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Component Processes Involved in Self-Derivation of New Knowledge in 4-Year-Olds

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An abstract of
a thesis submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Master of Arts
in Psychology
2018

Abstract

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By Ana Maria Hoffmann

Semantic memory is our repository of knowledge about the world. It expands through direct experiences, such as reading a textbook or attending a lecture, and through productive processes that allow knowledge extension beyond what is directly learned. This research thesis focuses on the productive process of self-derivation of new information through integration of separate, yet related episodes of new learning. This process allows individuals to derive the novel fact that, for instance, *pods talk by clicking and squeaking*, having learned at one time point that *dolphins talk by clicking and squeaking* (fact 1), and at a later time *dolphins live in groups called pods* (fact 2). Past research has found that relative to 6- and 8-year-olds, who self-derive on 67% and 75% of trials, 4-year-olds self-derive only on 13% of the trials (Bauer & Larkina, 2017; Bauer & San Souci, 2010). Based on the ERISS model (Bauer & Varga, 2017), which describes five temporally-staged processes involved in self-derivation, it is hypothesized that 4-year-olds struggle to reactivate the first fact upon encoding the second, and subsequently fail to form an integrated representation. Accordingly, in the present research the researcher sought to facilitate reactivation by having 4-year-olds recall the episodes immediately prior to the self-derivation test. Twenty-four 4-year-olds (14 female; mean age = 4.4 years) participated and were randomly assigned to either one of two conditions, Stem-Prime or No-Prime condition. All children were read 3 pairs of story passages; each story contained a novel fact (stem fact). The stem facts within a pair could be combined to generate an integration fact. Each story pair was read twice: Story1-Story2, Story1-Story2. Before the self-derivation test, children in the Stem-Prime condition were asked to recall the stem facts. Children in the No-Prime condition were asked to recall non-stem, story details. Contrary to our hypothesis, children's self-derivation performance did not differ based on the Stem-Prime manipulation. Yet performance was more than twice as high as observed in prior research with 4-year-olds (31% compared to 13%).

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Background

Semantic memory is an individual's general knowledge repository of the world (Tulving, 1972). It grows continuously across the lifespan, beginning in infancy and continuing through the geriatric years. Semantic memory accumulates through direct learning experiences, such as reading a textbook or attending a lecture. Similarly, knowledge can be extended beyond what was explicitly taught through productive processes (e.g., induction, deduction, and analogy; for review, see Goswami, 2011; 2013). Without productive processes, learning would be less efficient, as each fact would need to be individually acquired. The present study focused on the productive process of self-derivation of new information through the integration of separate, yet related, episodes of new learning. As early as 4-years of age, children self-derive new knowledge via the process of integration. However, successful self-derivation performance increases throughout childhood, with 6- and 8-year-olds exhibiting higher levels of self-derivation than their younger, 4-year old counterparts (Bauer & Larkina, 2017; Bauer & San Souci, 2010).The hypothesis guiding the present research was that 4-year-olds are less successful at self-derivation compared to 6- and 8-year olds, because they engage less readily in the preliminary steps to self-derivation, specifically reactivation.

Self-derivation and Developmental Change

Self-derivation of new knowledge through integration has been operationalized using a story-passage paradigm (Bauer & San Souci, 2010). In this paradigm, children 4 to 8 years of age are presented with two separate yet related story passages, each containing a true, but previously, unknown fact (i.e., a "stem" fact). The passages are presented in the form of a picture book, depicting a main character (e.g., a lady bug) that learns something new by engaging in an activity or a journey. The related passage pairs are constructed such that when the facts presented within them are integrated with one another, the integrated representation can be used to self-derive a true yet novel fact (i.e., an "integration" fact). For example, a child learns in one story that *dolphins talk by clicking and squeaking*. In a separate story, that same child learns that *dolphins live in groups called pods*. When the child is later asked "*how do pods talk*", the child has the opportunity to self-derive the novel fact that "*pods talk by clicking and squeaking*". Thus, new information that was neither observed nor explicitly taught is self-derived. Importantly, prior research has shown that integration of the related stem facts is necessary for individuals to self-derive novel facts. That is, when presented with only one stem fact, 6-year-olds and 4-year-olds generated the integration fact on 17% and 0% of the open-ended trials, respectively. Using this paradigm, we have observed age-related differences in self-derivation performance. Four-year-olds produced integration facts in response to an open-ended question only 13% of the time. In comparison, 6-year-olds and 8-year-olds self-derived knowledge on 67% and 75% of open-ended trials, respectively (Bauer & Larkina, 2017; Bauer & San Souci, 2010).

Component Processes involved in Self-derivation

What accounts for lower levels of performance among 4-year-olds relative to older children? Bauer (2017) suggests that age-related differences may be due to younger children's less efficient and thus less effective engagement of the component processes involved in self-derivation. Bauer and Varga (2017) proposed that self-derivation of new factual knowledge entails five temporally staged processes, namely, **E**ncoding, **R**eactivation, **I**ntegration, **S**election, and **S**elf-derivation (ERISS). The steps of the ERISS model are: 1) Encoding the first previously unknown fact in memory: "*dolphins talk by clicking and squeaking*"; 2) Reactivating knowledge of the first fact when encoding the second, previously unknown fact. Reactivation depends on the recognition of the relatedness between the two facts. For example, if the second fact is "*dolphins live in groups called pods*," the shared element that drives reactivation of the first fact would be "dolphins"; 3) Integrating the episodes of learning into a single representation. The two facts become linked within memory due to recognition of the shared element, "dolphins"; 4) Selecting an appropriate representation upon demand; when asked "*how does a pod talk?*" an individual has to sort the relevant facts (e.g., "*dolphins live in groups called pods*" and "*dolphins talk by clicking and squeaking*") from other information they may know about dolphins; 5) Self-deriving the new factual knowledge; "*pods talk by clicking and squeaking*."

The critical features of this model are that (a) the steps are temporally staged, and (b) the steps early in the process are necessary for the success of subsequent steps and ultimately, for self-derivation. According to Bauer (2017), 4-year-olds have lower self-derivation performance compared to 6- and 8-year olds because they do not successfully engage some of the preliminary steps necessary for self-derivation. Specifically, the hypothesis guiding the present research is that whereas each of the steps in the process may explain variance in 4-year-olds' performances, the step of reactivation warrants particular attention.

The focus of the present research is on reactivation because prior research suggests that encoding does not explain significant age-related variance. Bauer and San Souci (2010) found that 6-year-olds who recalled or recognized both stem facts successfully self-derived the new integration fact or selected it from forced-choice options. This correlation in performance did not hold among 4-year-olds. That is, 4-year-olds who recalled or recognized both stem facts were equally likely to self-derive the new integration fact or select it from among forced-choice distractors as they were to fail to. In a subsequent study, the researchers examined whether 4-year-olds' performance in self-derivation improved if their recall of the stem facts was higher (Bauer & San Souci, 2010). In order to test this question, participants were brought to a learning criterion by being asked to recall the stem fact after each story presentation. Seventy-three percent of 4-year-olds recalled both of the stem-facts after the presentation of each story passage, and 20% recalled at least one. These findings provide evidence that children encoded the stem facts presented in the story passages. The learning to criterion manipulation was associated with an improvement in self-derivation performance from 13% to 33%. Although 4-year-olds improved in self-derivation performance, their average performance did not improve to the level of performance (67%) seen in 6-year-olds. Thus findings in Bauer and San Souci (2010) suggest that although memory of both stem facts is necessary for integration, it is not sufficient. Furthermore, whereas 4-year-old children may learn the two related stem facts within a domain (e.g., *dolphins talk by clicking and squeaking* and *dolphins live in groups called pods*), they are more likely to recall just one of the two stem-facts rather than both of them (70% and 30% of the trials, respectively). This suggests that, although the facts have been encoded, they have not been linked together in memory.

The Role of Reactivation in Self-derivation

Rather than encoding, previous observations suggest that reactivation contributes substantial variance in young children's performance. Specifically, there is evidence that when the demands to reactivate are reduced, self-derivation performance increases. In a study by Bauer, Varga, King, Nolen, and White (2015), hints were provided to 4-year-olds in order to promote reactivation and the self-derivation of new factual knowledge, in turn. Self-derivation was higher in 4-year-olds (just over 50%) who received a hint (i.e., *think about the stories we just read to help you answer this question*) before open-ended testing for self-derivation compared to children (12.5%) who received only a generic hint (*think*; Bauer et al., 2015). Presumably, the hints before open-ending testing improved self-derivation performance by guiding children to recognize the relatedness between the separate passages (reactivation). However, even with the hints, 4-year-olds' self-derivation performance was still lower than 6-year-olds in both conditions (70% with the hints and 43% with generic hints).

In summary,4-year-olds have lower self-derivation performance compared to 6- and 8-year-olds.Evidence is consistent with the suggestion that this discrepancy in performance may be due to 4-year-olds'failure to successfully reactivate prior knowledge when learning new information. Though they successfully encode the two separate stem facts, 4-year-olds are unsuccessful at recognizing the relatedness between them. It is speculated that due to their failure to reactivate, 4-year-olds do not form an integrated representation of the facts in memory, and thus fail to self-derive. Furthermore, when evidence suggest that when the demand to reactivate is lowered, 4-year-olds self-derivation performance increases.

The Present Study

The aim of the present research was to test the hypothesis that4-year-olds are less successful at self-derivation compared to 6- and 8-year olds, because they engage less readily in Reactivation. Thus, two manipulations were introduced to increase the likelihood that individual stories in the passage pairs were perceived as related. It was expected that these manipulations would facilitate Reactivation, and consequently, self-derivation.

First, to lessen the demand of reactivating the first fact upon the presentation of the second fact, paired story passages were presented back-to-back. In prior related research, the story passages were interspersed with each other (for example, see Bauer & Larkina, 2016; Bauer & San Souci, 2010; Bauer, Varga, King, Nolen, & White, 2015) such that the first and second members of story passage pairs were separated in time and by other story passages. In the present research, the stories in a passage pair were presented together, one after another. This was expected to lessen the demand for reactivation by removing the interference and temporal delay associated with other stories and intervening activities. Consistent with this suggestion, in pilot testing when the second passage of a story pair in a domain followed right after the first, 33% of 4-year-olds self-derived the novel integration fact compared to the 13% in the standard test condition. Though back-to-back presentation of the stories increased the performance of the 4-year-old participants, self-derivation was still lower than what was observed among the 6-year-old participants (67%). For this reason, the researcher implemented a second manipulation to facilitate reactivation in the 4-year-old participants.

The second manipulation was to “prime” the stem facts immediately prior to the test for self-derivation of the integration fact. With the exception of Bauer and colleagues (2015), in prior research, children were not reminded of the stem facts prior to the open-ended self-derivation questions. Moreover, questions were separated from the stem facts by 10 to 15 minutes with intermediate activities, such as Verbal Comprehension measures. As mentioned above, children performed better when they were given a hint about the stem facts right before testing. The present study tested whether a similar aid to reactivation resulted in increased self-derivation performance following the back-to-back presentation of story passage pairs. To examine this effect, participants were randomly assigned to and tested in one of two conditions: the Stem-Prime or the No-Prime condition. In the Stem-Prime condition, participants were asked to recall the stem facts presented in the story passages (e.g., *how do dolphins talk?*) before being tested for open-ended self-derivation of the novel stem facts. If recall failed, children were reminded of the correct answer. It was expected that recall of the stem facts would aid in the reactivation of stem facts within each domain, leading to higher performance in self-derivation.

In contrast, in the No-Prime condition, 4-year-olds were asked about non-stem story elements (e.g., *why did the ladybug go to the zoo?*) from each passage. Just as with the Stem-Prime condition, if the participants failed to recall the correct information, they were reminded. The non-stem story elements, unlike the stem facts, could not be combined to produce the novel integration fact. For this reason, the No-Prime condition acted as the control condition: if there was no difference in self-derivation performance seen between the Stem-Prime and the No-Prime conditions it would be an indication that this paradigm did not promote the reactivation of the presented stem facts. In addition, it was expected that the Stem-Prime condition would make the stem facts more cognitively accessible at the time of test, thus promoting reactivation before participants completed open-ended testing for self-derivation.

In summary, previous research has shown that 4-year-olds have lower self-derivation performance compared to their older counterparts (e.g. Bauer and San Souci, 2010). The evidence is consistent with the suggestion that this disparity in performance is related to the second step of the ERISS (i.e., reactivation) model. In the present study, the researcher tested this suggestion by reducing the need to reactivate via the modification of experimental conditions from prior research. The experiment increased the temporal proximity of each passage pair (e.g., back-to-back performance). This uninterrupted presentation of passages was predicted to increase self-derivation by lowering the demand to reactivate prior information across the separate episodes of learning. To further reduce the reactivation demand, a Stem-Prime condition was included to prime participants with the necessary stem facts to self-derive the novel integration fact. Overall, it was expected that performance for the participants in the Stem-Prime condition would be higher in relation to the control condition (No-Prime). Specifically, it was anticipated that presenting the children with the stem-facts right before self-derivation would further them draw connections between the relation of the pairs of facts presented to them (e.g. reactivation and integration) and self-derivation of new knowledge.

Method

Participants

The participants are twenty-six 4-year-olds, including 14 girls (54%) and 12 boys (46%). The children ranged in age from 4 years old to 4 years old and 11 months (*M* = 4 years and 5 months, *SD* = 2.97 months). This sample was recruited from a volunteer pool consisting of families in a city in the South-Eastern United States who expressed interest in participating in child development research. Based on parental report, the sample was 15% Black, 4% Asian, and 81% White. Eight percent of the sample self-identified as Latino or Hispanic. Although no information on parental income or occupation was collected, the pool from which the participants were recruited from is composed primarily of families with middle- to upper-middle socioeconomic status. Therefore, it is reasonable to assume that the children in this study were from middle- to upper-economic backgrounds. Four additional four-year-olds were tested but excluded from data analysis due to not comprehending English (*n*= 1), failure to complete the study (*n*=2), and experimenter error (*n*=1). Participants were pseudo-randomly (constrained by gender balance) assigned to one of two conditions: the experimental condition (*n*=13) and the control condition (*n*=13). For this experiment a university institutional review board (IRB) approved the protocol and procedures. Before the start of the session, the experimenter thoroughly explained the methods to both the child and the parent or guardian, and obtained written informed consent from the parent or guardian. At the end of the session, each child received an age-appropriate toy to acknowledge their participation and their parent or guardian was given a $5.00 dollar gift card as a token of appreciation for their involvement in the study.

Measures

Stimuli. The stimuli were three pairs of story passages, each featuring one of three different domains: dolphins, deserts, and palm trees. Each passage contains 82 to 89 words that spanned over four pages (Appendix A). No words were featured on the pages, but all stories were illustrated and depict the main events occurring throughout the text. All stories follow the same format: a main character (e.g., a lady bug) learns something new (i.e., the novel stem fact). Within each domain, the main characters were the same; across the domains the main characters were different.

Each story contained a novel "stem" fact presented on the second or third page of each passage. The stem fact was repeated at the end of the story. Two of the stem facts were about dolphins (i.e., dolphins live in groups called pods; dolphins talk by clicking and squeaking), 2 of the stem facts were about deserts (i.e., the Sahara is largest desert in the world; the largest desert in the world is in Africa), and 2 of the stem facts were about palm trees (i.e., palm tree leaves are called fronds; palm tree leaves are used to make baskets). Each pair of stem facts could be combined to generate a novel integration fact (e.g., pods talk by clicking and squeaking). All the stem-facts were accurate and have been determined to be novel to children in the target age range by prior, related research (see Bauer & Larkina, 2016). In addition to the stem fact, each story featured a "non-stem" fact that was used in a question during the testing phase. Each non-stem fact was related to the story details (e.g., the characters) and introduced on the first page or second page of the stories. Unlike the stem fact, non-stem facts could not be combined across story pairs to create a novel integration fact. Furthermore, only stem and non-stem facts were presented in the passages; the integration facts were not presented.

Verbal Ability. Due to the verbal nature of this study and the between-subjects design, three subscales of the Woodcock–Johnson III Test of Verbal Comprehension (Woodcock, McGrew, & Mather, 2001) were administered to measure verbal ability: the picture vocabulary, synonyms, and antonyms subscales. This was done to ensure that the participants in the experimental and control conditions were comparable to each other in regards to their verbal comprehension. This was important to establish to avoid concerns about systematic differences in verbal ability between the two groups, which could confound any differences between the groups due to their exposure to the experimental or control conditions.

Procedure

Participants were tested individually in a room equipped with a table, two chairs, and a small couch. All testing was completed by the same female experimenter (the author). Participants were pseudo-randomly assigned to either the Stem-Prime or No-Prime condition (*n* = 13 per condition). The No-Prime condition acted as the control, allowing us to see whether the manipulation condition (Stem-Prime) lead to an improvement in self-derivation performance. The procedures were outlined in a written protocol, and the sessions were video-recorded to ensure protocol fidelity throughout data collection. Each session took approximately one hour, and was divided into two phases:

Phase 1: Exposure to Stem and Non-Stem Facts. Each child participant was presented with the three pairs of story passages (Appendix A). All children were instructed to listen quietly to the stories and to look at the pictures. The experimenter read both passages in a pair consecutively and then reread them. All the stories were counter-balanced so that each passage pair occurred equally often in each serial position throughout the study. After the presentation of the first passage pair, participants completed the picture vocabulary subscale. Following the presentation of the second passage pair, participants completed the synonym and antonym subscale, respectively. Once all story passages were presented, participants completed the Woodcock–Johnson III Test of Visual Matching (Woodcock, McGrew, & Mather, 2001) as buffer activity before the testing phase.

Phase 2: Test for Recall of Stem and Non-Stem Facts and Self Derivation and Force-choice Selection of Integration Facts. Immediately following the presentation of the story passages, the participants were tested in open-ended and forced-choice formats, for the recall of stem and non-stem facts and the self-derivation of integration facts. There were four test instalments (Appendix B), the first and third of which were interchanged depending on whether a given participant was placed in the Stem-Prime or No-Prime condition. All the questions were asked in the same order as the passages were read (i.e., if the passage pairs were read in order A1A2, B1B2, C1C2, then the presentation of the stem and non-stem questions followed the same order and the self-derivation questions was presented in the A, B, C sequence).

In the Stem-Prime condition, children were first tested for the open-ended recall of the stem facts presented in the stories (e.g., *how do dolphins talk*?). This was expected to help reactivate the stem facts before testing for self-derivation of the integration facts. If participants failed to recall a stem fact, the experimenter reminded the child of the answer before moving on to the next question. Participants were then provided with open-ended questions to assess the self-derivation of novel integration facts from each domain (e.g., *how does a pod talk*?). Next, participants were asked open-ended questions for their recall of the non-stem facts. Just as with the stem facts, reminders were provided for incorrect answers. Immediately after open-ended testing, participants were tested for the forced-choice selection of the correct integration fact that they initially answered incorrectly. All forced-choice questions included three answer choices, one of which is correct. Subsequently, participants were tested for the forced-choice selection of the correct stem facts and non-stem facts that were answered incorrectly during the open-ended testing. For example of recall and integration questions, see Appendix C.

Participants in the No-Prime condition were initially tested for their open-ended recall of the non-stem facts from each story passage. These are non-stem story elements that could not be integrated to form novel stem-facts (e.g., *what blew the ladybug out of bed?*) and, therefore, would not promote the reactivation of the stem facts. For this reason, the No-Prime condition was used as a control. Just as in the Stem-Prime condition, if recall failed, participants were reminded of the answer by the experimenter before moving on to the next question. The participants were then asked open-ended questions for the novel integration fact, followed by open-ended recall of stem facts from the story passages. After open-ended testing, participants in the No-Prime condition were tested for the forced-choice selection of the correct integration facts that were answered incorrectly during open-ended testing. This was followed by non-stem and stem fact forced-choice questions, which had been answered incorrectly during open-ended testing.

Scoring

The experimenter recorded participant's responses during open-ended and forced-choice testing as they occurred. First, children received a score of 1 or 0 (correct or incorrect, respectively) on each open-ended integration, stem fact recall, and non-stem fact recall question. The participants had the chance to get an aggregate of 3 for the integration facts in open-ended testing. That is, if they answered all 3 integration questions correctly, they would get 3 points. The possible aggregate score for the stem and non-stem recall was 6 each. In forced-choice, participants received a score of 1 or 0 on integration, stem, and non-stem fact questions they answered incorrectly during open-ended testing. The aggregated score in forced-choice was dependent on how many open-ended questions they failed to produce. Finally, the Total score was compromised of both the correct open-ended and forced-choice responses. Because children only received forced-choice questions for open-ended questions they answer incorrectly, the Total score for integration questions was 3; the Total score for stem questions is 6; the Total score for non-stem questions is 6.

Data Analytic Strategy

All analyses were conducted using SPSS Statistics package (Version 24). All statistical tests reported as significant were below an alpha level of 0.05. In order to analyze performance differences in open-ended self-derivation performance between the Stem-Prime and No-Prime conditions, the researchers ran an independent *t*-test. Additionally, a mixed model ANOVA was used to analyze the recall of stem and non-stem facts between the conditions. This allowed the researcher to compare the mean differences between groups. The design consisted of one within subject variable (question type), with two levels (stem and non-stem recall), and one between subjects variable (condition), with two levels (Stem-Prime and Non-Prime). The experimenter did not run analyses on forced choice responses, as that would have disregarded individuals who self-derived integration facts and recalled stem and non-stem facts in the open-ended test. Instead, an independent t-test of the Total self-derivation score (open-ended +forced-choice) was performed to analyze performance differences between the Stem-Prime and No-Prime conditions. A mixed model ANOVA was be used to analyze the Total stem and non-stem facts performance (recall + recognition scores) between conditions.

Results

Preliminary Analysis

The researcher ran an independent samples t-test to test whether children pseudo-randomly assigned to either the experimental (Stem-Prime) or the control (No-Prime) condition differed in their general language abilities (Woodcock et al., 2001). The analysis revealed no significant difference between conditions: t(24) = .49, p =.63.

Main Analysis

Children's self-derivation performance in open-ended and total performance (open-ended and forced-choice selection) are displayed in Figure 1, Panel a and Panel b, respectively. In order to analyze performance differences in open-ended self-derivation performance between the Stem-Prime and No-Prime conditions, the researchers ran an independent t-test. There was not a significant difference in the scores for the open-ended integration questions in the Stem-Prime (M= 0.31, SD= 0.25) and No-Prime (M= 0.28, SD= 0.27) conditions; $t(24) = 0.25$, p= 0.80. These results suggest that our reactivation manipulation had no effect on self-derivation performance. However, there was a significant difference in Total (i.e., open-ended + forced-choice) self-derivation performance between the Stem-Prime (M= 0.64, SD= 0.32) and No-Prime (M= 0.85, SD= 0.22) conditions; $t(24) = 1.91$, p= 0.04. Contrary to prediction, there was lower Total self-derivation performance in the Stem-Prime condition in comparison to the No-Prime.

Additionally, the researchers examined the recall of stem and non-stem facts between the conditions using a 2 (stem versus non-stem recall) by 2 (Stem-Prime versus

No-Prime condition) mixed factor Analyses of Variance. The results of the two-way mixed Analyses of Variance on open-ended testing showed that there was a significant main effect of question type on recall scores ($F(1,24)=65.19$, $p=0.00$, $\eta_p^2 = 0.73$). Across conditions, participants had lower levels of recall of the stem (*M*= 0.30, *SD*= 0.13) than the non-stem (*M*= 0.62, *SD*= 0.19) facts. In contrast, there was no significant main effect of condition ($F(1,24) = 0.04$, $p= 0.85$, $\eta_p^2 = 0.02$). Across question types, participants in the Stem-Prime (*M*= 0.45, *SD*= 0.12) and No-Prime (*M*= 0.46, *SD*= 0.15) conditions recalled the same number of stem and non-stem facts. There was no significant interaction between condition and question type ($F(1,24) = .15$, $p= 0.70$, $\eta_p^2 = 0.01$) in open-ended testing.

The findings for Total performance (recall + recognition performance) were parallel to those observed for open-ended recall. There was a significant main effect of question type on the Total recall scores ($F(1,24)= 10.72$, $p=0.00$, $\eta_p^2 = 0.31$), with overall lower performance in stem (*M*= 0.83, *SD*= 0.21) than non-stem questions (*M* = 0.93, *SD*=0.14). There was no significant main effect for condition ($F(1,24)=0.001$, $p= 0.97$, $\eta_p^2 = 0.97$). Participants in the Stem-Prime (*M* = 0.88, *SD* = 0.16) and No-Prime (*M*= 0.88, *SD*= 0.18) conditions had similar levels of Total performance. Additionally, there was no significant interaction between condition and question type ($F(1,24) = 0.24$, $p = 0.63$, $\eta_p^2 = 0.01$).

Discussion

The purpose of the present study was to test the hypothesis that reactivation contributes to the variance in self-derivation performance found in young children. This hypothesis was tested using a story-passage paradigm, in which a sample of 4-year-olds was presented with two related story passages. Each of these two passages contained a novel stem fact (e.g., *dolphins talk by clicking and squeaking* and *dolphins live in groups called pods*). These stem facts could be integrated to self-derive a novel integration fact (e.g., *pods talk by clicking and squeaking*). In the experimental– Stem-Prime –condition, the 4-year-olds in this study were asked to recall the stem facts before being prompted for the integration fact. The recall of the stem facts was predicted to reduce the demand of reactivation in 4-year-olds, thereby increasing self-derivation performance. Performance in this condition was contrasted with performance in another condition, the No-Prime, which acted as the control group.

Contrary to prediction, there was not a significant difference in self-derivation between the Stem-Prime condition and No-Prime condition in open-ended testing (31% and 28%, respectively). However, there was a significant difference in the Total performance (i.e., open-ended + forced-choice) between the Stem-Prime and No-Prime condition (64% and 85%, respectively). This pattern of results is the opposite of what was hypothesized: the No-Prime condition had higher total self-derivation performance than the Stem-Prime. It is possible that the order of stem and non-stem recall questions in open-ended testing played a role in the children's forced-choice self-derivation performance. Specifically, the 4-year-olds in the No-Prime condition were first asked to recall the stem facts following the integration questions whereas the Stem-Prime condition was asked to recall the stem facts before the integration question in order keep the conditions balanced. Perhaps participants in the No-Prime condition recognized the relevancy of the stem facts after being asked to recall them following self-derivation in open-ended testing, and were able to supply them during forced-choice testing. In comparison, it is possible that the children in the Stem-Prime condition did not recognize the relevancy of the stem facts as evidenced by performance in open-ended self-derivation. If they had, Stem-Prime self-derivation performance would have been higher than No-Prime performance, as initially predicted.

Additionally, the results showed that overall 4-year-olds recalled more non-stem than stem facts in both the experimental and control conditions. It is possible that the non-stem facts were more salient to the participants due to their representation in the passages and the nature of the questions. All non-stem facts were related to a main character in each story passage. To expand, three of the non-stem recall questions asked for the name of the character. The other three non-stem recall questions asked for either the character's motivation or their location in their respective story passage. In addition, the main character was always mentioned in the title (e.g., *The Travelling Ladybug*) and in the introduction when the passage was presented for the first time (e.g., *This story is about a ladybug. Let's see what happens in the story*).In this sense, the 4-year-olds were presented with the same piece of information (e.g. the character) multiple times throughout its respective passage. Participants may therefore have had more success when they were asked to recall the non-stem facts do to the repetitive exposure of the information. Another possibility is that, unlike the stem facts which were novel pieces of information, the non-stem facts were less definition like and therefore may have been easier to encode and recall. Contrary to expectations, the children across both conditions did not recall the stem facts on the majority of trials and the fact needed to be provided by the researcher. The results indicate that the Stem-Prime manipulation did not lower the demand of reactivation in 4-year-olds.

Though there was not a difference in self-derivation performance between the Stem-Prime and No-Prime conditions, there was nearly two-fold increase in self-derivation performance compared to previous research conducted with 4-year-olds (33% of the trials compared to 13%; Bauer & Larkina, 2016; Bauer & San Souci, 2010), except in Bauer and colleagues (2015; 50%). It is possible that the two-fold increase in performance in this present experiment occurred due to the ‘pre-integrated’ nature of the story passages in a pair. By reading the first and second passages in a pair consecutively, the participants had little to no reactivation demand at encoding as the separate episodes of learning were put into close proximity. That is, the presentation of the passages may have effectively created a pre-integrated representation, removing the need to reactivate as well as reducing the demand to integrate. Future research should test the hypothesis that 4-year-olds facilitated performance was due to the pre-integrated presentation of the stories. In order to test this hypothesis, passage pairs should be presented as separate episodes. That is, instead of the pre-integrated presentation, the researcher will read each story passage twice before moving on to the next story. This will also allow the researcher to further test the Stem-Prime manipulation, and whether lowering the demand to reactivate during test, instead of presentation, increases self-derivation in 4-year-olds.

The results of the current study are consistent with prior cueing research (Bauer, et al., 2015). By providing the hint to “*think about the stories*” before asking the 4-year-olds to self-derive the integration fact, Bauer and colleagues (2015) reduced the demand to reactivate leading to higher self-derivation performance in relation to that found in Bauer and Larkina (2016) and Bauer and San Souci (2010). Despite the consistent finding in regards to increased self-derivation by lowering reactivation demand, performance in the present study was lower than that in Bauer and colleagues (2015). It is possible that the number of passages presented to the participants is a key reason for the discrepancy between the results in the present study compared to Bauer and colleagues (2015). In consideration of children's relatively short attention span, prior studies only presented children with two passages pairs. The present study presented children with three pairs of passages. That is, the presentation of three passages pairs may have increased the cognitive load in the children in the present sample in comparison to Bauer and colleagues (2015), resulting in lower performance.

Limitations and Future Directions. The findings from this study should be evaluated in the context of certain limitations. First, the forced answer choices could have been affected by the recency effect, the tendency for individuals to be better able to recall the last items seen or heard in a series of items. On several of the forced-choice trials for non-stem recognition the correct answer was C. Due to the recency effect that is prevalent in this age group (Mehrani & Peterson, 2015; Mehrani & Peterson, 2017), it is possible that the participants preferentially selected the last answer choice, C, provided to them. However, this was not an issue: non-parametric statistics demonstrated that performance did not differ from trials where the first (A) or second (B) item where correct. That is, 4-year-olds in this study did not select C more frequently than A and B.

Furthermore, it is important to note that the present study was not designed to differentiate between reactivation and integration. Although reactivation is a preliminary step to integration, the current paradigm cannot separate these two steps in the ERISS model. That distinction will be left to future research. Likewise, future studies should investigate the change in self-derivation performance over age using the present paradigm. This would further understanding of the cognitive processes involved in self-derivation and which processes contribute to the variance seen in children's performance over development. Expanding this research is of importance, as evidence suggests that self-derivation is correlated with academic achievement in school-age children (Esposito & Bauer, 2017). The findings of the present and future studies can provide suggestions for when interventions to facilitate self-derivation would be most beneficial.

Conclusion

In conclusion, whereas the present study sought to reduce variance in self-derivation performance by lowering the demand of reactivation, no difference was found between the experimental and control group. However, self-derivation performance in 4-year-olds was twice as high as observed in prior research. It is possible that this was a result of the back-to-back presentation of the story passages created a pre-integrated representation therefore eliminating the need to reactivate prior information. Future studies should continue investigating the role of reactivation in self-derivation.

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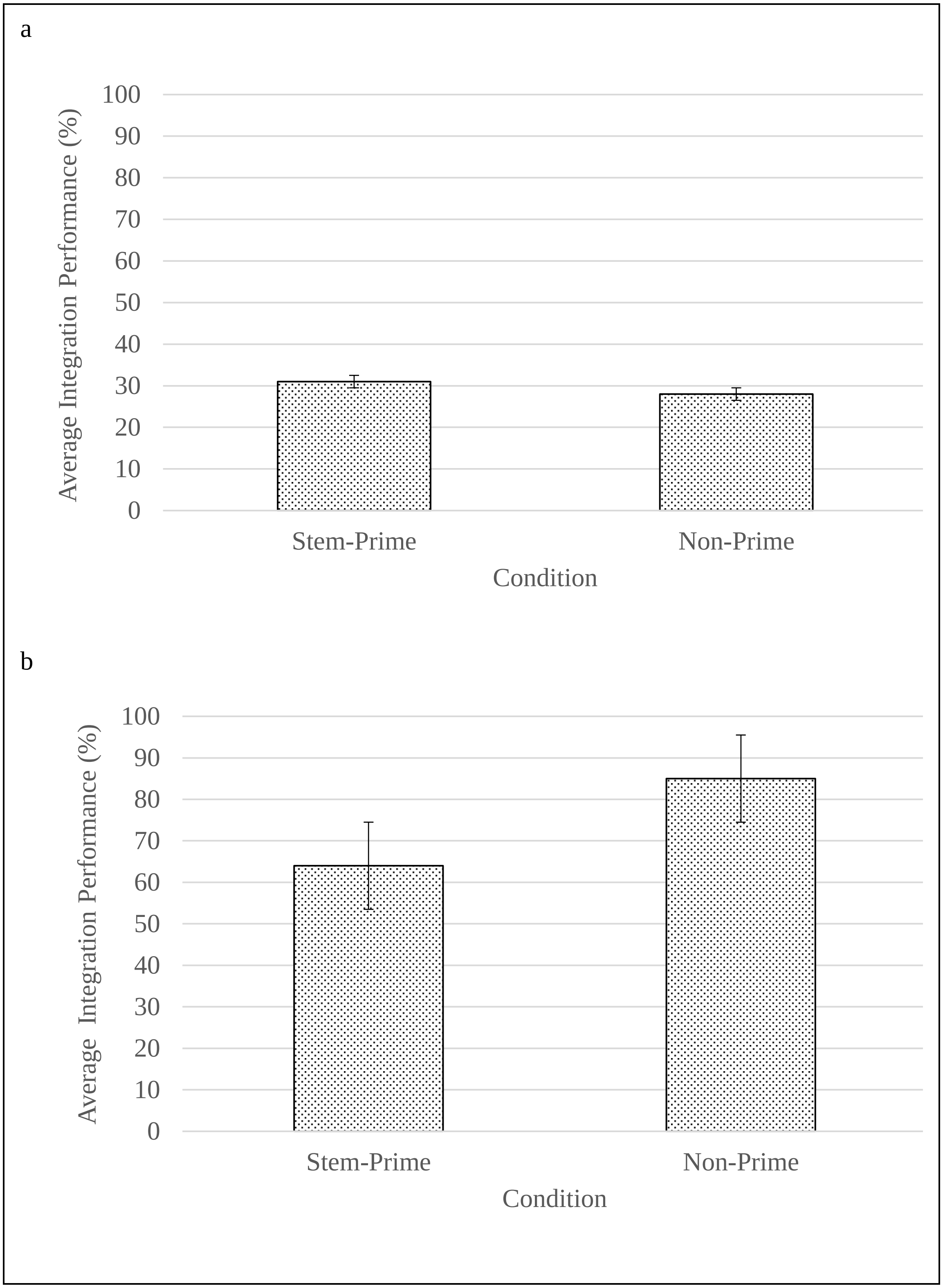

Figure 1: Average open-ended (a) and Total (b) self-derivation performance in 4-year-olds.

Appendix A

Sample stem-fact text passages (all passages 82-89 words in length) demonstrating separate yet related learning episodes (stem facts in *italics*). Thumbnail of illustrated pages below figure.

Passage A1: “Hoppy Rabbit’s Garden”	Passage A2: “Lady Bug Makes New Friends”
P.1 It was spring, and it was time for Hoppy Rabbit to play outside. **P.2.** So she looked through a book for ideas of fun things to do in her garden. She learned that *palm tree leaves are used to make baskets*. **P.3.** So Hoppy decided to make a basket for herself. She sat down in her sunny garden and got to work! **P.4.** By the afternoon, Hoppy was finished with her project, and now she knew that *palm tree leaves are used to make baskets*.	**P.1.** Hoppy Rabbit and her friend Monkey were flying a kite in the park. But the kite got to close to a palm tree. **P.2.** “Look Hoppy,” said Monkey. “The kite is stuck in the palm tree leaves. *Palm tree leaves are called fronds*.” **P.3.** Monkey climbed to the top of the tree and freed the kite from the fronds. But then a gust of wind blew the kite away. **P.4.** The friends chased after the fly-away-kite. And now Hoppy Rabbit knew that *palm tree leaves are called fronds*.

Figure A1

Passage B1: “Traveling Lady Bug”	Passage B2: “Lady Bug Makes New Friends”
P.1 Speedy Plane was lost. So he landed to ask Armadillo for directions. “I’m looking for the Sahara,” said Speedy. **P.2.** Armadillo pointed to the map saying, “You can’t miss it, because *the Sahara is the largest desert in the world*!” **P.3.** Armadillo decided to ride with speedy the rest of the way to make sure he found it. **P.4.** When they landed the friends said goodbye. Speedy went off to explore. And now he knew that *the Sahara is the largest desert in the world*.	**P.1.** Speedy plane was in flight school. Today the class was studying the world. Speedy’s group chose to learn about continents. **P.2.** Everyone gathered some neat facts and pictures. Then the groups took turns sharing what they learned with the rest of the class. **P.3.** Speedy Plane’s group went first. Speedy stood up and said, “*The largest desert in the world is in Africa*.” **P.4.** It was the end of the school day and now Speedy Plane knew that *the largest desert in the world is in Africa*.

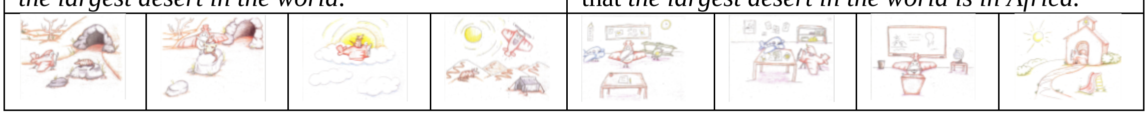

Figure A2

Passage C1: “Traveling Lady Bug”	Passage C2: “Lady Bug Makes New Friends”
P.1 As a ladybug slept one night a strong wind came and blew her out of bed. **P.2.** She woke up and found she was at sea. A dolphin came up and *said “hello”* to her by *clicking and squeaking*. **P.3.** Before the ladybug could say more than “hello,” the very strong wind blew again and she was swept back home. **P.4.** The ladybug didn’t get to play with the dolphin. But now she knew how *dolphins talk – by clicking and squeaking*.	**P.1.** One day, a ladybug went to the zoo so that she could make some new friends. **P.2.** At the zoo, she met some dolphins playing in the water. “Friendly dolphins,” she asked, “may I be part of your group?” **P.3.** The dolphins said, “We’d love to have you *join our pod*. But you’ll have to live in the water with us.” **P.4.** The ladybug shook her head and left to go home. But now she knew that a *group of dolphins was called a pod*.

Figure A3

Appendix B

Schematic Representation of Methods

Panel a: Schematic representation of Phase 1	
1. Passage A1 (e.g., *Hoppy Rabbit's Garden*) 2. Passage A2 (e.g., *Hoppy Rabbit Flies a Kite*) 3. Verbal Comprehension – Picture Vocabulary 4. Passage B1 (e.g., *Speedy Plane Loses His Way*) 5. Passage B2 (e.g., *Speedy Plane's School Project*) 6. Verbal Comprehension – Synonyms and Antonyms 7. Passage C1 (e.g., *The Traveling Ladybug*) 8. Passage C2 (e.g., *The Lonely Ladybug*) 9. Visual Matching Test	
Panel b: Schematic representation of Phase 2	
Stem-Prime Condition	No-Prime Condition
1. Stem fact recall 2. Open-ended self-derivation 3. Non-stem fact recall 4. Forced-choice self-derivation 5. Forced-choice stem fact recall 6. Forced-choice non-stem fact recall	1. Non-stem fact recall 2. Open-ended self-derivation 3. Stem fact recall 4. Forced-choice self-derivation 5. Forced-choice non-stem fact recall 6. Forced-choice stem fact recall

Appendix C

Sample Recall Questions

Panel a: Stem and Integration Fact Recall Questions		
Stem Fact 1	Stem Fact 2	Integration Facts
What are palm tree leaves used to make?	What are palm tree leaves called?	What are fronds used to make?
What is the name of the world's largest desert?	Where is world's largest desert located?	Where is the Sahara located?
How do dolphins talk?	What is a group of dolphins called?	How does a pod talk?

Panel b: Non-stem Facts Recall Questions	
Non-stem Fact 1	Non-stem Fact 2
Who read a book to get ideas for fun things to do in her garden?	Why did Monkey climb up the tree?
Who asked for directions because he was lost?	What type of school is Speedy Plane in?
Who was blown out of bed?	Why did the ladybug go to the zoo?