Distribution Agreement

Allison Carr March 16, 2016

Effects of Modality of Learning on Information Integration and Source Memory Judgments

by

Allison Carr

Patricia Bauer
Adviser

Neuroscience and Behavioral Biology

Patricia Bauer

Adviser

Joseph Manns

Committee Member

Barbara Strock

Committee Member

Leah Roesch

Committee Member

2016

Effects of Modality of Learning on Information Integration and Source Memory Judgments

By

Allison Carr

Patricia Bauer

Adviser

An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Sciences with Honors

Neuroscience and Behavioral Biology

2016

Abstract

Effects of Modality of Learning on Information Integration and Source Memory Judgments
By Allison Carr

The current study examined the effect of the modality of presentation of information on college students' ability to integrate that information to create knowledge they were not explicitly taught and the make judgments about the source of their knowledge. In two experiments, adults were presented with novel facts either visually or auditorily and asked to integrate those facts to form new information. No significant differences in integration ability were found between the different modality conditions, meaning that the modality of presentation of the facts did not appear to impact the integration process. This study also tested adults' awareness of their own memory processes by asking them to recall the modality in which they originally learned the different facts (i.e., source). Results revealed that adults who were aware of the modality of the facts and of the integration process itself were overall more successful in integrating information.

Keywords: knowledge integration, self-generation, modality, source, metacognition, learning

Effects of Modality of Learning on Information Integration and Source Memory Judgments

By

Allison Carr

Patricia Bauer

Adviser

A thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Sciences with Honors

Neuroscience and Behavioral Biology

2016

Acknowledgements

The authors thank Patricia Bauer for helping developing the protocol, Nicole Varga for the use of her stimuli, Jessica Dugan for assistance with data processing and analysis, and other members of the Memory at Emory laboratory for their help with various aspects of the research. The authors would also like to thank the Emory students who took part in the research.

Table of Contents

Effects of Modality of Learning on Information Integration and Source Memory Judgments

The process of learning involves gathering information in the environment and using this information to build a knowledge base. With an increased emphasis on improved learning with the goal of continued progress and innovation, examining how knowledge is collected is fundamental to understanding the learning process. In order to learn and make connections across pieces of knowledge, people are required to integrate information they learn in separate instances to create cohesive concepts and ideas. For example, school and college age students can make connections between what they hear in lecture and what they read while studying or in their textbooks. But this productive learning process is not limited to educational settings; knowledge learned in any setting can be integrated to generate new information. Current research shows that both children and adults can integrate information, but it does not address whether the factor of modality of learning impacts this ability. The current study specifically examined the effect of the modality of learning on the ability to create new information through integrating previously learned facts. It also examined how the modality of learning impacted later ability to identify the original modality in which a fact was learned.

A series of studies examining the ability to integrate previously learned facts to form new ones has termed this process *self-generation* (Bauer & San Souci, 2010). This ability has been empirically examined through teaching children or adults novel facts and then asking them questions requiring them to integrate these newly learned "stem facts" to provide a correct answer and self-generate a new "integration fact." For example, if a child receives one fact (the first of two stem facts) saying that "Dolphins travel in pods" and then receives another fact (the second stem fact) that tells them "Dolphins talk by clicking and squeaking," they can then integrate the two facts to self-generate the new integration fact "Pods talk by clicking and squeaking" that they were never explicitly taught before. Bauer and San Souci (2010) found that 6-year-old children were able to self-generate the integration fact when asked the open-ended question "How do pods talk?" and that children as young as 4 years old chose the correct answers in a multiple-choice question format. Four-year-old children have also been found to be able to retain both information that was explicitly taught to them (Baker-Ward, Gordon, Ornstein, Larus, & Clubb, 1993) and information that they self-generated (Varga, Stewart, & Bauer, in press) over delays of one week or more in time. This means that self-generated information can be both created and retained in the memory over time. Self-generation and integration of information has also been demonstrated in adults. Bauer and Jackson (2015) found that adults integrate novel facts to self-generate new knowledge, and that they then quickly incorporate this self-generated information into their current knowledge base.

Since the ability to self-generate information through integration plays a significant role in learning, it is important to examine factors that may affect this ability. Past research suggests that modality of learning may have an effect on memory for explicitly taught material, but no research to date has examined the effect of modality on information that is self-generated. Much of information is learned in different modalities or cross-modality, and past research shows that people's capacity to remember explicitly learned information may be dependent on the modality that the learning occurred in (visual or auditory). Research also shows that visual and auditory processing occurs in two separate neural pathways in the brain, called the *separate streams hypothesis*, which could explain differences in memory for information learned visually and auditorily (Penney & Butt, 1986). Many studies have found differences in memory for word lists presented either visually or auditorily, implying that the separate processing of visual and auditory information creates differences in people's ability to remember information (Brand & Jolles, 1985; Craik, 1969; Murdock & Walker, 1969). One study gave participants lists of words with mixed presentation modality, randomly presenting the words either visually or auditorily within each list (Murdock & Walker, 1969). The study found that memory for words presented auditorily was better than memory for words presented visually, but only for words presented toward the end of the word list. There was no difference in memory between words presented in the different modalities during the beginning and middle of the word lists. Two other studies examined memory for lists of digits presented visually or auditorily and came to the same conclusion - they found that memory for auditorily presented digits was better than visually presented digits for the digits that were most recently presented (Conrad & Hull, 1968; Margrain, 1967).

These results are consistent with literature on the *recency effect for auditory stimuli*, stating that auditory memory is superior for the most recently heard items (Gardiner, 1983). These results are also consistent with theories on *echoic memory* of auditory processing of information, which proposes that memory traces of sounds persist longer than *iconic memory* traces from processing of visual scenes (Carlson, 2010). In the case of these studies with word and digit lists, the recency effect for auditory stimuli explains why auditory memory was better for items at the end of the list as compared to the beginning and middle of the lists, and also why more auditory digits were recalled at the end of the lists than visual digits.

Another examination of the effect of modality on memory for explicitly taught information provided participants with lists of words presented either visually or auditorily and also asked them to generate words that either rhymed with or were related to the words provided (Penney, 2007). They were then tested for memory of both the originally presented words and the words that they generated themselves. In contrast to the previous studies, memory performance was found to be higher for the visually presented words and words that were generated from the visually presented words at all points within the word list. This result is inconsistent with previous knowledge on echoic memory and the distinctiveness of auditory stimuli in memory. This may be due to increased attention given to the words during the generation of a rhyming or related word, which could have improved memory for the visually presented words through using visual imagery (as compared to the superior auditory memory when memory was tested without the generation of a rhyming or related word). Overall, literature and theories on the impact of modality on memory for words and digits suggests that memory for facts presented either visually or auditorily will also be impacted by the modality of presentation, affecting the formation and memory of a knowledge base. Furthermore, these studies indicate that ability to integrate two facts would be impacted by the modality of presentation of each to-be-integrated fact, but this idea has not yet been tested.

Although past research on the effect of modality on memory for explicitly taught information had been conducted, there is limited research on the effect of modality on the ability to self-generate information from across learning episodes. The current study specifically examined the effect of modality on the ability to self-generate new information through integrating previously learned facts. Past research shows evidence that self-generation ability is impacted through changes to the structure and presentation of facts. By demonstrating factors that can affect self-generation of information, this research validates and motivates the current study's examination of the effects of learning modality on self-generation. Past studies has found that when separate episodes of learning have high surface similarity (meaning that they have a high degree of similarity), it is more likely that information from those episodes will be associated than when the episodes have low surface similarity. Literature on analogies has examined how the structure of information affects surface similarity through investigating analogical transfer of information and the ability to make logical inferences. Similarity across the structure of information presented in analogies has been found to facilitate analogical transfer better than when the information was presented without these structural clues (Spencer & Weisberg, 1986).

Other studies have demonstrated how structural similarity aids in making associations across information. One specific study had participants read a target passage, and then read other related passages while writing down pieces from the target passage's text that they were reminded of by cues in the subsequent passages (Wharton, Holyoak, Downing, Lange, Wickens, & Melz, 1994). Results found that when the wording and structure of the subsequent passages was more similar to the wording of the target passage, the participants more frequently made associations between the passages and wrote down more text from the target passage (as compared to when the wording and structure were dissimilar). In the context of the current study, the presentation of stem facts within the same modality may provide structural similarity that allows participants to more frequently make associations between the first and second stem fact, facilitating self-generation. Another study had participants read passages and then create possible solutions to problems presented within the passages (Holyoak & Koh, 1987). The passages either had a similar or dissimilar structure to one another, and they offered many opportunities to make inferences across the passages in order to create possible solutions. The results revealed that more solutions requiring inferential thinking were created when the passages had structural similarity than when they were dissimilar in structure. Together, these two studies demonstrate the importance of structural similarity in making associations across information.

Relating the concept of surface and structure similarity to the current study, past research has also examined specifically how surface similarity affects the self-generation process. In one study, children were read two separate story passages and were taught a fact from each one (Bauer, King, Larkina, Varga, & White, 2012). High surface similarity stories had the same main character in the story passages, providing a connection between the two passages, whereas the low surface similarity stories did not. Higher self-generation performance was observed in the high surface similarity condition (63% integration correct) as compared to the low surface similarity condition (37% integration correct). This literature on surface similarity and its effect on inferential thinking and information integration suggests that the modality of presentation of information may affect the strength of the association between two pieces of information. The presentation of facts within the same modality (as compared to cross-modality) may provide higher surface similarity that could improve integration performance. The parallel between the current study and past research on analogy and surface similarity implies that modality may alter the self-generation process. The current study specifically examined how presentation of the stem facts visually, auditorily, or across both modalities affected the ability to integrate information to self-generate new knowledge.

Another element of interest in the current study is awareness of one's own mental processes, or metacognition (Overschelde, 2008). The current paradigm presented facts in both the visual and auditory modalities, offering the opportunity to examine metacognition through investigation of how the participants thought they learned the information in question. Because of this, the current study examined meta-memory using a source question, which asked the participants the modality in which they thought each fact was learned (either visually, auditorily, or through self-generation) to further examine the role of modality in memory.

Past research on metacognition reveals that meta-memory (awareness of one's own memory processes) requires introspective monitoring of information coming in and maintenance of the newly acquired knowledge through mental review (Bahrick & Hall, 1991; Nelson & Narens, 1990). One past study asked participants' general information questions and found that participants were overall accurate in reporting their "feeling of knowledge" on whether they provided the correct answer, but in a report of confidence on their memory performance, participants were generally overconfident on the accuracy of their answers (Lichtenstein, Fischhoff, & Phillips, 1982). Another study examined the relation between awareness of mental processes and performance on a task involving transitive inferences (Smith & Squire, 2005). The study found that participants who were aware of the relations between items on the test were successfully able to make inferences, whereas participants who were unaware of the relations were unsuccessful. This relates to the concept of metacognition: when people are aware of their mental processes, they are better able to make logical inferences and associations between items.

The source question in the current study presented participants with either a stem fact that they learned previously or an integration fact created from the stem facts, and it then asked participants to report on how they thought they learned that fact (visually, auditorily, or through self-generation). This allowed participants the opportunity to report on their meta-memory, or their awareness of their own memory of receiving a fact visually or auditorily, and more importantly, of their awareness that they integrated information to self-generate new facts. In the current study, looking at metacognition and meta-memory during tests of self-generation of facts could reveal the mental processes occurring during the integration and retrieval processes, and the level of awareness of these processes.

Episodic memory, or "conscious memory for everyday events," is required for memory of the source in which something is learned because this type of memory involves recalling the specific episode or instance of learning (Tulving, 1983). Through the source question, the current study assessed whether successful self-generation of facts was facilitated by the episodic memory of the source in which the to-be-integrated facts were learned. In one study that examined memory for facts and the sources they were learned from, older adults were shown to have impaired fact memory and source memory, whereas younger adults had higher performance in both fact and source memory (Spencer & Raz, 1994). This implies that memory for the episode of learning a fact is correlated with memory for the fact itself. In the current study, this would mean that if participants successfully recalled the episode of learning (correctly identified the modality in which they learned a stem fact), they should be better able to remember each stem fact. Logically, better memory of the sources in which stem facts were learned would also increase the possibility that the facts would be combined to self-generate the new integration fact. The current study examined this possibility that retention of the source information was correlated with higher performance on the integration test.

Other research suggests that memory for individual facts may separate from their episodes of learning and become independent entities in memory, called sematic memory. This has been defined as more general information for facts and ideas, disconnected from a personally experienced event (Tulving, 2002). If this were the case, semantic memory for a fact would become independent of the episodic context that the fact was learned in (Tulving, 2002). In the context of self-generating information through integration, memory for the source (modality) of to-be-integrated facts would be necessary for integration only if memory of the episode of learning is necessary for the semantic memory of the facts. If not, then the semantic memory of the facts should be accessible for integration even without clear memory of their source.

The current research included two experiments, each consisting of three components – a presentation phase, an integration test phase, and a source test phase. During the presentation phase, the stem facts were presented to participants in either the visual or auditory modality. During the integration test, participants were asked questions that required them to integrate information in order to provide a correct answer, and during the source test, participants were asked to recall the source in which they learned both the stem facts and the integration facts. The purpose of the current research was to examine how modality affects ability to integrate information across and within modalities, and whether metacognition plays a role in this integration ability.

Since information is learned in different modalities, examining the ability to integrate information across episodes and modalities is important to gaining an understanding of how people build a knowledge base. Having a comprehensive understanding of these processes can be achieved through examining how successfully information can be integrated across or within the visual and auditory modalities, how connected these integrated facts are to their sources and original episodes of learning, and awareness of memory processes while integrating information in different modalities. These results could have classroom applications through aiding in design of a curriculum that facilitates information recall and integration in the visually modality, auditorily modality, and across both modalities.

Experiment 1

Methods

Participants

Participants were 28 Emory University undergraduate students who were 18 years of age or older and whose native language is English. There were 18 females and 10 males. Based on self-report, the participants were 50.0% White or Caucasian, 46.5% Asian, and 3.5% did not report (ethnic makeup 93.0% not Hispanic or Latino, 3.5% Hispanic or Latino, and 3.5% did not report). There was no participant attrition. Participants were recruited from the introductory psychology classes at Emory University, and the students signed up for the study online. They received class credit for completing the study. Upon entering the lab, each participant read and signed an informed consent and filled out a demographic information questionnaire and a participant questionnaire. Each participant session lasted approximately 1 hour. All procedures were reviewed and approved by the Emory University Institutional Review Board.

Stimuli

The study included 56 facts, called "stem facts," broken down into pairs of facts (28 total pairs) that were integratable to form "integration facts." Similar to the dolphin example that was used in studies with children, this study utilized stem facts such as "The dilation of the pupil is called mydriasis" and "Stress can often cause mydriasis," that could then be combined to form the integration fact "The dilation of the pupil can be caused by stress." Each fact was between 5 and 10 words long.

Procedure

Presentation Phase. Each participant came into the lab for approximately one hour and was given 56 novel facts in PowerPoint presentations on a computer screen. Participants were told that the purpose of the study was to examine memory for different types of facts. Before beginning the task, participants were instructed that they would be asked a question after the presentation of each fact about the school subject that the fact belonged in, and that they could provide an answer by choosing a key on the keyboard. They were also informed that they would be given a memory test on the facts in a few minutes.

As in past studies on self-generation, the integration fact was never directly presented; only the stem facts were presented during this phase of the study, providing the participant with enough information to self-generate the integration fact. The facts were presented either through an auditory recording or through a sentence read one word at a time on a computer screen. The stem facts within a fact pair were presented in one of four conditions: both facts presented visually, both facts presented auditorily, or one fact presented in each modality. The four conditions are displayed in Table 1.

After the presentation of each fact, the participants were asked to choose which subject domain in school each fact belonged in. They could choose between “science,” “art,” “history,” and “other” options. The purpose of this question was to ensure that the participants were attentive and actively encoding and processing each fact for the memory test later. After the participants received all 56 facts, they completed a buffer activity lasting approximately 10 minutes before moving on to the test phase.

The visual and auditory facts were presented for an amount of time proportional to the number of words in the fact, so that each fact was either read on a screen or heard in an audio recording for approximately 4 seconds. There were two to four facts separating each stem within a pair. The order of facts was counterbalanced across participants so each fact was presented to the participants at different points within the presentation of the facts and in all four conditions. Each fact also appeared in the first, second, and last third of the presentation an approximately equal number of times across participants.

Integration Fact Test Phase. After the participants received all 56 facts and completed the 10 minute buffer activity, they moved on to the test phase. There were two parts to the test phase of the study: an integration fact test and a stem fact test. During the integration test, the participants received all of the integration facts with a blank at the end of each sentence prompting them to verbally give the experimenter a word to the complete the sentence. This tested the participant's ability to integrate the two stem facts to self-generate the integration fact. Continuing with the example above, the participants would be asked "Pupil dilation can occur due to _____" and the correct answer would be "stress." After each integration test question, the participants were asked two additional questions about their responses to the integration question. The first question was a source question asking the participant how they thought they learned each fact. They were able to choose from a list of answers that included the options that they learned the fact visually, auditorily, or through both modalities (indicating that they believe that they used information from both modalities to answer the question). As stated before, the purpose of this question was to test whether the participants connected the memory of the integration fact back to the episode of learning the stem facts by recalling whether they read the facts, heard them aloud, or used both modalities to answer the integration question.

After the source question, participants were asked how confident they were on the source judgment they just made. Participants reported that they either had low, moderate, or high confidence in their source judgment on the modality each fact was learned. The purpose of this question was to verify that the participants were not guessing for the majority of the source test (evidenced by many "low confidence" answers), and confidence rating were not analyzed in the results. The source and confidence questions were repeated after each integration fact test question, and then the participants moved on to the next fact.

Across participants, the integration fact questions were presented in one of four counterbalanced orders. These questions were given to the participants either auditorily or visually (they either heard or read each integration question, source question, and confidence rating question) on a PowerPoint presentation. A specific participant received the questions either all visually or all auditorily, but not in mixed modalities. The experimenter recorded all participant answers after each question. A list of acceptable answers was decided upon before the beginning of the experiment to clarify whether ambiguous answers would be accepted as correct.

Stem Fact Test Phase .The second part of the test phase examined memory for the stem facts that participants were explicitly taught in the initial phase of the study. Because of the large amount of novel information the participants received, there was no explicit memory test for each of the 56 individual facts (as in the integration fact test phase), but the participants were still tested on their source memory for each fact. In this phase of the study, participants received each full stem fact again (like at the beginning of the study), and were then asked the same two questions as after each fact during the integration source test (source judgment on how they learned the fact and how confident they were in that judgment). This part of the test phase revisited the initially presented stem facts and tested whether participants remembered the episode of learning each stem fact. As in the integration test, participants received the source and confidence questions either all visually or all auditorily, but not in mixed modalities. Once again, participant answers were recorded after each question. At the conclusion of this test phase, participants left the lab.

Results

The purpose of the main manipulation of the current study was to examine the effect of the modality of presentation of the stem facts on self-generation performance. A one-way repeated measures ANOVA with four levels of modality condition revealed no significant effect of presentation modality on self-generation performance ($F(3, 25) = 2.345$, $p = .079$). The means for performance on the integration test are displayed in Table 2, separated by condition. The means are out of a total of 7 possible correct answers per condition.

The source test measured participants' knowledge of how they thought they learned both the stem facts and the integration facts. Descriptive statistics for the source test performance for the integration facts is displayed in Table 2. The means are out of a total of 7 possible correct answers for each condition. An answer on the integration fact source test was counted correct if the participant correctly identified the modality of the stem facts that formed the integration fact; in the visual-visual condition the correct answer would be "visual," in the auditory-auditory condition the correct answer would be "auditory," and in either of the mixed-modality conditions the correct answer would be "both modalities." A one-way repeated measures ANOVA with four levels of modality condition revealed a significant difference in performance on the integration source test between conditions ($F(3, 25) = 19.015$, $p = .000$). Pairwise comparisons showed that source memory for integration facts learned in the visual and auditory conditions ($M = 4.18$ ($SD = 1.36$) and $M = 3.79$ ($SD = 1.69$)) did not differ and that both were significantly higher (at a level of $p < .05$) than the visual-auditory and auditory-visual mixed conditions ($M = 1.93$ ($SD = 2.02$) and $M = 1.43$ ($SD = 1.40$)). The visual-auditory and auditory-visual conditions did not significantly differ from each other.

The relation between performance on the test for self-generation and correct identification of the source of the integration facts was also examined using a Pearson correlation. There was a positive correlation in performance on the two tests in the visual-auditory condition only ($r(27) = .46$, $p = .01$). Correlations for all other modality conditions were not significant. Correlation values are displayed in Table 3.

The stem facts were also examined for memory of the source in which each fact was learned. Descriptive statistics for source performance for Stem Fact 1, Stem Fact 2, Total Stem Source performance (sum of Stem Fact 1 and Stem Fact 2 performance), and Both Stems Source (trials where sources for both stem facts within a pair were identified correctly) are presented in Table 2. The means for Stem Fact 1, Stem Fact 2, and Both Stems Source are out of a total of 7 possible correct answers per condition, and the Total Stem Source performance is out of 14 possible correct answers per condition. A correct answer was earned through correctly identifying the source in which a stem fact was learned (visual or auditory) during the presentation phase. A 4 X 2 ANOVA (with four levels of modality condition and two levels of stem fact) revealed a significant main effect of modality condition ($F(3, 25) = 6.139$, $p = .001$). Pairwise comparisons showed that the auditory condition ($M = 10.21$ ($SD = 2.67$)) had significantly higher performance (at a level of $p < .05$) on the stem fact source test than both the visual-auditory and auditory-visual mixed conditions ($M = 8.25$ ($SD = 2.15$) and $M = 7.93$ ($SD = 2.19$)). The visual-visual condition did not have significantly different performance than any other condition. Overall, differences between modality conditions consisted of overall higher performance in the single modality (auditory) condition than the mixed modality conditions. The 4 X 2 ANOVA also revealed no main effect of stem fact ($F(1, 27) = .189$, $p = .67$), and no significant interaction was found ($F(3, 25) = 1.89$, $p = .14$). This means that the main effect of modality did not differ between Stem Fact 1 and Stem Fact 2.

The stem fact source performance was also examined in relation to performance on the integration test to observe whether retention of the source of the stem facts was associated with successful integration. Total source performance across all conditions for Stem Fact 1, Stem Fact 2, Total Stem Source (sum of Stem Fact 1 and Stem Fact 2 performance), and Both Stems

Source (trials where sources for both stem facts within a pair were identified correctly) was examined in relation to performance on the integration test using Pearson correlations. Only source performance for Stem Fact 1 was significantly associated with integration test performance ($r(27) = .38$, $p = .045$). The correlation between the Both Stems Source measure of source performance and integration test performance was also marginally significant ($r(27) = .37$ $p = .05$). None of the other measures of source performance were significantly associated with successful integration. Correlation values are displayed in Table 4.

Discussion

The main purpose of the current study was to examine the effect of modality on college students' ability to integrate information learned in separate instances to self-generate new knowledge. This was measured through presenting students' with pairs of facts that could be integrated visually, auditorily, or across both modalities. Performance on an integration test, which required the participants to integrate each pair of facts to correctly answer each question, was then assessed across these conditions. No significant differences in performance on this test were found across conditions. More specifically, this means that the total integration test performance did not differ depending on the modality of presentation of the stem facts. The visually and auditorily learned facts were integrated with similar levels of success, and, more importantly, whether a pair of facts was learned within a single modality or across modalities also did not appear to impact integration performance. This finding contradicts past research on surface similarity and analogy, which postulates that when two items are more similar, it is more likely that an association will be made between them than when they are dissimilar. In the context of this study, two facts presented in the same modality would have higher surface similarity and would be more likely to be associated and integrated than two facts presented in different modalities. This expected trend was not observed in the integration test results.

These results imply that modality does not have a strong effect on integration performance. Alternate explanations to the observed results could be that the time gap between the presentation phase and the integration test phase (approximately 10-15 minutes) was not a large enough gap in time to bring out any differences in memory for facts that were presented visually and auditorily. It could be the case that over such a short time gap, memory for the original stem facts was high in both modalities, so no effect of modality on integration performance was observed.

Another temporal issue could be the shortness of the time gap between the presentations of each fact within a pair. Each pair of facts was separated by only two to four facts, taking on average about 20 to 30 seconds, which may have facilitated awareness of the relatedness of two stem facts in a pair. This short time span may conceal any effect of modality through enabling participants to observe the connection between two stem facts regardless of the modality, which could improve later memory for the stem facts and self-generation of the integration fact. Past literature reveals that within a short time span of 20 to 30 seconds, information is retained within working memory, which is maintained through mental rehearsal of information in the prefrontal cortex (Baddelley & Hitch, 1974). If the short time span between the presentations of the two stem facts allowed both of the facts to be kept in working memory, this may have facilitated integration regardless of the modality in which the facts were learned. Although this was a large volume of information to keep available in working memory, in the present research the facts were meaningful and educationally relevant; this could have improved memory for these facts, particularly when memory for the first stem fact was cued by the presentation of the second stem fact 20 to 30 seconds later.

A secondary goal of the current study was to examine the role of metacognition and meta-memory in performance on the integration test. Meta-memory was measured by performance on the source tests, which asked participants to reflect on the episode of learning each fact to report the modality in which each stem and integration fact was learned. Participants were instructed to report that they learned each fact visually, auditorily, or through both modalities. The results from the integration facts on the source test cannot be interpreted without further study; the lack of clarity in the answer choices on the source test in Experiment 1, which eventually led to the creation of Experiment 2, may have had an effect on participant performance.

The issue with the source question was its ambiguous interpretation; although the source question revealed information about what modality or modalities the participants thought they learned the facts in, it did not reveal anything about whether the participants were aware they were self-generating the facts. The first two answer choices ("visually" and "auditorily") *could* imply a conscious integration of two visually or auditorily presented facts, but they also may only reflect a familiarity with the stem facts presented in those modalities without any awareness of integration. The source question does not provide a distinction, so there is no clear interpretation. The "both modalities" answer choice implies that two pieces of information were used (one in each modality) to create the integration fact, but it still does not fully distinguish whether the participant is aware that they are self-generating or if they just chose this answer choice because they recollected receiving pieces of the fact from stem facts in both modalities. For this reason, the source test data for the integration facts in Experiment 1 cannot be interpreted. Experiment 2 was created with revised answer choices for the source question, which clarified when facts were learned explicitly in one modality versus when they were self-generated through combining facts from one or more modalities.

Although there was ambiguity introduced by the protocol on the integration source test, the stem fact source test data was not impacted. Differences in performance between modality conditions were observed on the stem fact source test, with the auditory condition having higher source performance than the visual-auditory and auditory-visual conditions. In other words, the auditory single modality condition had higher performance than the mixed modality conditions. This means that when both auditory stem facts (combined to make an integration fact) were learned in the same modality, participants were better able to correctly identify the source in which they learned each stem fact. This is consistent with literature on surface similarity, which proposes that a stronger association is formed between information that is more related. The stem facts in the same modality could have been seen as more related, aiding in the recall of the source for each fact. The same effect was observed for the integration fact source test, although, as stated previously, this cannot be confirmed because of ambiguity in the answer choices on the source question.

The current study also examined metacognition through the stem fact source test. Logically, memory for the source of the stem facts would increase the probability that the stem facts would be combined to self-generate the integration fact. However, since direct recall of the stem facts was not tested and stem fact source performance is not necessarily a direct predictor of integration performance, we cannot say for sure that retention of the source of the stem facts is imperative for integration. Whether memory for the source of the stem facts is important is dependent on whether the episode of learning the stem fact is retained (including the source in which the stem fact was learned in), or whether the fact itself becomes separated from its episodic details. Overall, the results indicated the stem fact source memory was not associated with integration performance, implying that the facts were retained in semantic memory, making them accessible for integration even without memory of their source. The source of the stem facts was not important for integration. The results also indicated that performance on the source test for Stem Fact 1 was significantly associated with integration performance; this is contradictory to the other measures of stem fact performance and could be the result of participants having superior memory for the first stem fact in a pair before they are overloaded with information after being presented with the second stem fact. The marginally significant correlation on the Both Stems Source measure of stem fact performance could also be explained by the possibility of superior memory for the source of the first stem fact, since this measure required the sources of both stem facts to be correctly identified. Overall, these results do not show strong evidence that stem fact source information is related to self-generation.

Experiment 2

Methods

Participants

Participants were 20 Emory University undergraduates that are 18 years of age or older and who learned English as their native language. There were an equal number of females and males (10 of each). Based on self-report, the participants were 40.0% White or Caucasian, 35.0% Asian, 15.0 % Black or African American, 5.0% American Indian or Alaskan Native, and 5.0% did not report (ethnic makeup 90.0% not Hispanic or Latino, 5.0% Hispanic or Latino, and 5.0% did not report). There was no participant attrition. Participants were recruited, consented, and given class credit through the same procedures as in Experiment 1. None of the participants had taken part in Experiment 1. Each participant session lasted approximately 1 hour. All procedures were reviewed and approved by the Emory University Institutional Review Board.

Stimuli

The stimuli were the same 56 stem facts were used in Experiment 1.

Procedure

Presentation Phase The presentation of the stem facts was the same as in Experiment 1, using the same PowerPoint presentations and counterbalancing.

Integration Fact Test Phase In this experiment, the integration fact questions were asked with the same methodology as in Experiment 1. However, unlike Experiment 1, the source and confidence questions about each fact were not asked at this point, so the integration questions were asked one directly after another. This change in the protocol was made to avoid the potential issue of the source questions hinting to the participants early in the integration test that some of the facts were self-generated, which could then facilitate self-generation performance later on in the test. Integration questions were presented either all visually or all auditorily on computer PowerPoint presentations in the same open-ended structure as Experiment 1, where the participants filled in the blank, self-generating the answer. The same test order counterbalancing was used.

Mixed Source Test Phase After the integration fact questions, source and confidence questions were asked for 112 different facts in a separate PowerPoint. These facts included the 56 previously presented stem facts, the 28 integration facts, and 28 novel facts that the participants had never seen or heard before. These novel facts were added in an attempt to see if participants could accurately identify the source of each fact (novel, stem, and integration facts), and to reduce the chances that participants would report learning a stem or integration fact correctly by chance through the addition of more answer choices. Each fact was read aloud to the participants in an audio recording, and then the source question was displayed visually on a computer screen. To address the shortcomings in the source question of Experiment 1, participants were given 5 clearly defined answer choices. Detailed explanations of the five answer choices are displayed in the Table 5. For each source question, participants were asked how they learned the fact they just heard and told to choose from the following answer choices: they learned the fact visually, they learned the fact auditorily, they self-generated the fact, the fact was new knowledge to them, or the fact was something they already knew. The source questions in this experiment attempted to clarify whether the participants were aware of when they were self-generating information from within the same modality or across modalities, as opposed to thinking that they learned that fact explicitly in the visual modality, auditory modality, or in both modalities.

Novel facts were used as a contrast to the stem and integration facts that the participants had explicitly learned or could self-generate, and also so the answer choice “New knowledge” would be correct approximately as often as the other answer choices. To help participants understand the idea of self-generation without explicitly explaining that they were combining facts, each participant was given the following example: “If you’re painting and want to use green paint but only have yellow and blue, you can combine those together to self-generate the green paint.”

Participants verbally gave their answers to the source questions, and then read the same confidence question as in Experiment 1 on the computer screen. They reported that they had low, moderate, or high confidence in the source judgment they just made. Once again, the confidence ratings were used to ensure that participants were not guessing on the source test, and they were not analyzed with the data. Participant answers were recorded after each question. All facts were counterbalanced throughout the source and confidence tests so the participants could not predict whether a stem fact, integration fact, or new fact would come next. At the conclusion of this test phase, participants left the lab.

Results

The main manipulation of the effect of modality of presentation of facts on integration ability yielded the same result as Experiment 1. That is, a one-way repeated measures ANOVA with four levels of modality condition yielded no significant differences in self-generation performance between conditions ($F(3, 17) = 2.074$, $p = .114$). The means for performance on the integration test are displayed in Table 6, separated by condition. The means are out of a total of 7 possible correct answers per condition. The manipulation of the effect of modality on self-generation ability was replicated from Experiment 1 to Experiment 2.

Descriptive statistics for performance on the source test for the integration facts is reported in Table 6. The means are out of a total of 7 possible correct answers for each condition. An answer on the integration fact source test was scored as correct if the participant identified that they self-generated the answer through choosing the "self-generated" answer choice. A one-way repeated measures ANOVA with four levels of modality condition yielded no significant differences in integration source test performance between conditions ($F(3, 17) = .907$, $p = .443$). This means that there were no differences in ability to identify the integrated facts as self-generated across all modality conditions.

Like in Experiment 1, the relation between performance on the integration test and correct identification of the source of the integration facts was also examined using a Pearson correlation. Correlation values are displayed in Table 7. Overall, self-generation performance and judgments on the source tests were positively correlated for the visual-visual ($r(19) = .66$, $p = .001$), visual-auditory ($r(19) = .64$, $p = .002$), and auditory-visual ($r(19) = .63$, $p = .003$) conditions. There was also a marginally significant correlation on the auditory-auditory condition ($r(19) = .44$, $p = .053$). This means that there was an association between performance on the integration test and identification of the integration facts as self-generated. Descriptive statistics on participants' answer choices on the integration source test are displayed in Table 9, and descriptive statistics on participants' reports of their confidence rating for the integration source test are displayed in Table 10. Further examination of when participants correctly answered both the integration fact and source questions showed that of the correctly answered integration fact questions, participants also correctly identified the source of those facts as self-generated an average 13.4% of the time (ranging from 0% to 57.1%).

The source test also collected data on the modality through which participants thought they learned the stem facts. Descriptive statistics for source performance for Stem Fact 1, Stem Fact 2, Stem Fact 2, the Total Stem Source (sum of Stem Fact 1 and Stem Fact 2 performance), and Both Stems Source (trials where sources for both stem facts within a pair were identified correctly) are presented in Table 6. The means for Stem Fact 1, Stem Fact 2, and Both Stems Source are out of a total of 7 possible correct answers per condition, and the Total Stem Source performance is out of 14 possible correct answers per condition. A correct answer was earned through correctly identifying the source in which a stem fact was learned (visual or auditory) during the presentation phase. Descriptive statistics on participants' reports of their confidence rating for the stem fact source test are displayed in Table 10. A 4 X 2 ANOVA (with four levels of modality condition and two levels of stem fact) revealed no main effect of modality condition ($F(3, 17) = 2.10$ $p = .11$), no main effect of stem fact ($F(1, 19) = 2.31$, $p = .15$), and no significant interaction ($F(3, 17) = .67$, $p = .57$). This means that, in contrast to Experiment 1, no differences in stem fact source performance were found between modality conditions, and that this was consistent for both Stem Fact 1 and Stem Fact 2.

The stem fact source performance was also examined in relation to performance on the integration test to observe whether retention of the source of the stem facts was associated with successful integration. Total source performance across all conditions for Stem Fact 1, Stem Fact 2, Total Stem Source (sum of Stem Fact 1 and Stem Fact 2 performance), and Both Stems Source (trials where sources for both stem facts within a pair were identified correctly) was examined in relation to performance on the integration test using Pearson correlations. Correlation values are displayed in Table 8. None of these measures of source performance were significantly associated with performance on the integration test.

An analysis of performance on the source test for the 28 novel facts showed that participants were overall successful in identifying these facts as new information. In Experiment 2, an average of 24.5 ($SD = 2.9$) out of 28 of the novel facts were correctly identified as new (87.5% accuracy). There was no significant correlation found between the number of new facts correctly identified and the overall performance on the integration test ($r(19) = .342$, $p = .140$).

Discussion

This main manipulation of this experiment examined the effects of modality on ability to integrate information. Like in Experiment 1, there were no significant differences in integration performance found between the different modality conditions. This result implies that modality does not have a significant effect on integration performance. Since the protocol for this portion of the experiment is the same as Experiment 1, the alternate explanations to this result are the same.

A secondary goal of the current study was to examine the role of metacognition and meta-memory in performance on the integration test. This was measured through performance on the source test, which in this experiment asked participants to report that they learned the stem or integration facts visually, auditorily, through self-generation, that they fact was new knowledge, or that they already knew the fact prior to coming into the lab. In contrast to Experiment 1, no differences in performance on the stem fact and integration source questions were found between modality conditions on any of the source tests. Participants identified the source of the stem facts equally well across all conditions, and they also accurately reported that they self-generated the integration facts equally well across all conditions. This means that the modality in which a fact was learned had no effect on whether participants were able to recall the episode of learning the fact and correctly report the source in which the fact was learned. Even when two stem facts within a pair were learned across the visual and auditory modalities, participants were equally successful in naming the modality in which each individual fact was learned.

The revised answer choices used in Experiment 2 also clarified how participants should report that they were aware when a fact was formed by integrating two stem fact through providing a the “self-generated” answer choice. This clearly defined that the integration facts were formed through a combination of stem facts, separating out participants who were unaware of the integration process and may have chosen an answer to the source question arbitrarily or through mistaking the integration fact for one of the stem facts. Across all 4 modality conditions, participants were equally successful on the source test in identifying facts that were self-generated, on average identifying that they self-generated 8.1 out 28 of the integration facts on the source test.

Experiment 2 also found a different result than Experiment 1 when examining the association between performance on the integration test in each condition and performance on the source test for the integration facts on the visual-visual, visual-auditory, and auditory-visual conditions, and a marginally significant association on the auditory-auditory condition. These significant correlations indicate that a conscious awareness of the integration process facilitates successful self-generation on the integration test. In other words, when participants had better performance on the integration test, they also correctly identified that they self-generated a larger number of integration facts on the source test. This result is consistent with the findings of Smith and Squire (2005), who discovered that participants who were aware of the association between items on a transitive inference task were more successful in making inferences. It is also consistent with literature on the importance of episodic memory (in this context of this study, conscious awareness of how a fact was learned) to semantic memory (correct answers on the integration test). Performance on the integration test was higher when the episodic details (learning through integrating two stem facts) were recalled. Overall, these results support the idea that increased metacognitive awareness of the relation between items on tasks involving inferential or analogical thinking leads to higher performance on the task. Metacognition, and in the case of the current study, meta-memory, can have a facilitative effect on performance on this integration task through awareness of the relatedness of the stem facts and of the integration process.

Metacognition was also examined through the stem fact source test. As in Experiment 1, the results overall indicated that the stem fact source memory was not associated with integration performance. This is particularly interesting in this experiment since the results of the integration source test suggest the opposite; those results indicate that awareness of the self-generation process (through correctly identifying an integration fact as self-generated on the source test) is associated with higher performance on the integration test.

One of changes to the source test in Experiment 2 added an additional 28 novel facts to the source test. Participants were overall successful in identifying the novel facts as new information. Even though there was a wide range in performance on the integration test (ranging from 2 to 20 correct out of a total of 28 possible correct answers), participants were consistently good at identifying the novel facts, with an average of 24.5 correct answers. To further illustrate this point, both the lowest and highest scores on the integration test correctly identified the same number of novel facts as new information (26 correct answers out of 28). This result demonstrates that ability to identify when a piece of information is new knowledge is independent from ability to identify when information is being integrated. To further support this, there was no correlation between performance on the integration test and ability to correctly identify novel facts in the source test. The high performance on novel fact identification even in participants who had low performance on the integration test also confirms that this low performance was not due to a complete lack of attention. These participants were paying enough attention to correctly identify the novel facts, verifying that they were mentally present during the presentation phase.

General Discussion

The main purpose of the current study was to examine the effect of modality on college students' ability to integrate information learned in separate instances to self-generate new knowledge. Neither experiment found significant differences in performance on the integration test between modality conditions. In contrast to past studies on surface similarity that altered more major elements in their manipulations, the current study only changed the modality in which facts were learned. This manipulation may not have been strong enough to elicit a difference in performance between modality conditions. For example, Bauer *et al.* (2012) changed the characters in story passages read to children, and Smith, Glenburg, and Bjork (1978) changed the physical location in which their study took place. Both of these are stronger manipulations that more significantly impacted the observed results. The idea that manipulating modality has less impact on surface similarity would explain the consistent performance across modality conditions on the integration test in both experiments, and also the consistent performance in the source tests in Experiment 2.

A secondary purpose of the current study was to examine the role of metacognition and meta-memory in ability to integrate information. Experiment 1 was unsuccessful in measuring participants' awareness of the source in which they learned the integration facts, so Experiment 2 was created to accurately measure this. The differences in performance on the integration source test from Experiment 1 to Experiment 2 with the change in instructions confirms that the lack of clarity in the answer choices in Experiment 1 may have created a false effect in the source tests (particularly the integration source test) that was not replicated in Experiment 2. Overall, the Experiment 2 results revealed no differences in source performance across modality conditions, which is consistent with absence of condition differences on the integration fact test. Experiment 2 also found that participants who knew that a fact was formed through self-generation were overall more successful on the integration test. This supports the importance of meta-memory in memory performance on tasks like the integration test.

The importance of the source in which a fact was learned to the self-generation of information differed between the integration and stem facts. Awareness of the source of the integration fact was associated with self-generation, whereas memory for the source of the stem facts did not appear important to the self-generation process. This emphasized a distinction in the importance of meta-memory to self-generation: when information was learned explicitly, the episodic details (source) in which it was learned were not important to self-generation, whereas when information was created through self-generation, the episodic details were linked to the integrated fact and were important for successful integration.

Limitations

The purpose of the current research was to examine how individuals build a knowledge base. Information is learned explicitly through multiple modalities, and it is also formed through integrating information across learning episodes. This study looked at how modality affects this learning through integration. A major limitation of this study is its ecological validity when the paradigm is translated to a different environment. More specifically, the current study involves participants learning novel facts in a single session over a short time span. Realistically, information that can be integrated is learned in a variety of different settings across different time spans. For example, a student could hear a piece of information on Monday in lecture, and then on Thursday they could read a related piece of information in their textbook while sitting in their kitchen. This example has both a difference in context (lecture hall vs. kitchen) in which the two to-be-integrated facts were learned, and it also has a three-day time span over which the learning occurred. Both of these factors are different than the conditions that the participants experienced in the current study, and they will vary by person and with each episode of learning. The results of the current study may be applicable only to the specific time span and context that the study occurred in. Differences in integration performance between learning modalities may emerge depending on whether to-be-integrated facts were learned in the same or different contexts, or based on how long the delay in time is between the learning of each fact. Because of this, the results of the current study are informative, but not necessarily generalizable to all situations in which learning occurs.

Another limitation of the current study was the large degree of variability in performance on the integration test across participants. The distribution of integration test scores is displayed in Table 11, with scores ranging from 1 to 27 out of 28 total integration questions correct across both experiments. Low performance was an issue because it meant that there were few data points to be considered for the source memory tests. The lower number of correct answers also made it difficult to gather enough data to compare across the four different modality presentation conditions. Having more correct data points for these participants could cause the emergence of a trend in performance that may have been masked by the lack of correctly answered integration questions by some participants.

Another possible limitation to the study involves consistency in the time of day and time within the semester that each participant session was run. Due to scheduling conflicts with participants, participant sessions for both experiments occurred at different times in the day, ranging from mid-afternoon to later in the evening. The sessions also took place over many months over the course of a semester. This study did not control for differences in the times and dates that each session took place, so these factors could have had an effect on participant performance due to fatigue or lessened focus at certain times of the day or within the semester.

Lastly, another limitation of the current study was the specific and unique characteristics of the sample of participants in this study. All participants were Emory University undergraduates, who generally have high ability and are highly achievement driven. Because of this, results may not be reflective of integration performance across the general population. That said, even with this specific group of students, the high variability observed in performance on the integration test suggests that the sample may not be skewed from the capabilities of the population as a whole.

Future Directions

To attempt to both bridge the gaps caused by the limitations of the current and to build upon these findings, many relevant future studies stem from the current findings. To improve the ecological validity of this study, future studies could work with a similar paradigm manipulating the modality in which to-be-integrated facts were learned, but they could alter the time and context in which the learning occurred. For example, participants could be given facts to read at home or an audio recording to listen to at home. They could be instructed to read or listen to these stem facts after different delays in time, and they could then come into the lab a specified amount of time later to learn the second stem fact and be given the integration test. This could address the issue of how time affects integration across and within modalities. Adding the component of learning in both the home and lab environments would also address how learning in different contexts effects integration.

To provide further experimental control, the study could be repeated with more consistency given to when the participant sessions took place. For example, the sessions could all occur in the afternoon when participants are not as tired, or they could occur at roughly the same time within the semester to reduce differences in participant performance caused by environmental factors. These measures could also improve participant performance, helping to eliminate the limitation of the study due to low overall integration performance.

A new future experiment could further elucidate the differences between visual and auditory integration of facts through the use of EEG or other neuroimaging tools. One study used MEG to examine the process of integrating memories through logical inference and found that knowledge integration requires changes to the neural oscillations between the medial prefrontal cortex (mPFC) and the hippocampus (Backus, Schoffelen, Szebenyi, Hanslmayr, & Doeller, 2016). In the context of the current study, changes and activations of this pathway or other neural pathways could differ based on the modality that the information is encoded in. For example, the neural oscillations may be different when two facts are learned visually and integrated than when one fact is learned visually and the other auditorily. A future study could examine the neural basis of differences in integration due to the modality of presentation.

Another future line of research could further examine the role of metacognition and meta-memory in information integration through examining how participants' awareness of the integration process confers benefits for subsequent memory for the integrated information after a delay in time. Past research has found that self-generation improves memory for previously known knowledge after a one-week delay, but the impact of a conscious integration process has not been specifically examined (Slamecka & Graff, 1978). This research could also examine whether these facts that were self-generated remain attached to their episode of learning over time (whether participants can continue to identify those facts as self-generated) or if the episodic details are eventually lost.

Conclusion

In conclusion, the current study successfully introduced research on the effects of modality on ability to integrate information. It took important steps in examining a factor that could impact self-generation, affecting how people build a knowledge base. Although the current study did not discover a significant difference in self-generation ability based on the modality of presentation of the stem facts, it set the stage for future studies that further pull apart the relationship between integration and modality. The current study also opened up a line of research into the impact of metacognition and meta-memory on self-generation. Different manipulations with improved ecological validity could provide new information on the relationship between modality, metacognition, and self-generation.

References

Backus, A.R., Schoffelen, J., Szebenyi, S., Hanslmayr, S., Doeller, C.F. (2016). Hippocampal-prefrontal theta oscillations support memory integration. *Current Biology,* 26 (4), 450-457.

Baddeley, A. & Hitch, G. (1974). Working Memory. In Bower, G.H. (Ed.), *The Psychology of Learning and Motivation* (47-87). New York, New York: Academic Press, Inc.

Bahrick, H.P. & Hall, L.K. (1991). Lifetime maintenance of high school mathematics content. *Journal of Experimental Psychology*. 120, 20-33.

Baker-Ward, L., Gordon, B. N., Ornstein, P. A., Larus, D. M., & Clubb, P. A. (1993). Young children's long-term retention of a pediatric examination. *Child Development*, 64(5), 1519-1533.

Bauer, P.J. & Jackson, F.L. (2014). Semantic elaboration: ERPs reveal rapid transition from novel to know. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 41(1), 271-182.

Bauer, P.J., King, J., Larkina, M., Varga, N., & White, E. (2012). Characters and clues: Factors affecting children's extension of knowledge through integration of separate episodes. *Journal of Experimental Child Psychology*, 111, 681-694.

Bauer, P. J. & San Souci, P. (2010). Going beyond the facts: Young children extend knowledge by integrating episodes. *Journal of Experimental Child Psychology*, 107, 452-465.

Brand, N. & Jolles J. (1985). Learning and retrieval rate of words presented auditorily and visually. *Journal of General Psychology,* 112, 201-210.

Carlson, N. R. (2010). *Psychology the science of behaviour*. Pearson Canada Inc.

Craik, F. (1969). Modality effects in short-term storage. *Journal of Verbal Learning and Verbal*

Behavior, 8, 658-664.

Conrad, R. & Hull, A.J. (1968). Input modality and the serial position curve in short-term memory. *Psychonomic Science*, 10, 135-136.

Gardiner, J.M. (1983). On recency and echoic memory. *Philosophical Transactions B,* 302, 1110.

Holyoak, K. J. & Koh, K. (1987). Surface and structural similarity in analogical transfer. *Memory and Cognition,* 15(4), 332-340.

Lichtenstein. S., Fischhoff, B. & Phillips. L.D. (1982). Calibration of probabilities: The state of the art to 1980. New York, NY: Cambridge University Press.

Margrain, S.A. (1967). Short-term memory as a function of input modality. *Quarterly Journal of Experimental Psychology*, 19, 109-114.

Murdock, B.B. & Walker, K.D. (1969). Modality effects in free recall. *Journal of Verbal Learning and Verbal Behavior*, 8, 665-676.

Nelson, T.O. & Narens L. (1990). The psychology of learning and motivation vol. 26. San Diego, CA: Academic Press, Inc.

Overschelde, J.P.V. (2008). *Handbook of metamemory and memory*, New York, NY: Psychology Press.

Penney, C.G. (2007). Modality effects in delayed free recall and recognition: Visual is better than auditory. *The Quarterly Journal of Experimental Psychology Section A*, 41, 455-470.

Penney, C. G. & Butt, A.K. (1986). Within- and between-modality associations in probed recall: A test of the separate-streams hypothesis. *Canadian Journal of Psychology,* 40, 1-11.

Slamecka, N. & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of*

Experimental Psychology: Human Learning and Memory, 4(6), 592-604.

Smith, C. & Squire, L.R. (2005). Declarative memory, awareness, and transitive inference. *The Journal of Neuroscience*, 25 (44), 10138-10146.

Smith, S., Glenberg, A., & Bjork, R. (1978). Environmental context and human memory. *Memory and Cognition,* 6(4), 342-353.

Spencer, R.M. & Weisberg, R.W. (1986). Context-dependent effects on analogical transfer. *Memory and Cognition*, 14(5), 442-449.

Spencer, W. & Raz, N. (1994) Memory for facts, source, and context: Can frontal lobe dysfunction explain age-related differences? *Psychology and Aging*, 9, 149-159.

Tulving, E. (1983). *Elements of Episodic Memory.* Oxford, England: Oxford University Press.

Tulving, E. (2002). Episodic memory: From mind to brain. *Psychology*, 53, 1-25.

Varga, N. L., Stewart, R. A., & Bauer, P. J. (under review). Effects of delays and reminders on the accessibility of self-generated knowledge in 4-year-old children.

Wharton, C.M., Holyoak, K.J., Downing, P.E., Lange, T.E., Wickens, T.D, and Melz, E.R. (1994). Below the surface: Analogical similarity and retrieval competition in reminding. *Cognitive Psychology*, 26(1), 64-101.

Tables

Table 1

Modality of presentation of stem facts in each condition in Experiment 1.

	Visual Condition	**Auditory Condition**	**Mixed Condition 1**	**Mixed Condition 2**
Stem Fact 1	Visual	Auditory	Visual	Auditory
Stem Fact 2	Visual	Auditory	Auditory	Visual

Table 2

Descriptive statistics on performance on the integration fact test, integration source test, and stem fact source tests for Experiment 1.

	***M* (and *SD*) performance on tests by modality condition**			
	Visual-Visual	**Auditory-Auditory**	**Visual-Auditory**	**Auditory-Visual**
Integration Fact Test	3.00 (1.91)	2.54 (1.82)	2.75 (1.46)	2.18 (1.25)
Integration Source	4.19 (1.36)	3.79 (1.69)	1.93 (2.02)	1.43 (1.40)
Total Stem Source	9.25 (2.76)	10.21(2.67)	8.25 (2.15)	7.93 (2.19)
Stem 1 Source Test	4.39 (1.57)	5.00 (1.47)	4.57 (1.77)	4.00 (1.59)
Stem 2 Source Test	4.86 (1.65)	5.21 (1.67)	3.68 (1.59)	3.90 (1.72)
Both Stems Source	3.21 (1.62)	3.71 (2.00)	2.36 (1.77)	2.04 (1.48)

Note: Means are out of a total of 7 possible correct answers on all tests, except the Stem Total Source Test, which is out of a total of 14 possible correct answers.

Table 3

Pearson correlation values for associations between integration source test performance and integration fact test performance in Experiment 1.

	Condition			
	Visual-Visual	Auditory-Auditory	Visual-Auditory	Auditory-Visual
Correlation	$r(27) = .19$, $p = .35$	$r(27) = -.25$, $p = .20$	$r(27) = .46$, $p = .01$*	$r(27) = .15$, $p = .46$

Table 4

Pearson correlation values for associations between four different measures of performance on the stem fact source test and performance on the integration fact test in Experiment 1.

	Measure of Source Performance			
	Stem 1	Stem 2	Total Stem	Both Stems
Integration Performance	$r(27) = .38$, $p = .045$*	$r(27) = -.22$, $p = .27$	$r(27) = .34$, $p = .07$	$r(27) = .37$, $p = .05$

Table 5

Source question answer choices in Experiment 2.

Answer Choice Title:	Visually	Auditorily	Self-generated	New Knowledge	Already Knew
Description:	Participant read the fact on the computer screen.	Participant heard the fact in the audio recording.	The fact was self-generated through a combination of information obtained in the experiment that day.	Participants did not see or hear the fact today, and they did not know the fact prior to beginning the session.	Prior knowledge from before the session was used to answer the question.

Table 6

Descriptive statistics on performance on the integration fact test, integration source test, and stem fact source tests for Experiment 2.

	***M* (and *SD*) performance on tests by modality condition**			
	Visual-Visual	**Auditory-Auditory**	**Visual-Auditory**	**Auditory-Visual**
Integration Fact Test	2.50 (1.85)	1.85 (1.73)	2.00 (1.69)	1.60 (1.70)
Integration Source	1.80 (1.83)	2.20 (1.85)	1.85 (1.71)	2.20 (1.68)
Stem Total Source	7.95 (3.38)	8.15 (3.17)	6.80 (2.65)	6.60 (1.79)
Stem 1 Source Test	4.35 (1.90)	4.20 (1.54)	3.50 (1.91)	3.35 (1.04)
Stem 2 Source Test	3.60 (1.76)	3.95 (1.85)	3.30 (1.56)	3.25 (1.33)
Both Stems Source	2.75 (1.77)	2.75 (1.83)	1.70 (1.45)	1.40 (1.10)

Note: Means are out of a total of 7 possible correct answers on all tests, except the stem total source test, which is out of a total of 14 possible correct answers.

Table 7

Pearson correlation values for associations between integration source test performance and integration fact test performance in Experiment 2.

Condition

	Visual-Visual	Auditory-Auditory	Visual-Auditory	Auditory-Visual
Correlation	$r(19) = .66$, $p = .001$**	$r(19) = .44$, $p = .05$	$r(19) = .64$, $p = .002$**	$r(19) = .63$, $p = .003$**

Table 8

Pearson correlation values for associations between four different measures of performance on the stem fact source test and performance on the integration fact test in Experiment 2.

	Measure of Source Performance			
	Stem 1	Stem 2	Total Stem	Both Stems
Integration Performance	$r(19) = .12$, $p = .63$	$r(19) = -.10$, $p = .66$	$r(19) = .003$, $p = .99$	$r(19) = .02$, $p = .92$

Table 9

Participant reports for each answer choice on the integration source test in Experiment 2.

Answer Choice on Source Test

	Visual	Auditory	Self-generated	New Knowledge	Already Knew
% of total reports	24.7%	29.5%	27.7%	14.7%	3.4%

Table 10

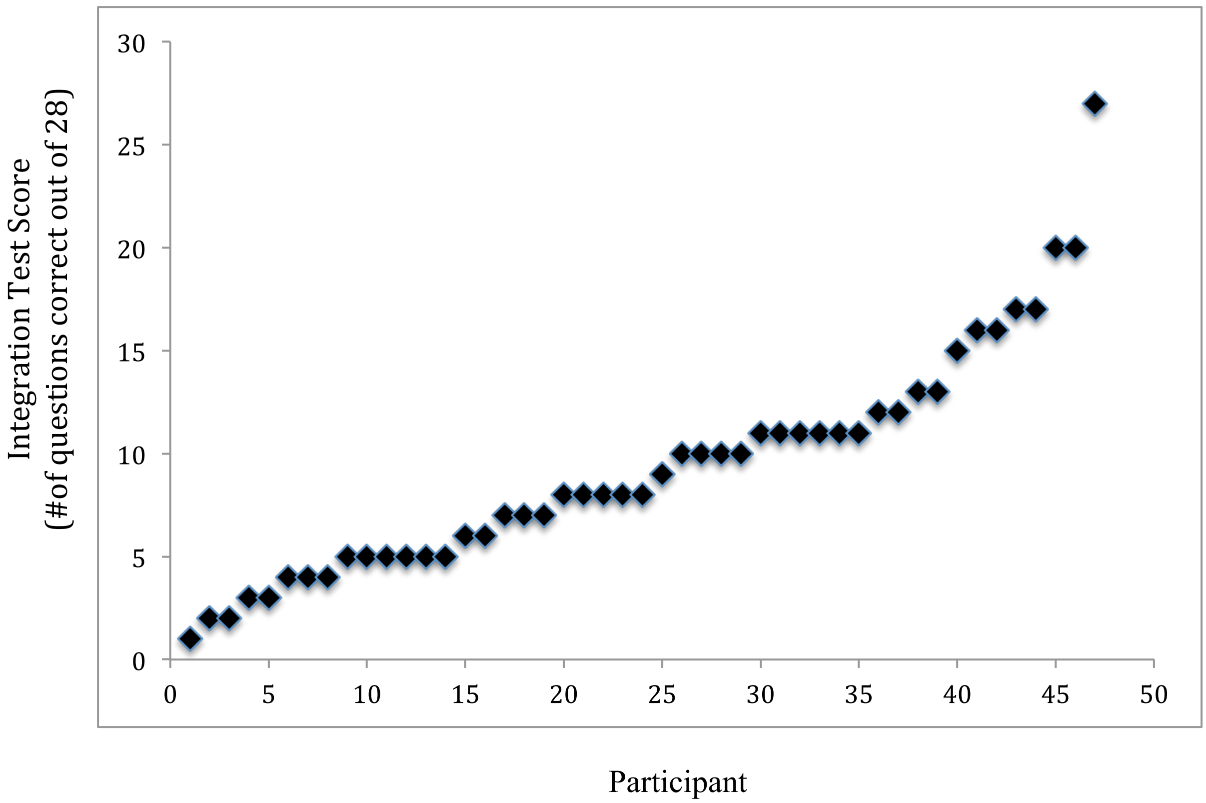
Distribution of confidence ratings (in % of responses for each rating) during source test for both integration and stem facts in Experiment 2.

Confidence Rating

	Low Confidence	**Moderate Confidence**	**High Confidence**
Integration Facts	21.9%	49.1%	29.0%
Stem Facts	20.9%	42.1%	37.0%

Table 11

Variability in scores on the integration test across Experiment 1 and Experiment 2.



Note. Scores are ranked from highest to lowest. Each data point represents on participant's score on the integration test.

For reports on additional data, please contact the authors.