The filler activities ensured that there was a delay of roughly 15 min between presentation of the stem facts in the Two-Stem condition. Each pair of passages was used in the Two-Stem and One-Stem conditions approximately equally often.

Phase 2: Test for generation and recognition of integration facts and recall and recognition of stem facts: Following the second set of filler activities (and, thus, a delay of ~15 min), children were tested for generation and recognition of the integration facts and recall and recognition of the stem facts. The experimenter recorded children's responses as they were made. As depicted in Table 2, first, the experimenter asked each of three integration fact questions: "How does a pod talk?", "What is a baby Blue Flyer called?", and "Where is Mauna Loa located?" The integration fact questions were interspersed among five facts commonly known to 6-year-olds, including "What is a baby cow called?" and "Where does Mickey Mouse live?" (for a total of eight 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 with both stems for only one pair of passages (those in the Two-Stem condition), they were expected to generate the integration fact only in the Two-Stem condition.

Second, the experimenter asked eight fact recall questions; four questions probed children's recall of the stem facts to which they had been exposed via the passages, and four probed facts to which children had not been exposed. Example questions include "What is a joey?", "Where is the world's largest volcano?", and "How does a dolphin talk?" Children could be expected to recall the four stem facts to which they had been exposed. Two of the four additional fact questions were from the One-Stem passages that children had not experienced. The final two fact questions were commonly known, thereby providing 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 the Appendix. The integration fact 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. Both the questions and options were read aloud by the experimenter. Children were asked the recognition questions only for the integration facts that they failed to generate during the open-ended phase of testing. Thus, children received different numbers of recognition questions, depending on the number of integration facts generated in the open-ended 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 the Appendix. 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. As for the integration fact questions, all recognition questions had three alternatives, one of which was correct. Children were asked the stem fact recognition questions only for the stem facts that they failed to recall during the recall phase of testing.

Testing for the integration and stem facts was administered in the fixed order just described, although the order of questions presented in each section was counterbalanced among the participants. The open-ended format provided the strongest test of children's ability to integrate the two stem facts into the novel integration fact. To be valid, the open-ended format test needed to be administered before the test of recognition. Within each test modality (open-ended or 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

Generation of integration facts

Open-ended format: In the Two-Stem condition, where children had been exposed to both of the stem facts necessary to produce the novel integration fact, 37% of the children (n = 7) generated the novel integration fact. Performance in the One-Stem control condition made clear that children generated the novel integration facts as a result of exposure to the pair of related stem facts. In the One-Stem condition, children generated the novel integration facts on only 2 of the 38 trials (5% of total). The two facts were generated by two different children (i.e., two children generated one fact each). With-in-participants logistic regression using the SAS PROC GENMOD procedure indicated that the conditions were significantly different from one another ($z = 2.38$, $p < .02$). (Logistic regression was used because the measure of performance in the Two-Stem condition was dichotomous; for each child, we randomly selected one One-Stem trial for comparison with the one trial in the Two-Stem condition.)

Recognition format and across open-ended and recognition formats: Children achieved a high level of recognition of the novel integration facts in the Two-Stem condition and, thus, a high level of overall performance. However, because children's total performance in the Two-Stem and One-Stem conditions did not vary statistically (83% vs. 67% total performance; logistic regression: $z = 1.89$, $p < .06$), total performance did not inform the phenomenon of interest and, thus, is not discussed further.

Relations between generation of integration facts and recall of stem facts— Consistent with prior research (Bauer & San Souci, 2010), children's success in generating the novel integration facts was related to their recall of the individual stem facts. That is, all 7 of the children who generated the integration facts in open-ended format testing also recalled both of the stem facts. Moreover, children who recalled both of the stem facts were more likely to generate the integration fact in the open-ended format than to fail to generate it (64% vs. 36%, respectively, $p = .013$, Fisher's exact test). This pattern provides further support for the suggestion in Bauer and San Souci (2010) that memory for individual stem facts is an important ingredient of successful integration.

Discussion

Experiment 1A was a test of whether 6-year-olds integrate information presented in separate passages or episodes even when there is not a high degree of surface similarity between the related passages. Of the 19 children in the sample, 7 (37%) generated the integration fact in open-ended format testing. In contrast, in the One-Stem (control) condition, children generated the integration fact on only 5% of the trials. The sevenfold difference between conditions is evidence of integration of the separate passages of text.

The current research is a conceptual replication of the findings of Bauer and San Souci (2010), demonstrating integration under low surface similarity conditions. Yet, the level of integration in the current research (37%) was not as robust as that observed in Bauer and San Souci (67%). Although the most likely explanation of lower performance in the current research is the manipulation of surface similarity, an alternative explanation is possible, namely that Bauer and San Souci overestimated 6-year-olds' propensity to integrate. To test this possibility, in Experiment 1B we tested a new group of 6-year-olds under high surface similarity conditions. A replication of the levels of integration observed in Bauer and San Souci's study would be consistent with interpretation of the current findings in terms of an effect of the surface similarity manipulation.

Experiment 1B

Method

Participants—The participants were 16 6-year-olds (8 girls and 8 boys, M = 6 years 6 months, range = 6;0–6;11). The children were recruited from the same source and represent the same population as in Experiment 1A. In this sample, 6% of the participants were African American, 6% were Asian, and 88% were Caucasian. None of the children had taken part in Experiment 1A. Children participated in two sessions separated by 1 week. The data for the current experiment were collected in the first session. At the end of the second session, children were given an age-appropriate toy and a $10 gift certificate. An additional 3 participants were tested but were excluded due to an auditory/visual learning disability, failure to attend to the stimuli and test questions, or a procedural error.

Stimuli and procedure—The stimuli were the same high surface similarity passages used in Bauer and San Souci (2010). That is, in each of a pair of passages, the same character (e.g., a ladybug) learned a novel fact. Thus, whereas in Experiment 1A a ladybug learned that dolphins communicate by clicking and squeaking and a rabbit learned that dolphins live in groups called pods (see Table 1), in the current experiment a ladybug learned both facts of a pair. The paradigm differed from Experiment 1A in two other ways as well. First, children were tested only in the Two-Stem condition; no One-Stem condition passages were included in the protocol. The control condition was eliminated because in both Bauer and San Souci (2010) and Experiment 1A of the current research it was demonstrated that children generate the integration facts only when they have been exposed to both stem facts in a pair.

Elimination of the One-Stem condition passages also made way for the second methodological difference relative to Experiment 1A, namely that children were exposed to a total of three pairs of passages. The data for the current experiment were derived from the first pair of passages that was presented and tested; the data from the other two pairs of passages were used to address a question that is beyond the scope of this report. Specifically, children were read one passage from each pair (i.e., dolphin, kangaroo, volcano) prior to a set of filler activities, and the second member of each pair was read after a set of filler activities. The order of presentation of the passages was the same before and after the filler activities. Prior to the tests for generation and recognition of the integration facts and recall and recognition of the stem facts, children participated in additional filler activities. The design was counterbalanced such that each pair of passages was presented first, second, and third approximately equally often, thereby ensuring that each pair of passages was the source of data for the current experiment approximately equally often (i.e., the data were derived from the first pair of passages).

The testing format for the integration and stem facts was the same as in Experiment 1A. Because in Experiment 1A evidence of integration came from open-ended format testing only, we analyzed only the open-ended format data.

Children were tested by one of two female experimenters (N.L. Varga and E.A. White), one of whom (E.A. White) also tested children in Experiment 1A. Protocol fidelity was ensured as in Experiment 1A.

Results and discussion

Of the 16 children, 10 (63%) generated the integration fact in open-ended format testing. Between-participants chi-square tests revealed that the level of integration in open-ended format testing did not differ from the 67% observed in Bauer and San Souci (2010), $\chi^2(1, N = 31) = 0.06$, p = .81. The comparison of performance under the high surface similarity conditions of the current experiment and the low surface similarity conditions of Experiment 1A also was not significant, although the trend was in the expected direction, $\chi^2(1, N = 35) = 2.31$, $p = .13$.

The current experiment tested competing explanations for the levels of generation of the integration facts in Experiment 1A. By one account, the less robust integration observed in Experiment 1A relative to Bauer and San Souci (2010) was due to the surface similarity manipulation. By another account, Bauer and San Souci overestimated 6-year-olds' propensity to integrate. Experiment 1B clearly supported the first hypothesis. Under conditions of high surface similarity, 6-year-olds' levels of integration were on par with those observed in the previous research.

As a whole, the results of Experiment 1 indicate that 6-year-olds integrate between separate passages of text to generate new knowledge. Under high surface similarity conditions, the new knowledge is relatively readily available; children generated it on roughly two-thirds of trials. Under low surface similarity conditions, the level of self-generation of the new knowledge is lower; it was apparent on roughly one-third of trials. A likely explanation for the lower performance was that the use of different characters in the passages reduced children's recognition of their relevance to one another. In Experiment 2, we tested whether a "hint" to use the passages to help answer the integration questions would allow children to appreciate the relevance of the two passages to one another and, thus, successfully integrate them even in the face of low surface level similarity.

Experiment 2

Method

Participants—The participants were 36 6-year-olds (18 girls and 18 boys, *M* = 6 years 4 months, range = 6;0–6;11). The children were recruited from the same source and represent the same population as in Experiment 1. In this sample, 11% were African American, 11% were bi- or multi-racial, 3% were American Indian, 72% were Caucasian, and 3% did not indicate their race. None of the children had participated 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.

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Stimuli and procedure—The stimuli were the same low surface similarity passages that were used in Experiment 1A (see Table 1). All children were tested by the same experimenter (J.E. King), who also served as an experimenter in Experiment 1A. The procedure was similar to that used in Experiment 1B in that children were read all six passages and, thus, were exposed to all three sets of stimuli in the Two-Stem condition. Therefore, children could be expected to generate all three novel integration facts. As in Experiment 1B, one passage from each pair (i.e., dolphin, kangaroo, volcano) was read prior to a set of filler activities, and the second member of each pair was read after the set of filler activities. The order of presentation of the passages was the same before and after the filler activities. Following the logic outlined in Experiment 1B, the One-Stem control condition was not included. Elimination of the One- Stem condition allowed all stimuli to be used in the Two-Stem condition.

An equal number of participants was tested in each of two conditions ($n = 18$ per condition, 9 girls and 9 boys). In the No-Hint condition, the testing format for the integration and stem facts was the same as in Experiments 1A and 1B. In the Hint condition, Trials 1 and 3 were tested in the same manner as in the No-Hint condition. On Trial 2, children received the "hint" to "Think about the stories we just read to help you answer this question." Thus, Trial 1 of the two conditions was identical, and no difference in performance between the conditions was expected. Trial 2 was the test of the efficacy of the hint to use the stem fact passages; we expected higher performance in the Hint condition relative to the No-Hint condition. Trial 3 allowed an exploratory test of the possibility that the hint to think about the passages would generalize to the No-Hint Trial 3 (generalization trial). Higher performance on Trial 3 (which did not feature a hint) by children in the Hint condition relative to the No-Hint condition would be suggestive of generalization of the hint provided on Trial 2 (hint trial). Each pair of passages was used in each serial position of presentation approximately equally often (and, thus, was tested under Hint, No-Hint, and generalization conditions approximately equally often).

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The sequence of testing was the same as in Experiment 1 (i.e., open-ended format followed by recognition format). However, because in Experiment 1A evidence of integration came only from open-ended format testing, we analyzed only the data from that format.

Results

Generation of integration facts—The focus of the analysis was on group differences between children's performance in the Hint and No-Hint conditions for each trial. As suggested by Fig. 1, on Trial 1 children's performance did not differ between conditions; half of the children in each condition generated the integration fact. In contrast, on Trial 2, children's performance in the Hint condition (78%) was significantly higher than in the No-Hint condition (44%), $\chi^2(1, N = 36) = 4.21$, $p < .05$. On Trial 3, although children's performance in the Hint condition (67%) was higher than in the No-Hint condition (44%), the difference was not statistically significant, $\chi^2(1, N = 36) = 1.80$, $p = .18$.

Relations between generation of integration facts and recall of stem facts—In Experiment 1A of the current research and in Bauer and San Souci (2010), children's success in generating the novel integration facts was related to their recall of the individual stem facts. Importantly, in the current experiment, the greater success in generating the integration facts on Trial 2 by children in the Hint condition relative to the No-Hint condition was not due to differential success in remembering the stem facts. As reflected in Table 3, on Trial 2 approximately equal numbers of children recalled both of the stem facts in the Hint (61%) and No-Hint (50%) conditions. The only suggestion of differential levels of recall of the stem facts was on Trial 1, where 78% and 39% of children in the Hint and No-Hint conditions, respectively, recalled both of the stem facts. As presented above, however, the difference in recall of the stem facts on Trial 1 did not translate into higher levels of generation of the integration facts (see Fig. 1).

Discussion

The "hint" to use the stem fact passages to help answer the integration fact questions was successful in facilitating integration even in the face of low surface level similarity. Fully 78% of the children who on Trial 2 were instructed to "Think about the stories we just read to help you answer this question" generated the integration fact in open-ended format testing. Their performance on the second (hint) trial was significantly higher than Trial 2 performance of children in the No-Hint condition. In the Hint condition, the change in the number of children who generated the integration fact from 50% on Trial 1 to 78% on Trial 2 cannot be attributed to practice. In the No-Hint condition, where no hints were provided on either trial, 50% and 44% of children generated the integration facts in recall format testing on Trials 1 and 2, respectively. There also was suggestion in the data of generalization of the hint to facilitate performance on Trial 3 even though no explicit hint was provided. In the Hint condition, 67% of children generated the integration fact on Trial 3, compared with 44% of children in the No-Hint condition. Although the difference between conditions on Trial 3 was not statistically significant, the direction of the trend was consistent with the suggestion of generalization of the hint.

General discussion

The purpose of the current experiments was to test 6-year-olds' integration between separate yet related episodes under conditions that in other knowledge extension paradigms have been shown to pose challenges (Experiment 1A) and to be conducive (Experiments 1B and 2) to enrichment of semantic memory. The manipulations were successful. In Experiment 1A, low surface level similarity between two related textual passages resulted in integration on 37% of trials, a reduction from 67% observed in Bauer and San Souci (2010) under high surface level similarity conditions. Experiment 1B provided evidence consistent with the suggestion that the difference in performance in the two experiments was due to the reduction in surface feature similarity between the passages in the current research. Specifically, the 6-year-olds tested under conditions of high surface similarity between passages generated the novel integration facts on 63% of the trials, a level comparable to that observed in Bauer and San Souci's study. In Experiment 2, the detrimental effect of lower surface level similarity between passages was overcome by providing children with "hints" to use the passages to answer the questions posed to them. Children who received the hints had higher levels of performance relative to children who did not (78% and 44%, respectively).

Experiment 1 is an important replication (Experiment 1B) and extension (Experiment 1A) of the initial test of integration between separate episodes provided in Bauer and San Souci (2010). In the earlier research, the passages of text that children were challenged to integrate had high levels of surface similarity between them. That is, the members of the pairs of related passages of text involved the same character (e.g., a ladybug) who learned two facts about another entity (dolphins, kangaroos, or volcanoes). Thus, children had two bases for connecting the pair of related passages in memory: the main character and the target entity. In contrast, in Experiment 1A of the current research, the opportunity for connection based on the main character in the passages was eliminated, leaving only the common target entity. Rather than hearing two passages of text about ladybugs, children heard one passage about a ladybug and another passage about a rabbit, for example. The manipulation was associated with less robust integration relative to the high surface level similarity conditions of Bauer and San Souci and of Experiment 1B in the current research. Thus, the current research adds to the list of knowledge extension paradigms in which surface level similarity has been shown to be an important determinant of performance, including analogical problem solving (e.g., Gentner & Toupin, 1986; Holyoak et al., 1984), inductive reasoning (e.g., Gelman, 1988; Hadjichristidis, Sloman, Stevenson, & Over, 2004), and causal reasoning (e.g., Shultz & Ravinsky, 1977). Importantly, although children's performance was negatively affected by the surface similarity manipulation, children nevertheless generated the novel integration facts on 37% of the trials, compared with only 5% of trials in the One-Stem control condition. Thus, the experiment provides evidence that at least by 6 years of age, children are able to make use of a powerful semantic memory enrichment mechanism even when integration is not strongly supported by surface level similarity. The mechanism clearly is aided by surface level similarity nonetheless.

Experiment 2 also makes an important contribution to the literature. In Experiment 1 of the current research and in Bauer and San Souci (2010), children were left to their own designs to notice the commonality between the two related passages of text. Young children, in particular, are notoriously poor at spontaneously employing strategies or heuristics to aid their performance whether in the context of knowledge extension (e.g., analogical problem solving; Brown et al., 1986; Crisafi & Brown, 1986) or, more broadly, in memory (e.g., see Bjorklund, Dukes, & Brown, 2009, for a review). When they receive explicit hints of ways to aid their performance, it typically improves (although utilization deficiencies are observed in deliberate memory tasks when children use strategies but seemingly do not derive benefit from them; see Bjorklund, Miller, Coyle, & Slawinski, 1997). In the current research, an explicit hint to "Think about the stories we just read to help you answer this question" improved integration performance. The performance of children in the Hint condition improved from Trial 1, on which no hint was provided, to Trial 2, on which the hint was provided (50–78%). Comparison of the performance of children in the Hint condition with that of children in the No-Hint control condition provided compelling evidence that practice with the task was not the source of children's improved performance. Rather than improving from Trial 1 to Trial 2, the performance of children in the No-Hint condition was nominally lower on the second trial relative to the first trial (44% and 50%, respectively). Although practice was not the source of improved performance for children in the Hint condition, there was some suggestion of a version of transfer of the strategy from Trial 2, on which a hint was provided, to Trial 3, on which no hint was provided (in either condition). Whereas the Trial 3 performance of children in the Hint condition (67%) was not as high as it had been when the explicit hint was provided, neither did it fall to the Trial 1 (prior to hint) levels. In contrast, Trial 3 performance of children in the No-Hint condition remained at 44%. The experiment provides evidence that a simple hint can overcome the impediment to integration between separate episodes associated with low levels of surface level similarity between passages of text.

The results of the current research, coupled with those of Bauer and San Souci (2010), make clear that children integrate information learned in different episodes. How is integration accomplished? Although substantial additional research will be required to determine the mechanism(s) of integration, we suggest that integration between related passages of text is a natural by-product of the processes by which memories of experiences are formed. As reviewed elsewhere (e.g., Bauer, 2009; McGaugh, 2000; Wixted, 2004), there is growing evidence that subsequent to their initial formation, memory traces undergo substantial additional processing that lasts for minutes, hours, days, and even months. There is general consensus that the additional processing—termed *consolidation*—involves two processes that occur in parallel. First, memory traces are stabilized through formation of associations among the individual elements of experience (the sights, sounds, smells, etc.). Second, even as they are being stabilized, new memory traces are being integrated with old traces already stored in long-term memory (e.g., Zola & Squire, 2000). The basis for association of new information with old is shared elements that are simultaneously activated; neurons that are repeatedly activated together tend to become associated. The result is an entire pattern of interconnection of new information with old information.

Critically, once consolidated and stored, memory traces are not permanently fixed. Rather, each time a stored trace is cued—typically by elements of the current situation that overlap with elements that are part of the stored trace (cueing may be either intentional or unintentional)—it is reactivated and undergoes consolidation all over again (Nader, 2003), although the period of reconsolidation may be shorter than the period of initial consolidation (Debiec, LeDoux, & Nader, 2002). We suggest that reactivation and reconsolidation are key to understanding integration between separate yet related episodes. Consider that an initial learning episode sets into motion the processes of encoding and consolidation. A subsequent episode of a similar—but not identical—kind sets into motion its own processes of encoding and consolidation. Assuming that some elements are shared between the episodes (e.g., a ladybug, dolphins), they will become linked in memory. A demand for retrieval of information related to either episode will cause both to be reactivated, making them simultaneously available for integration. The process is consistent with the results of the manipulations employed in the current research. In Experiment 1A, integration was less frequent under conditions of low surface level similarity, presumably because fewer features in common between the episodes resulted in lower levels of simultaneous activation of both episodes. In Experiment 1B, integration was more frequent under conditions of high surface level similarity, presumably because more features in common between the episodes resulted in higher levels of simultaneous activation of the episodes. In Experiment 2, integration improved when children were explicitly instructed to think about (i.e., reactivate) “the stories we just read.”

As we make the suggestion that reactivation and reconsolidation are means by which information from separate yet related episodes is integrated, we acknowledge the unfamiliar use that we are making of the concepts. Consolidation and reconsolidation typically are associated with vulnerabilities in memory, not means of productive extension of semantic knowledge. That is, most of the work on these processes has emphasized the negative consequences of trace malleability, demonstrating that throughout the period of consolidation (and reconsolidation), memory traces are vulnerable to disruption and interference (e.g., Reed & Squire, 1998). For example, in animal models, lesions to the medial temporal structures implicated in consolidation have pronounced negative effects on memory if administered during—but not after—the period of consolidation (e.g., Takehara, Kawahara, & Kirino, 2003; see Debiec, LeDoux, & Nader, 2002, for conceptually similar demonstrations in the domain of reconsolidation). Although this work clearly illustrates memory vulnerabilities and failures, we maintain that it also illustrates the openness of memory traces to positive or productive post-encoding experiences that result in growth and development of knowledge. Expansion of knowledge occurs as memory traces with common elements become simultaneously activated and linked. On demand, the now-linked traces are simultaneously available for integration and generation of new knowledge, which itself then presumably undergoes the process of consolidation. Adequate tests of these suggestions will require substantial additional research. For now, they provide a plausible explanation for the phenomenon of integration between separate yet related episodes.

In conclusion, in the current research we tested 6-year-olds' integration of information presented in two separate passages of text. Under the high surface level similarity conditions of Experiment 1B, children showed evidence of integration. Thus, this study served as an independent replication of Bauer and San Souci (2010). Under the low surface level similarity conditions of Experiment 1A, integration was lower. Nevertheless, even under the more challenging conditions, children integrated on 37% of the opportunities in Experiment 1A and on 50% of the opportunities in Experiment 2 (Experiment 2, Trial 1; compare with only 5% of trials in the One-Stem control condition of Experiment 1A). These results demonstrate that at least by 6 years of age, children are able to exploit a powerful semantic memory enrichment mechanism. The results of Experiment 2 make clear that the mechanism can be prompted to work more effectively by providing a "hint" to think about the learning episodes from earlier in the test session. The simple hint was associated with an increase of more than 50% in the number of children who spontaneously integrated between the episodes. The hint was effective even under conditions of low levels of surface similarity between passages of text. Future research will further clarify the conditions under which children integrate between or across separate episodes and the mechanism(s) that supports this important means of knowledge extension.

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Appendix A. Sample passage with stem facts (in italics) and sample recognition questions

Sample passage: The Lonely Rabbit

Page 1: One day, a rabbit went to the zoo so that she could make some new friends.

Page 2: At the zoo, she met some friendly dolphins playing in the water. "Friendly dolphins," she asked, "may I be part of your group?"

Page 3: The dolphins said, "We'd love to have you *join our pod*. But you'll have to live in the water with *us*."

Page 4: The rabbit shook her head sadly, and then she left to go home. But now she knew that *a group of dolphins was called a pod*.

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: What is a group of dolphins called? — (a) tribe, (b) gam, (c) pod.

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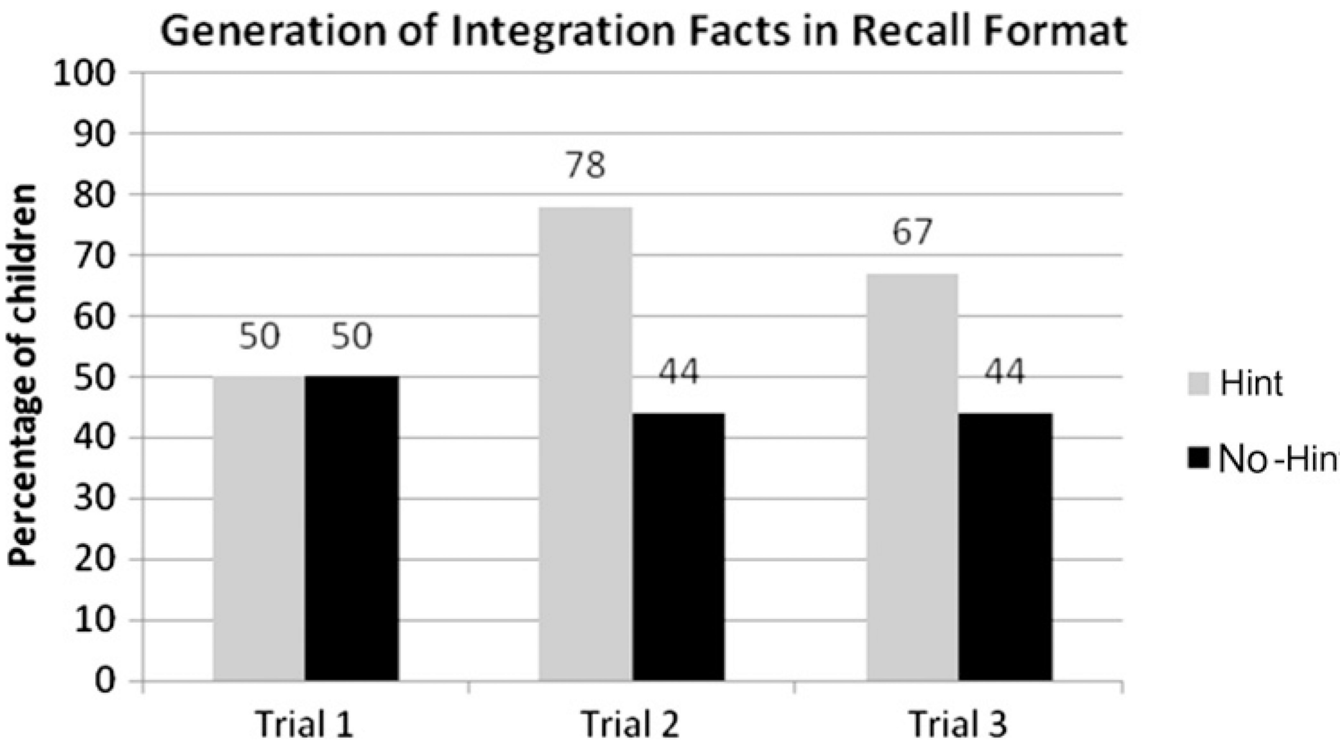

Fig. 1.
Percentages of children in the Hint and No-Hint conditions who generated the integration facts in open-ended format testing on each of three trials.

Table 1

Facts and main characters in stem fact passages and integration facts used in Experiments 1A and 2.

Facts and main characters in stem fact passages		**Integration facts**
Passage 1	**Passage 2**	
Ladybug learns that dolphins communicate by clicking and squeaking	*Rabbit* learns that dolphins live in groups called pods	Pods communicate by clicking and squeaking
Deer learns that a baby kangaroo is called a joey	*Lizard* learns that Blue Flyer is a type of kangaroo	A baby Blue Flyer is called a joey
Wave learns that the largest volcano is in Hawaii	*Cloud* learns that Mauna Loa is the world's largest volcano	Mauna Loa is located in Hawaii

Note: The main character in each passage is indicated in italics.

Table 2

Schematic representation of procedure used in Experiment 1A.

Phase 1: Exposure to stem facts
1. Passage 1 for Two-Stem condition (e.g., kangaroo story: *The Hungry Deer*)
2. One passage for One-Stem condition (e.g., dolphin story: *The Traveling Ladybug*) 15 min of filler activities
3. Passage 2 for Two-Stem condition (e.g., kangaroo story: *The Friendly Lizard*)
4. One passage for One-Stem condition (e.g., volcano story: *The Rainy Cloud*) 15 min of filler activities
Phase 2: Test for generation and recognition of integration facts and recall and recognition of stem facts
1. Integration fact questions: Open-ended format
2. Stem fact questions: Recall format
3. Integration fact questions: Recognition format
4. 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 One-Stem and Two-Stem conditions.

Table 3

Relation between recall of stem facts and generation of integration facts in Experiment 2.

Both stem facts recalled	Number (and %) of children who generated integration facts		
	Trial 1	Trial 2	Trial 3
Hint condition	14 (78)	11 (61)	12 (67)
No-Hint condition	7 (39)	9 (50)	12 (67)

Note: Percentages are in parentheses.