The Generation Effect and Memory

By

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Abstract

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Educators and psychologists have extolled the benefits of active learning techniques such as organizing material, self-explaining, learning through experience, and practicing retrieval for years. Underlying these strategies is the *generation effect*, an encoding phenomenon in which actively generating rather than passively learning information improves the subsequent retrieval of item information. Despite rather extensive analysis of the generation effect, the processes underlying it are not fully understood. Theories suggest that active generation increases cognitive effort, conceptual processing, item distinctiveness, and semantic processing. Further, generation has also been shown to have varying positive, negative and null effects for contextual features such as order, color, and spatial location, prompting tradeoff and transfer-appropriate processing accounts. This dissertation investigates the positive and negative effects of generation, the universality of the generation effect, and its underlying neural mechanisms. Further, these studies test various explanations of the generation effect, and a transfer-appropriate processing account is considered in detail.

In the first set of studies, I used five experiments to investigate the ways in which active generation can influence memory for item information, related item information, and contextual information. Employing synonym (e.g., *ACADEMIC – SCH_L_R*), antonym (e.g., *question – a*____), idiom (e.g., *it's raining cats and (   )*), picture, and category-exemplar (e.g., *animal – c_t*) generation tasks, the positive generation effect for item memory was generally robust, and persisted over long periods of retention and in the face of cognitive distraction. However, negative generation effects were found for font color memory, while null effects were found for background color and location memory. Further, generation was found to impair memory for related items and even the items themselves under certain circumstances.

The second set of studies investigated the degree to which the positive generation effect translates to participants in China, a country that stresses a Confucian rather than Socratic learning style reminiscent of active generation. To address memory for contextual details in a culture that processes information in a field-dependent rather than field-independent manner as in the United States, we also examined the effect of generation on color and spatial location. American and Chinese participants read or generated idioms (e.g., *it's raining cats and (   ); 倾家荡(   )*) presented in different colors or locations, and were tested for item and context memory. For both groups, generation improved item memory. However, American individuals exhibited a negative generation effect only for color memory, while Chinese individuals exhibited negative effects for both color and location memory. These experiments demonstrate the universality of the positive generation effect and the first negative generation effect for location memory to my knowledge.

Finally, I explored the neural basis of the generation effect in an fMRI study. During encoding, participants read or generated synonyms from cues (e.g., *GARBAGE – W_ST_*). Again, compared to simply reading target words, generating target words significantly improved later recognition memory performance. During encoding, this benefit was associated with a broad neural network that involved both prefrontal (inferior frontal gyrus, middle frontal gyrus) and posterior cortex (inferior temporal gyrus, lateral occipital cortex, parahippocampal gyrus, ventral posterior parietal cortex). These results leave open the possibility that active generation increases attention and cognitive effort (prefrontal and posterior cortical activation), conceptual and semantic processing (IFG and MTG), and item distinctiveness (LOC and ACC).

Overall, active generation proved to be a powerful encoding strategy, engaging a wide range of cognitive processes and broad networks of neural activity. Seemingly an almost effortless task, generation enhanced item memory for various stimuli under several conditions. However, active generation had limitations, as it impaired both item and context memory in certain situations. I propose that a transfer-appropriate processing account in which active generation promotes conceptual processing and reduces perceptual processing, ultimately enhancing memory for item information, impairing memory for intrinsic contextual information, and ignoring memory for extrinsic contextual information, best accounts for this pattern of positive and negative generation effects.

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Chapter 1: Introduction

Introduction

Educators have long praised the benefits of active learning techniques such as paraphrasing information, self-explaining, self-testing, and learning through experience. One common underlying aspect of each of these learning strategies is the *generation effect*, an encoding phenomenon in which actively generated information is retrieved more successfully than passively learned information. Slamecka and Graf (1978) demonstrated the positive effects of active generation on item memory. For example, when generating information during an antonym completion task at encoding, some participants saw the word pair *hot-c___*, whereas in the read condition others saw *hot-cold*. In either instance, the word *hot* was the cue, and *cold* was the target. Participants demonstrated both better recall and recognition of items that were previously generated rather than read. This positive generation effect for item memory has been demonstrated with verbal information (Slamecka & Graf, 1978), arithmetic problems (McNamara & Healy, 2000; R. W. Smith & Healy, 1998) and pictures (Kinjo & Snodgrass, 2000), and can occur in as little as 250 milliseconds (R. W. Smith & Healy, 1998). Further, actions that are performed rather than observed (Zimmer et al., 2001) and arguments that are self-generated rather than listened to (Petty, 1981) are better remembered. These effects persist for various study paradigms including intentional and incidental learning, and for different testing methods including recognition, cued recall, and free recall (Bertsch, Pesta, Wiscott, & McDaniel, 2007). Additionally, generating information has proven beneficial in older adults (Taconnat et al., 2006; Taconnat & Isingrini, 2004), patients with various traumatic brain injuries, (Lengenfelder, Chiaravalloti, & DeLuca, 2007) and even in patients with mild cognitive impairment or early stages of Alzheimer's Disease (Souliez, Pasquier, Lebert, Leconte, & Petit, 1996).

Despite rather extensive analysis of the generation effect, the processes underlying it are not fully understood. Theories suggest that active generation increases cognitive effort (McFarland Jr. et al., 1980; Tyler et al., 1979), conceptual processing (Jacoby, 1983), item distinctiveness (Begg, Snider, Foley, & Goddard, 1989; Hunt & McDaniel, 1993; Kinoshita, 1989), and semantic processing (McElroy, 1987; McElroy & Slamecka, 1982), yet none of these views completely explains the phenomenon. Further, generation has been proposed to improve cue-target encoding (Hirshman & Bjork, 1988) and, when using structured lists of related items, inter-target relational encoding (McDaniel, Waddill, & Einstein, 1988). While much evidence exists to support the overarching positive effects of generation, there are limitations. For example, the generation effect is reduced when the read and generate conditions are manipulated between rather than within subjects (Slamecka & Katsaiti, 1987). Additionally, generation appears to have no effect on the recognition of nonwords (McDaniel et al., 1988; Payne, Neely, & Burns, 1986), indicating that the generation effect may only occur for stimuli with preexisting representations (Gardiner & Hampton, 1985; Nairne, Pusen, & Widner, 1985).

Further, there are instances in which generation impairs certain aspects of memory, a phenomenon known as the *negative generation effect*. For example, the activate generation of items impairs memory for source or contextual features, such as memory for temporal order (Nairne, Riegler, & Serra, 1991), the color and font of presented items (Mulligan, 2004; Mulligan, Lozito, & Rosner, 2006), and the person who presented items (Jurica & Shimamura, 1999). To explain this negative generation effect, Jurica & Shimamura (1999) proposed an item-context trade-off account in which active generation enhances the encoding of item information at the expense of forming contextual associations. Mulligan et al., (2006) on the other hand, adopted a *transfer-appropriate processing* (TAP) account (see Jacoby, 1983), arguing that active generation promotes relatively more conceptual processing, whereas passive reading allows participants to rely relatively more on perceptual processing. As item retrieval is generally assessed in a conceptual manner, TAP predicts positive generation effects on most standard tests of memory. However, memory for perceptual features, such as the color or font type of presented items, should benefit more from passive study.

This dissertation first describes the history of our understanding of the positive and negative effects of active generation. Then, the following studies aim to add to our knowledge of, and test various theories for, the generation effect. These goals are accomplished through 3 collections of experiments investigating the positive and negative effects of active generation, the universality of the generation effect among different cultures, and the neural mechanisms underlying the generation effect.

The Positive Generation Effect

Slamecka and Graf (1978) were among the first to delineate the positive effects of active generation on item memory. In a series of experiments that set a foundation for a number of subsequent studies, participants viewed blocks of various stimuli including antonyms, synonyms, associates, categories and rhymes. The read condition consisted of intact cue-target word pairs (e.g., *lamp-light*), while the generate condition consisted of an intact cue, and only the first letter of the target word (e.g., *lamp-l*). For incidental and intentional encoding, cued and free recall (retrieval of previously presented targets when presented with and without a cue, respectively), uncued and cued recognition (discrimination between previously presented targets and novel items), experimenter-paced and self-paced timing, and between- and within-subject designs, active generation consistently enhanced memory performance and confidence.

An early argument for this positive generation effect for item memory was the cognitive effort hypothesis (McFarland Jr. et al., 1980; Tyler et al., 1979). In a series of several experiments, increasing the cognitive effort involved in solving anagrams (Tyler et al., 1979), completing sentences (McFarland Jr. et al., 1980; Tyler et al., 1979), and completing rhymes (McFarland Jr. et al., 1980) enhanced subsequent memory. Indeed, a meta-analytic review by Bertsch et al., (2007) found that increasing the amount of generation required, such as generating an entire word rather than simply a portion of a word, tended to increase the size of the generation effect. However, individual studies have revealed mixed results (Nieznański, 2011, 2012). More difficult math problems have not been shown to improve memory as compared to easy math problems (McNamara & Healy, 2000), and other studies have found that while solving more difficult anagrams leads to improved source memory (in this case, memory for whether participants scrambled or solved an anagram), the difficulty of the anagram did not impact later item recognition performance (Foley & Foley, 2007). Further, generation can fail to benefit memory for nonwords when using a letter transposition task (e.g., *ralt-lart*) (Mulligan, 2002; Payne et al., 1986), obviating any sort of cognitive effort effect.

The lack of generation effect for nonwords suggests that preexisting representations are necessary for active generation to benefit item memory, and that generation may increase semantic processing (McElroy & Slamecka, 1982). For example, the generation benefit may depend on the semantic relationship of the generated compound, as the generation effect exists when using meaningful rather than meaningless units of letters (e.g., *E T* vs. *E C*), unitized rather than nonunitized 2-digit numbers (e.g., *28* vs. *2 8*), and familiar rather than unfamiliar noun compounds (e.g,. *cheesecake* vs. *cheese ketchup*) (Gardiner & Hampton, 1985). However, while preexisting representations may be necessary for a generation effect, they may not be sufficient. Even after teaching participants the meanings of nonwords, or when using low frequency words rather than medium and high frequency words, the generation effect is absent (Nairne et al., 1985). Additionally, the generation effect occurs when using nonsemantic phonological tasks such as rhyme generation (Payne et al., 1986). In one set of experiments, however, participants generated homographs using rhymes and synonyms. When presented with cues related to the initially generated word, cues related to the dominant meaning showed a stronger generation effect than did cues related to the weaker meaning. As meaning could not have been encoded before generation took place, the authors argued that participants may spontaneously process semantic information after generation (McElroy, 1987).

Another possible explanation for the positive generation effect is the item distinctiveness account, which proposes that actively generating an item increases its distinctiveness, enhancing later memory for that item (Begg et al., 1989; Kinoshita, 1989). For example, Kinoshita (1989) found that letter transposition enhanced later recognition but not recall, implying that generation enhances the distinctiveness of the word, which facilitates its discriminability among targets while failing to enhance its semantic availability. Threatening this account, however, is the finding that when provided with the target and asked for the cue at retrieval, there was still a positive generation effect (Hunt & McDaniel, 1993).

Threatening all extent accounts, however, was the argument that the generation effect is simply an artifact of displaced rehearsal (Slamecka & Katsaiti, 1987). Slamecka and Katsaiti (1987) found that when the encoding condition was manipulated between subjects, the generation effect vanished. In another experiment, the authors also required participants to rehearse the words aloud, forcing them to study only the words currently on the screen during a within-subjects design, and again found no generation effect. Slamecka and Katsaiti (1987) therefore argued that participants may spend more time rehearsing generated items at the expense of rehearsing read items. However, the generation effect has been found to survive when using pure lists (Begg et al., 1989), and within-subjects tests likely only inflate the size of this effect (Hirshman & Bjork, 1988). The previously mentioned meta-analysis found that while the generation effect is smaller when the generate and read conditions are manipulated between- rather than within-subjects, it remains robust (Bertsch et al., 2007).

Further research suggested that generation may enhance more than one type of processing. Hirshman and Bjork (1988) found a greater generation effect for cued recall than for free recall, prompting them to propose a 2-factor account in which active generation enhances both item-specific and cue-target information. This idea was later expanded into a 3-factor account in which generation can also enhance whole-list processing (McDaniel et al., 1988). The authors tested participants using several structured categories of related target items (e.g., *furniture: chair, table, couch, bed*), and found that while generation may impair whole-list informational processing in unstructured lists, generation may strengthen the relationship between targets in structured lists.

The Negative Generation Effect

While active learning has proven to be an extremely powerful mnemonic, this benefit may come at a cost. Active generation has been shown to have positive effects on item memory, yet there are instances in which generation may actually impair memory for contextual features of the item, termed the *negative generation effect*. Multi-factor theories suggest that while generation enhances response-specific and stimulus-response encoding, it may actually disrupt other relational encoding (Burns, 1990, 1992). Adding to this negative generation effect, Nairne et al., (1991) proposed an item-order tradeoff account. In a set of experiments, participants read and generated lists of words. While participants better recognized items that were initially generated, they were better able to place randomly organized read items into the correct order. These results indicated that increased engagement with generated items improves memory for the word at the expense of processing relational information, such as order. Indeed, this idea is consistent with a more recent experiment in which Hendry & Tehan (2003) found that increasing word length promotes better item memory but worse order memory.

Subsequent experiments extended these negative generation effects. Jurica and Shimamura (1999) had participants view faces associated with either statements (e.g., B*asketball is a fun sport*) or questions that required generating an answer (e.g., *Which sport do you think is the most fun?*). Participants remembered topics presented as questions better than those presented as statements (i.e., positive generation effect for item information), but they had better source memory (i.e., memory for the face that presented the statements or posed the questions) for items presented as statements. Jurica and Shimamura (1999) therefore expanded the item-order tradeoff account to an item-context tradeoff account in which actively generating information forces one to attend to generated items at the expense of forming contextual associations.

In contrast, however, some researchers have found that generation can enhance both item and context memory. Consistent with such an idea are dual-process theories of memory such as remember-know and recollection-familiarity dissociations. For example, recollection may be characterized as a vivid re-experiencing of a prior event, rich with contextual information, while familiarity may be characterized an acknowledgment of recognition devoid of contextual details (Yonelinas, 2002). As generation enhances subsequent recollection, dual-process theories of memory suggest that this recollection should entail greater contextual binding. In a similar experiment to the one performed by Jurica and Shimamura (1999), participants answered questions or made statements to faces presented on a computer screen by either reading, unscrambling, or filling in words (Geghman & Multhaup, 2004). Rather than being tested for the prompts as in Jurica and Shimamura (1999) study, participants responded directly to the information that was actually read and generated, which resulted in positive generation effects for both item and context memory. Also finding uniformly positive generation effects, Marsh, Edelman, and Bower (2001) varied color, computer screen location, and room location of category-exemplar word pairs. Regardless of manipulation, active generation consistently benefited both item and context memory. Consequently, the authors concluded that any operation that strengthens item memory should strengthen memory for contextual associations as well (Marsh et al., 2001).

Upon attempting to replicate these results, however, Mulligan (2004) found generation to have a consistent positive effect on item memory, yet varying effects on context memory including a negative effect on color memory and no effect on location, background color, and cue-word color memory. Claiming that an item-context account fails to explain this pattern of effects, Mulligan (2004) adopted a TAP account (see Blaxton, 1989; Jacoby, 1983) in which active generation encourages the use of conceptual processing, while passive reading encourages the use of perceptual processing. Previously, Jacoby (1983) had participants read a word out of context, read a word in context, or generate a word. Consistent with a TAP account, generation provided the greatest memory benefit for item recognition, trailed by reading a word out of context, and then reading a word in context, while perceptual identification followed the opposite pattern. Indeed, Blaxton (1989) found that conceptually driven tasks at retrieval such as cued and free recall benefit from conceptually driven tasks at encoding (i.e., generating), while data driven tasks at retrieval such as word fragment completion using graphemic cues benefit from perceptually driven tasks at encoding (i.e., reading). As item retrieval is generally assessed in a conceptual manner, TAP predicts positive generation effects on most standard tests of memory. However, memory for perceptual features such as memory for the color of presented items should benefit more from passive study. Such dissociations between item and context memory fit well within a source-monitoring framework (Johnson, Hashtroudi, & Stephen, 1993) in which perceived events contain more sensory and spatiotemporal information, while imagined events contain more information about the mental processes engaged in their creation.

To investigate the apparent discrepancy between studies that find various positive and negative effects of generation on context (specifically location) memory, Marsh (2006) compared her previous study with Mulligan's (2004) study by manipulating three differing conditions. In the Marsh et al., (2001) study, items were generated covertly, the distractor task involved visuospatial puzzles, and people responded at test with pen and paper. In the Mulligan (2004) study, participants wrote down the generated and read words, completed a state-name fragment distractor task, and made their responses on a computer. Marsh (2006) found that when conditions were most similar to her own work, there was a positive generation effect on location memory, while when conditions were most similar to Mulligan's (2004) work, there was a null effect. If anything, these results illustrate the malleability and susceptibility of generation effects to slight experimental manipulations.

Amassing evidence of the negative generation effect on context memory, Mulligan et al., (2006) manipulated several aspects of generation. Using an antonym generation task, the authors again found positive generation effects for item recognition, a negative effect for color, a negative effect for font type, and a null effect for location. Additionally, they used a letter transposition task with real words (e.g., *a̲nge̲r-rage*) in which generation should increase the amount of conceptual processing while equating the amount of perceptual processing with the read condition. In support of a TAP account, this study eliminated the negative generation effect on color memory while preserving the positive generation effect on item memory. Further, they performed a nonperceptual rhyming task with nonwords (e.g., *rart-lart*), and found a negative generation effect on color memory, yet no generation effect on item memory. Dissociating these positive and negative item and source memory generation effects and independently manipulating each without impacting the other type of memory directly disputed any trade-off account that posits that the negative effect on source memory is a necessary byproduct of the positive effect of generation. In an attempt to explain the various generation effects for context memory, Mulligan (2011) recently argued that generation disrupts memory for intrinsic contextual details such as color or font type while ignoring extrinsic contextual details such as location.

The Value of the Generation Effect

Memory researchers have now spent countless hours over more than 30 years studying the generation effect. Why devote so much time to studying a phenomenon that has been practiced since Socrates and preached by our parents? One answer is that students may not be quite convinced enough of the power of active learning to put principle into practice. While pupils might admit the value of active generation, a survey of the metacognitive learning strategies of 177 college students found that in practice the vast majority of students simply reread textbooks or notes despite the limited benefit of this learning strategy (Karpicke, Butler, & Roediger III, 2009). Not only is the memory benefit of repeated study sessions far outweighed by active encoding strategies such as self-testing (Roediger III & Karpicke, 2006a), many students may not recognize instances in which they have insufficiently learned information if that information is explicitly provided, a problem that is eliminated when students test their own memories (Roediger III & Karpicke, 2006b). Thus, in addition to strengthening memories, active generation through self-testing provides an opportunity for students to understand when they sufficiently understand material.

Accruing evidence demonstrating the true power of the generation effect in the classroom could endorse the use of active learning strategies. Self-testing has been shown to greatly enhance learning in the classroom, and active generation is a major component of this effect. For example, after studying prose passages, students who took open or closed-book tests performed better than those who simply restudied the passages (Agarwal, Karpicke, Kang, Roediger III, & McDermott, 2008). Self-testing has even been shown to improve memory relative to commonly practiced mnemonic techniques such as elaborative encoding for material including scientific text (Karpicke & Blunt, 2011).

While the benefits of retrieval practice have been recently demonstrated with educational materials, key differences exist between active generation and retrieval practice that require consideration. The first difference is retrieval mode. In a direct comparison between the generation effect and self-testing, after studying words, some participants re-read the same words while others were shown fragments of those words along with instructions for one of two conditions. In the generate condition, participants were instructed to generate the first word that came to mind, while in the self-test condition participants were instructed to use the fragments as cues to recall the initially presented words. While generating words led to better memory than re-reading words, self-testing was superior to both. Self-testing may be more a powerful mnemonic than generation, but its effect can only capitalize on previously learned information. Active generation, on the other hand, may be more practical during the initial encoding session. Indeed, studies have found that in education, generation enhances learning, and the errors students might make by generating incorrect information are not harmful if feedback is provided to correct those errors (Metcalfe & Kornell, 2007). Further, the benefits of generation can continue past the initial encoding phase, as students who generated words a second time showed a memory advantage over those who generated and then read words or simply read words twice (MacLeod, Pottruff, Forrin, & Masson, 2012). To be sure, in a meta-analysis of 17,771 subjects over 445 studies, active generation has been shown to yield an 8.8% advantage over passive learning (Bertsch et al., 2007).

Not only can active generation serve as a valuable tool in student learning, it can aid people with memory impairments. For example, while smaller than that seen in unimpaired populations, people with various causes of traumatic brain injury do show a positive generation effect (Lengenfelder et al., 2007). Additionally, patients exhibiting dementia of Alzheimer type (DAT) and frontal lobe type (FTD) both showed generation benefits for verbal and visuospatial short-term memory (Souliez et al., 1996).

These improvements extend to older people with milder memory impairments (Luo, Hendriks, & Craik, 2007). Studies suggest that older adults lack the self-initiated strategic encoding techniques often employed by younger adults. For example, when using shallow encoding tasks such as rhymes, older adults often fail to display the generation effect observed in younger adults. This finding may be due to the fact that only young adults engage in postgeneration semantic processing, as the use of deeper semantic generation tasks rescues the generation effect in older adults. Several studies further illustrate this point that older adults lack self-initiated strategic encoding processes. For example, dividing attention during semantic encoding disrupts a generation effect in both younger and older adults (Taconnat & Isingrini, 2004). However, younger adults demonstrate a relatively greater generation effect for weakly than strongly associated word pairs (Taconnat, Froger, Sacher, & Isingrini, 2008) as compared to older adults, indicating greater semantic processing. Further, young adults allocate relatively more time to generation (Froger, Sacher, Gaudouen, Isingrini, & Taconnat, 2011), and the magnitude of the generation effect correlates with executive function abilities (Taconnat et al., 2006). Given the apparent value of the generation effect in everyone from students to younger adults to older adults to those with memory impairments, a fuller understanding of the positive and negative effects of generation, the underlying mechanisms of the generation effect, and the universality of this phenomenon is warranted.

Themes of this Dissertation

This dissertation is broken up into three themes investigating the positive and negative effects of generation, the universality of the generation effect, and its underlying neural mechanisms. Further, these studies test various explanations of the generation effect, and a transfer-appropriate processing account is considered in detail.

Theme 1: The Positive and Negative Effects of Generation

In what ways can actively generating information influence memory for item information, related item information, and contextual information? How resilient is the positive generation effect on item memory over long intervals of retention and in the face of divided attention? Which aspects of context memory are negatively impacted by active generation? Are there instances in which active generation can impair memory for related items or even the items themselves?

Theme 2: The Universality of the Generation Effect

How universal is the generation effect? Is it an effective encoding strategy among people from China who are accustomed to Confucian rather than Socratic learning styles? Further, how does the manner in which Chinese people process information (field-dependent rather than field-independent) influence the way that generation impacts memory for contextual information?

Theme 3: Mechanisms Underlying the Generation Effect

What are the neural mechanisms that drive the generation effect? Are there specific regions within the brain that are more active when we actively generate rather than passively learn information? If so, do these brain activations drive the mnemonic benefit of active generation, and how can this information inform our understanding of why generation enhances memory?

Chapter 2: The Positive and Negative Effects of Generation

Introduction

As stated earlier, the mechanisms driving the generation effect are still not fully understood. Theories which attempt to account for positive generation effects on item memory have argued that active generation increases cognitive effort (McFarland Jr. et al., 1980; Tyler et al., 1979), conceptual processing (Jacoby, 1983), item distinctiveness (Begg et al., 1989; Hunt & McDaniel, 1993; Kinoshita, 1989), and semantic processing (McElroy, 1987; McElroy & Slamecka, 1982). Other theories posit that generation may enhance memory along multiple dimensions, including item-specific, cue-target (Hirshman & Bjork, 1988), and inter-target relational information (McDaniel et al., 1988). Still, there are instances in which the generation effect is reduced or absent, for example when manipulating the read and generate condition between subjects (Slamecka & Katsaiti, 1987), or when using nonwords as stimuli (McDaniel et al., 1988; Payne et al., 1986).

For all of the documented positive generation effects, negative effects have been found for contextual information such as the order (Nairne et al., 1991), color, and font of items (Mulligan, 2004; Mulligan et al., 2006), and the person who presented information (Jurica & Shimamura, 1999). To explain these negative generation effects, item-context tradeoff (Jurica & Shimamura, 1999) and transfer-appropriate processing accounts (Jacoby, 1983; Mulligan et al., 2006) have been proposed. However, other researchers have found positive generation effects for item color and location, and proposed that active generation can enhance both item and context memory (Marsh, 2006; Marsh et al., 2001). As evidenced by these contradictory results, the effects of generation are sensitive to slight experimental manipulations, leaving various findings open to interpretation and multiple accounts plausible. This first series of studies sought to characterize the boundaries of the generation effect by addressing several issues. How resilient is the positive generation effect on item memory to decay over time and in the face of distraction? Which aspects of context memory are negatively impacted by active generation? Are there instances in which active generation can impair memory for related item information or even the item itself?

Experiments 1.1A and 1.1B (Synonym Immediate Recognition; Synonym Delayed Recognition)

The purpose of these two experiments was to test the resistance of the generation effect to decay over time. Active generation has proven beneficial after short periods of delay. Positive generation effects over longer retention intervals, as seen in self-testing experiments (Roediger III & Karpicke, 2006a), would demonstrate more value as an effective learning strategy. In these first experiments, participants read (e.g., *STUDENT-PUPIL*), or generated (e.g., *STUDENT-P_P_L*) target synonyms and were tested either immediately or 24 hours later.

Materials and Methods

Participants

Seventy one UC Berkeley undergraduate students participated in these experiments. Forty of the students participated in the Synonym Immediate Recognition experiment for 1 hour of research participation credit for partial fulfillment of a psychology course requirement. Forty-one of these students participated in the Synonym Delayed Recognition experiment for $12 for 1 hour.

Design and Materials

Encoding stimuli consisted of 48 synonym word pairs. Half of the stimuli were presented in the read condition, meaning that synonym pairs were presented in complete form (e.g., *STUDENT - PUPIL*). The other half of the stimuli were presented in the generate condition, meaning that the vowels of the second word were removed (e.g., *STUDENT – P_P_L*). Encoding strategy (generate vs. read) was manipulated within participants and counterbalanced such that each synonym pair appeared in each condition with equal frequency. Only synonym pairs in which participants were able to correctly generate the second word with at least 99 percent accuracy (demonstrated through prior experiments to pilot stimuli) were used. The distractor task consisted of a worksheet of 162 simple arithmetic problems, including addition, subtraction, multiplication, and division. The recognition portion of the experiment contained 96 randomly ordered items. Forty-eight of these items were old, consisting of the second, target word of each synonym pair from the encoding phase. The other 48 items were new, consisting of the second, target word of unused synonym pairs. Stimuli appeared as old and new with equal frequency over all participants.

Procedure

Participants were seated facing a computer and told that they would see a series of synonym pairs, and while some pairs would be complete, the second word of other pairs would have the vowels removed. Regardless of condition, they were asked to say the second word of each pair aloud for the experimenter to record. This ensured that the correct word was generated, enabling the elimination of incorrectly identified words from future analyses. Participants were also told to remember the word for a later memory test. Before beginning the encoding phase, 2 practice encoding trials (1 read and 1 generate) were performed to ensure that participants sufficiently understood the task. Participants then viewed a series of 48 randomly ordered read and generate synonym pairs. Each trial began with a 2-second fixation inter-trial interval, followed by the presentation of a synonym pair for 3 seconds (see Figure 1.1A). Following the encoding portion of the experiment, participants performed the math distractor task. They were asked to answer as many of the problems as they could in 2 minutes. The purpose of the distractor task was to prevent the rehearsal of recently presented word pairs, and ensure that long-term memory would be tested.

Participants in the Synonym Immediate Recognition experiment performed the retrieval task immediately following the distractor task, while participants in the Synonym Delayed Recognition experiment performed the retrieval task 24 hours following the onset of the encoding session. Participants viewed a series of 96 randomly ordered words. Forty-eight of these words were old, consisting of the second, target word of each synonym pair from the encoding phase. The other 48 words were new, consisting of the second, target word of unused synonym pairs. Participants decided if each word was old or new with a confidence rating (1 = definitely old, 2 = probably old, 3 = probably new, 4 = definitely new. Words were presented one at a time, in black, in the center of the screen.

Results and Discussion

There was a positive generation effect for item memory in both experiments (Figure 1.1C; Table 1.1). In the Synonym Immediate Recognition experiment, participants recognized an average of 92% of generated items and 67% of read items, $t(39) = 9.53$, $p < .001$. In the Synonym Delayed Recognition experiment, participants recognized an average of 86% of generated items and 56% of read items, $t(40) = 11.87$, $p < .001$. Thus, this set of experiments demonstrated the generation effect's durability over a 24-hour retention interval.

Experiments 1.2A and 1.2B (Antonym Focused Attention; Antonym Divided Attention)

The purpose of these experiments was to test the resilience of the generation effect in the face of divided attention. Previous studies have shown that tasks intended to reduce the attention to, and rehearsal of, generated items may also reduce the size of the generation effect (Slamecka & Katsaiti, 1987). Specifically, if generation requires increased cognitive effort, semantic processing, or attention, as many theories posit, then increasing cognitive load during encoding may prevent the positive generation effect on item memory. In this experiment, participants read (e.g., *NORTH - SOUTH*) or generated (e.g., *NORTH – S__TH*) antonyms while performing a working memory task in which they were required to keep count of the number of times a fixation was presented.

Materials and Methods

Participants

Forty-six UC Berkeley undergraduate students participated for one hour of research participation credit for partial fulfillment of a psychology course requirement. Twenty-two of these students participated in the Antonym Focused Attention experiment and 24 participated in the Antonym Divided Attention experiment.

Design and Materials

Encoding stimuli consisted of 40 antonym word pairs. Half of the stimuli were presented in the read condition, meaning that antonym pairs were presented in complete form (e.g., *NORTH - SOUTH*). The other half of the stimuli were presented in the generate condition, meaning that only the first letter of the second word was presented (e.g., *NORTH – S____*). Additionally, half of the stimuli were presented in green, while the other half were presented in red. Both encoding strategy (generate vs. read) and color (green vs. red) were manipulated within participants and counterbalanced such that each antonym pair appeared in each possible combination of conditions with equal frequency. Only antonym pairs in which participants were able to correctly generate the second word with at least 99 percent accuracy (demonstrated through prior experiments to pilot stimuli) were used. For the Antonym Divided Attention experiment, fixation slides displaying "+" or "o" were presented during each inter-trial interval. The distractor task consisted of a worksheet of 162 simple arithmetic problems, including addition, subtraction, multiplication, and division. The recognition portion of the experiment contained 80 randomly ordered items. Forty of these items were old, consisting of the second, target word of each antonym pair from the encoding phase. The other 40 items were new, consisting of the second, target word of unused antonym pairs. Stimuli appeared as old and new with equal frequency over all participants.

Procedure

Participants were led into the testing room and seated facing a computer. They were told that they would see a series of antonym pairs, and while some pairs would be complete, the second word of other pairs would only contain the first letter. Regardless of condition, they were asked to write down the second word on a provided response sheet. This ensured that the correct word was generated, enabling the elimination of incorrectly identified words from future analyses. In the Antonym Divided Attention experiment, participants were also told that between each trial, a fixation of either "+" or "o" would appear, and that they should keep count of the total number of "+" fixations presented during the encoding phase. Participants were also told to remember target words for a later memory test. Before beginning the encoding phase, 2 practice encoding trials (1 read and 1 generate) were performed to ensure that participants sufficiently understood the task.

Participants then viewed a series of 40 randomly ordered read and generate antonym pairs. In the Antonym Focused Attention experiment, each trial began with a 2-second "+" fixation, while in the Antonym Divided Attention experiment, each trial began with a 2-second randomly ordered "+" or "o" fixation. Both experiments followed the fixation with a 2-second presentation of an antonym pair (Figure 1.1B). In the Antonym Divided Attention experiment, following the encoding portion of the experiment, participants were asked for the total number of "+" fixations presented. Then, they performed the math distractor task by answering as many of the problems as they could in 2 minutes. The purpose of the distractor task was to prevent the rehearsal of recently presented word pairs, and ensure that long-term memory would be tested.

During recognition, participants viewed a series of 80 randomly ordered words. Forty of these words were old, consisting of the second, target word of each antonym pair from the encoding phase. The other 40 words were new, consisting of the second, target word of unused antonym pairs. Participants decided if each word was new or old with a keypress.

Results and Discussion

For the Antonym Focused Attention Experiment, participants recognized an average of 88% of the generated items and 60% of the read items, $t(21) = 9.55$, $p < .001$. For the Antonym Divided Attention experiment, participants recognized an average of 85% of generated items and 53% of read items, $t(23) = 13.18$, $p < .001$ (Figure 1.1C; Table 1.1). Thus, the positive generation effect was 28% in Focused Attention experiment and 32% in the Divided Attention experiment. These results indicated that the positive generation effect persists, and may even increase, when attentional resources are divided. The possibility does exist that the divided attention task was insufficient to detract from attentional resources necessary at encoding. However, overall memory was 5% better in the focused than the Divided Attention experiment, suggesting that the divided attention manipulation succeeded.

Experiments 1.3A, 1.3B, and 1.3C (Idiom Text Color; Idiom Text Location; Idiom Background Color)

While positive generation effects appear to be relatively widespread, negative generation effects have been restricted to certain conditions. Nairne et al., (1991) found that while generating information benefitted memory for item information, it impaired memory for order information. This led to the item-order tradeoff account. In another study, participants had better memory for topics (item memory), but worse memory for which face presented the topics (source memory), when presented as questions (e.g., *Which sport do you think is the most fun?)* rather than as statements (e.g., B*asketball is a fun sport)* (Jurica & Shimamura, 1999). These findings expanded the item-order tradeoff account to a more general item-context tradeoff account in which actively generating information forces one to attend to generated items at the expense of forming contextual associations. Further, Mulligan (2004) found generation to have a positive effect on item memory, a negative effect on color memory and font memory (Mulligan et al., 2006), and no effect on location memory. Instead of a tradeoff account, Mulligan (2004, 2011; Mulligan et al., 2006) adopted a TAP account in which active generation promotes conceptual processing, which generally enhances memory for item information. More passive study, on the other hand, promotes perceptual processing, which in turn enhances memory for intrinsic contextual information such as color or font type and ignores extrinsic contextual information such as location. Still, Marsh et al., (2001; 2006) found that generation can benefit memory for item information and various forms of contextual information such as word color, word location on a computer screen, and participant location (the location of a participant when performing the task). Since positive, negative, and null generation effects have been found for source memory tasks, the purpose of this set of experiments was to investigate the effects of generation on various aspects of context memory including text color, text location, and background color using an idiom generation task.

Methods and Materials

Participants

One hundred forty UC Berkeley undergraduate students participated for 1 hour of research participation credit for partial fulfillment of a psychology course requirement. Fifty students participated in the Idiom Text Color experiment, 48 participated in the Idiom Text Location experiment, and 42 participated in the Idiom Background Color Experiment.

Design and Materials

Encoding stimuli consisted of 40 idioms. Half of the stimuli were presented in the read condition, meaning that idioms were presented in complete form (e.g., *a penny saved is a penny (earned)*). The other half of the stimuli were presented in the generate condition, meaning that idioms were presented without the last word (e.g., *a penny saved is a penny (   )*). In either condition, the last word, or space for the last generated word, of each idiom was presented within parentheses. Additionally, for each experiment half of the stimuli were presented in one context, while the other half were presented in another. In the Idiom Text Color experiment, the idiom was presented in either red or green. In the Idiom Text Location experiment, the idiom was located on either the top or bottom of the screen. In the Idiom Background Color experiment, the idiom was presented on either a red or green background. Both encoding strategy (generate vs. read) and source were manipulated within participants and counterbalanced such that each idiom appeared in each possible combination of conditions with equal frequency. Only well-known idioms in which participants were able to correctly generate the last word with at least 99 percent accuracy (demonstrated through prior experiments to pilot stimuli) were used. The distractor task consisted of a worksheet of 162 simple arithmetic problems, including addition, subtraction, multiplication, and division. The recognition portion of the experiment contained 80 randomly ordered words. Forty of these words were old, consisting of the last word from idioms previously read and generated at encoding. The other 40 were new, consisting of the last word from unused idioms. Stimuli appeared as old and new with equal frequency over all participants.

Procedure

Participants were led into the testing room and seated facing a computer. Participants were told that they would see a series of idioms, and that some of them would be complete, and others would be missing the last word. Additionally, they were instructed that some of the idioms would be presented in one context, and others in a different context (red or green colored words, located on the top or bottom of the computer screen, or presented with a red or green background). Regardless of condition, they were asked to write down in black ink the last word of each idiom. This ensured that the correct item was generated, enabling the elimination of incorrectly identified idioms from future analyses. Participants were also told to remember both the idiom, and its context, for a later memory test. Before beginning the encoding phase, 2 practice encoding trials (1 read and 1 generate) were performed to ensure that participants sufficiently understood the task. Participants then viewed a series of 40 randomly ordered read and generate idioms. Each trial began with a 1-second fixation inter-trial interval, followed by the presentation of an idiom for 7 seconds (Figure 1.2A-C). Following the encoding portion of the experiment, participants performed the math distractor task. They were asked to answer as many of the problems as they could in 3 minutes. The purpose of the distractor task was to prevent the rehearsal of recently presented idioms and ensure that long-term memory would be tested.

During retrieval, participants viewed a series of 80 randomly ordered words. Forty of these words were old, consisting of the last word from idioms previously read and generated at encoding. The other 40 were new, consisting of the last word from unused idioms. Participants decided if each word was new or old, and if it was old, in which context it was previously presented by making the appropriate keypress (Idiom Text Color experiment: N = new, R = old / red, G = old / green), (Idiom Text Location experiment: N = new, T = old / top, B = old / bottom), (Idiom Background Color experiment: N = new, R = old / red, G = old / green).

Results and Discussion

There was a positive generation effect for item memory in all three experiments (Figure 1.2D; Table 1.1). For the Idiom Text Color experiment, participants correctly recognized 69% of generated items and 57% of read items, $t(49) = 4.17$, $p < .001$. Color accuracy was 59% in the generate condition and 68% in the read condition, $t(49) = 2.65$, $p = .01$. For the Idiom Text Color experiment, participants correctly recognized 71% of generated items and 60% of read items, $t(47) = 5.36$, $p < .001$. Location accuracy was 73% in the generate condition and 68% in the read condition, $t(47) = 1.80$, $p = .08$. For the Idiom Background Color experiment, participants correctly recognized 72% of generated items and 60% of read items, $t(41) = 3.99$, $p < .001$. Background color accuracy was 52% in the generate condition and 55% in the read condition, $t(41) = .43$, $p = 0.67$.

Thus, while consistently benefitting item memory, generation had a negative effect on color memory, a nonsignificant positive effect for location memory, and no effect for background color memory. These results are consistent with Mulligan's (2004; 2006) previous research and support his (2011) account of the generation effect. Generation appears to increase conceptual processing, which benefits later item recognition. However, this positive effect is not always accompanied by the negative effect for context memory that would be predicted by tradeoff accounts. Rather, generation may impair memory for intrinsic contextual details (font color) while leaving memory for extrinsic contextual details unimpaired (location; background color).

Experiments 1.4A and 1.4B (Picture Fragment Completion: Picture-Picture; Picture Fragment Completion: Word-Picture)

While negative generation effects for context memory such as color have been documented, negative generation effects for item memory are less common. These experiments were motivated by the TAP account's predictions of positive and negative generation effects as influenced by relative amounts of conceptual and perceptual processing. Using line drawings of common objects, complete (read condition) and fragmented (generate condition) pictures and words were presented at encoding, while complete pictures were presented at test. Previously, Kinjo and Snodgrass (2000) presented complete and fragmented pictures during study and found that both recall and source memory (defined as memory for whether the picture was initially presented in complete or fragmented form) was better if the picture was initially presented in fragmented form. When presented with complete or fragmented pictures during a recognition task, however, performance was best when viewing complete pictures at study and test rather than when viewing fragmented pictures at study and test. This result may be due to similar perceptual processing during both study and test. Further, when presented with a more conceptual retrieval task, such as the name of the picture rather than the picture itself, there was a positive generation effect. These results indicate that the relative conceptual and perceptual processes engaged during study and test may affect the successful retrieval of item and source information. Typically, the retrieval of a word is considered to be a conceptually-driven task. However, if a person is tested with the same form of a picture as during study, then utilizing perceptual processing may be more beneficial. In these two experiments, participants viewed either pictures or words at study and then were tested with the picture. A TAP account would predict that if presented with a picture at both study and test, there should be a negative generation effect for both item and color memory. Active generation should promote more conceptual processing, but in this instance the test of both item and source information is perceptual in nature. When presented with a word at study and a picture at test, however, participants should rely more on the concept of what was seen rather than the consistent processing of perceptual information, which should result in a positive generation effect for item memory. Color memory, however, is still a perceptual task, and should benefit from the read condition at study.

Materials and Methods

Participants

Ninety-seven UC Berkeley undergraduate students participated for 1 hour of research participation credit for partial fulfillment of a psychology course requirement. Forty-eight participated in the Picture-Picture experiment and 49 participated in the Word-Picture experiment.

Design and Materials

Encoding stimuli consisted of 40 pictures derived from the Snodgrass and Vanderwart standardized picture set (Snodgrass & Vanderwart, 1980) of simple line drawings or the corresponding words used to describe them. For the Picture-Picture experiment, half of the pictures were presented in complete form, and the other half were presented in fragmented form. For the Word-Picture experiment, half of the words were presented in complete form (e.g., *FLOWER*), while the other half were presented in fragmented form, meaning they were presented with their vowels removed (e.g., *FL_W_R)*. Additionally, for each experiment half of the stimuli were presented in red, while the other half were presented in blue. Both encoding strategy (generate vs. read) and color (red vs. blue) were manipulated within participants and counterbalanced such that each picture appeared in each possible combination of conditions with equal frequency. Only pictures and words that were identifiable with at least 95% accuracy (demonstrated through prior experiments to pilot stimuli) were used. The distractor task consisted of a worksheet of 162 simple arithmetic problems, including addition, subtraction, multiplication, and division. The recognition portion of the experiment contained 80 randomly ordered pictures. Forty of these items were old, consisting of items previously presented during the encoding phase, while 40 were new, consisting of unused items. Stimuli appeared as old and new with equal frequency over all participants.

Procedure

Participants were either told they would see a series of pictures (Picture-Picture experiment) or words (Word-Picture experiment). Either way, all participants were told that some of the items would be complete, and others would be fragmented. Additionally, they were instructed that some of the items would be presented in blue, and the others would be presented in red. Regardless of condition, they were asked say the name of each item aloud. This ensured that the correct item was generated, enabling the elimination of incorrectly identified items from future analyses. Participants were also told to remember both the item, and its color, for a later memory test. Before beginning the encoding phase, 2 practice encoding trials (1 complete and 1 fragment) were performed to ensure that participants sufficiently understood the task. Participants then viewed a series of 40 randomly ordered items. Each trial began with a 2-second fixation inter-trial interval, followed by the presentation of the item for 3 seconds (Figure 1.3A-C). Following the encoding portion of the experiment, participants performed the math distractor task. They were asked to answer as many of the problems as they could in 2 minutes. The purpose of the distractor task was to prevent the rehearsal of recently presented pictures, and ensure that long-term memory would be tested.

During retrieval, participants viewed a series of 80 randomly ordered pictures. Forty of these items were old, consisting of items that were previously presented during the encoding task, and 40 were new, consisting of unused items. Participants decided if each item was old or new with a confidence rating (1 = definitely old, 2 = probably old, 3 = probably new, 4 = definitely new). If the item was determined to be old, the participant then decided in which color the item was previously presented with a confidence rating (1 = definitely blue, 2 = probably blue, 3 = probably red, 4 = definitely red). Words were presented one at a time, in black, in the center of the screen.

Results and Discussion

In the Picture-Picture experiment, participants correctly recognized 86% of generated items and 93% of read items, $t(47) = 3.60$, $p < .001$. Color accuracy was 74% in the generate condition and 81% in the read condition, $t(47) = 2.05$, $p < .05$ (Figure 1.3D; Table 1.1). In the Word-Picture experiment, participants correctly recognized 90% of generated items and 74% of read items, $t(48) = 9.10$, $p < .001$. Color accuracy was 58% in the generate condition and 65% in the read condition, $t(48) = 2.79$, $p < .01$.

For item recognition, when a person was presented with a picture at both study and test, there was a negative generation effect for both item and color memory. While the generation task still promoted conceptual processing, the retrieval task was more perceptual in nature, and seeing rather than generating the picture at study resulted in better item and color memory. When presented with a word at study and a picture at test, however, participants could no longer rely on similar perceptual processing during retrieval, thus driving the positive generation effect for item memory. Color memory, however, still relied on perceptual processing, as it is unlikely that participants conceptually processed color information during encoding, resulting in a negative generation effect. While these results do not rule out an item-context tradeoff account (Jurica and Shimamura, 1999), they are more consistent with a TAP account (Jacoby, 1983; Mulligan et al., 2006). These experiments demonstrated that the negative generation effect is not a necessary consequence of a positive generation effect for item memory. Specifically, when encoding and retrieving picture stimuli, generation impaired both item and color memory.

Experiment 1.5 (Category Retrieval Blocking)

The previous experiments demonstrated that active generation can negatively impact memory both for the item and its context. Can such negative influences extend to memory for other items? Hirshman and Bjork (1988) found that when using structured lists of related items, generation benefited memory for other target items through inter-target relational processing. However, it is possible that that the enhanced memory of generated items may impair memory for related items to the extent that generation fails to activate these items. Previously, Anderson, Bjork, and Bjork (2000) found that retrieving category exemplars strengthens memory for those items while weakening memory for unretrieved exemplars, a phenomenon known as retrieval-induced forgetting (Anderson, Bjork, & Bjork, 1994). Indeed, Bäuml (2002) found that the act of self-generating exemplars may impair the recall of previously presented exemplars. However, questions remain. Does the positive effect for generated items interfere with the non-generated related items? If generation does impair memory, does this impairment operate proactively as well as retroactively? Therefore, the purpose of this experiment was to investigate potential negative generation effects on other previously learned information through a task similar to retrieval-induced forgetting (Anderson et al., 1994). During an initial encoding task, participants read or generated category-exemplar word pairs (e.g., *FURNITURE – CH_ _R* or *ANIMAL – DOG*). Then, during a second encoding task, participants saw the same categories paired with new read (e.g., *FURNITURE - TABLE*) or generate (e.g., *ANIMAL – C_T*) exemplars. Generation enhances item memory to such a great extent that it is possible that this memory strength can block the retrieval of previously learned items through a mechanism similar to that of retrieval-induced forgetting.

Materials and Methods

Participants

Sixty UC Berkeley undergraduate students participated for 1 hour of research participation credit for partial fulfillment of a psychology course requirement.

Design and Materials

Encoding phase 1 stimuli consisted of 60 category-exemplar word pairs (e.g., *FURNITURE – CHAIR*). Encoding phase 2 stimuli consisted of the same 60 categories from encoding phase 1 associated with new exemplars (e.g., *FURNITURE – TABLE*). Stimuli were either presented as complete in the read condition (e.g., *ANIMAL - CAT*) or fragmented, with the vowels removed, in the generate condition (e.g., *ANIMAL – C_T*). Twenty of the items were presented in the read condition in both study phases, twenty were presented in the read condition during encoding phase 1, and the generate condition during encoding phase 2, and twenty were presented in the generate condition in encoding phase one, and the read condition in encoding phase 2. The encoding strategy (Read-Read, Read-Generate, Generate-Read) was manipulated within participants and counterbalanced such that each category-exemplar pair appeared in each condition with equal frequency. Only well-known category-exemplar pairs in which participants were able to correctly generate the exemplar with at least 99 percent accuracy (demonstrated through prior experiments to pilot stimuli) were used. The distractor task consisted of a worksheet of 162 simple arithmetic problems, including addition, subtraction, multiplication, and division. The retrieval task consisted of the 80 previously presented categories. Directly beneath each category, participants were asked to type both related exemplars.

Procedure

Participants were seated facing a computer and told that they would see a series of category-exemplar word pairs. Some of these word pairs would be complete, while for others the exemplar would have its vowels removed. Regardless of condition, they were asked to make a keypress of "1" if they could identify the exemplar. This ensured that the correct exemplar was generated, enabling the elimination of incorrectly identified items from future analyses. Participants were told to remember the category-exemplar word pair for a later memory test. Before beginning the encoding phase, 2 practice encoding trials were performed to ensure that participants sufficiently understood the task. Participants then viewed a series of 60 category-exemplar word pairs. Each trial began with a 2-second fixation inter-trial interval followed by the presentation of a category-exemplar pair for 3 seconds (Figure 1.4A, 1.4B). Following the first encoding portion of the experiment, participants performed a math distractor task. They were asked to answer as many of the problems as they could in 2 minutes. The purpose of the distractor task was to prevent the rehearsal of recently presented word pairs. Next, participants viewed a series of the same 60 categories from the first encoding phase paired with new read or generate exemplars. Following the second encoding portion of the experiment, participants performed another math distractor task. During retrieval, participants viewed the series 60 categories in random order. Participants were asked to respond by typing both previously associated exemplars.

Results and Discussion

In the Read-Read condition, participants correctly recalled the first presented exemplar 60% of the time and the second presented exemplar 49% of the time. In the Read-Generate condition, participants recalled the first exemplar 53% of the time and the second exemplar 71% of the time (Figure 1.4C). Thus, generating the second item enhanced memory for the generated item by 22%, $t(59) = 8.89$, $p < .001$, while impairing memory for the read item by 7%, $t(59) = 3.33$, $p = .001$. In the Generate-Read condition, participants recalled the first exemplar 72% of the time and the second exemplar 46% of the time. Generating the first item therefore improved memory for the generated item by 12%, $t(59) = 5.69$, $p < .001$, while only impairing memory for the read item by 3%, $t(59) = 1.66$, $p = .1$. Overall, memory was 62% in the Generate-Read condition, 59% in the Read-Generate condition, and 55% in the Read-Read condition. These results indicate that active generation, while a powerful mnemonic, has potential the consequence of impairing memory for other related item information. This negative effect is particularly powerful retroactively, and may not exist proactively. Further, it appears that this deficit is less strong than the positive generation effect, as demonstrated by the fact that both the

Generate-Read and Read-Generate conditions elicited better overall memory than the Read-Read condition.

General Discussion

These experiments demonstrated that while active generation can be an extremely powerful encoding strategy for item information, there are also instances in which it can impair memory for contextual information, related item information, and even the item itself. In general, the positive generation effect was robust, and existed over multiple types of stimuli, including synonyms, antonyms, idioms, pictures and categories, and under different encoding conditions such as covert generation, overt verbal generation, and overt writing. Further, these positive generation effects on item memory persisted over a 24-hour delay, consistent with the work of Roediger III & Karpicke (2006a), who found that active learning techniques such as self-testing can promote long-term retention. Additionally, the benefit of active generation was strong in the face of cognitive distraction, which provides some evidence against attention accounts of the generation effect. These findings are significant, as they extend our knowledge of the generation effect, which is most typically tested without distraction over short time periods, to scenarios more reminiscent of actual academic scenarios.

However, active generation does not result in universally enhanced memory, even for the item itself. When presented with picture stimuli at both encoding and retrieval, generation impaired memory for the item. While one could argue that study and test stimuli were more similar in the read than generate condition, Kinjo & Snodgrass (2000) accounted for this, finding that viewing complete items at study and test resulted in better subsequent recognition memory than viewing fragmented items at study and test. In that same study, however, generating pictures at study led to better subsequent recall memory than did reading. The present study further found that when presented with pictures at test, generating rather than reading words at encoding led to superior memory. Taken together, these results are consistent with Mulligan et al.'s (2006) TAP account. Essentially, generation benefits later memory to the extent that it promotes the appropriate type of processing. If tested with a picture (a perceptual task), studying a complete rather than fragmented picture benefits both item and color memory as the complete (read) condition allows for more perceptual processing. However, studying a fragmented word allows for greater conceptual processing which benefits later item memory as the participant can only rely on the concept of the item as no picture was initially presented. Color memory, however, is still a perceptual retrieval task, and benefits more from the read condition. Further, while the Word-Picture experiment demonstrated the typical positive generation effect for item memory and negative generation effect for context memory tradeoff, the Picture-Picture experiment demonstrated a negative generation effect on both item and color memory. These results suggest that the negative generation effect on source memory is not a necessary consequence of the positive generation effect on item memory, which is again more consistent with a TAP rather than tradeoff account.

Active generation can also impair memory for other items. In the Category Retrieval Blocking experiment, active generation enhanced memory for the generated items at the expense of related non-generated items. This finding is consistent with Bäuml's (2002) finding that generating exemplars impairs the recall of previously presented related exemplars. This result may be driven by a similar mechanism to that of retrieval-induced forgetting (Anderson et al., 1994), in that the strengthening of one memory may impair memory for related information. Thus, the benefit of generation is not without consequence, even for item information. It should be noted, however, that the overall benefit of generation for generated items was greater than the deficit generation created for read items, and both the Generate-Read and Read-Generate conditions led to better overall memory than the Read-Read condition. Further, a Generate-Generate condition may be superior to any of these conditions, and should be tested in the future. Regardless, it is apparent that active generation, while enhancing memory for the generated item, may impair memory for other related information.

Finally, the Idiom experiments replicated and extended Mulligan's (Mulligan, 2004; Mulligan et al., 2006) studies by finding that generation benefits item memory, impairs text color memory, and has no effect on text location and background color memory. It should be noted, however, that there was a slight, although nonsignificant, positive generation effect on location memory, which would be consistent with some previous research (Marsh, 2006; Marsh et al., 2001). These results are highly consistent with a TAP account (Jacoby, 1983; Mulligan et al., 2006) with the caveat that generation impairs memory for intrinsic, but not extrinsic, contextual details (Mulligan, 2011). Typically, generation promotes conceptual processing, while reading promotes perceptual processing. Word recognition is generally considered to be conceptual in nature, and therefore item memory often benefits from generation at encoding. Source memory, on the other hand, is often a perceptual task, and benefits from reading at encoding. However, this holds true only for intrinsic contextual details, while extrinsic contextual details are unaffected by generation.

These experiments demonstrated the strengths, weaknesses, and boundaries of active learning. The positive generation effect on item information is quite powerful, existing in the face of distraction and over long intervals of retention. Under certain conditions, however, generation can impair memory for other items and even the item itself. Further, the negative generation effect was found to occur only for intrinsic contextual details, and coexisted with both positive and negative generation effects on item memory. These results are highly consistent with a TAP processing account.

Tables

				Item Memory				*Source Memory*		
Experiment	**Task**	**Condition**	**N**	**Generate**	**Read**	**FA**	**Sig**	**Generate**	**Read**	**Sig**
1.1A	Synonym	*Immediate*	40	.92 (.03)	.67 (.03)	.08 (.02)	<.01			
1.1B	Synonym	*Delay*	41	.86 (.02)	.56 (.03)	.23 (.02)	<.01			
1.2A	Antonym	*Focus*	22	.88 (.03)	.60 (.04)	.12 (.02)	<.01			
1.2B	Antonym	*Divided*	24	.85 (.02)	.53 (.03)	.18 (.03)	<.01			
1.3A	Idiom	*Text Color*	50	.69 (.03)	.57 (.03)	.06 (.01)	<.01	.59 (.03)	.68 (.03)	.01
1.3B	Idiom	*Text Location*	48	.71 (.02)	.60 (.02)	.06 (.01)	<.01	.73 (.02)	.68 (.02)	.08
1.3C	Idiom	*Back. Color*	42	.72 (.02)	.60 (.03)	.09 (.02)	<.01	.60 (.02)	.61 (.03)	.67
1.4A	Picture-Picture	*Color*	48	.86 (.02)	.93 (.02)	.03 (.00)	<.01	.74 (.03)	.81 (.03)	<.05
1.4B	Word-Picture	*Color*	49	.90 (.02)	.74 (.02)	.12 (.02)	<.01	.58 (.02)	.65 (.02)	<.01

Table 1.1 – Behavioral performance for experiments 1.1-1.4.

Figures

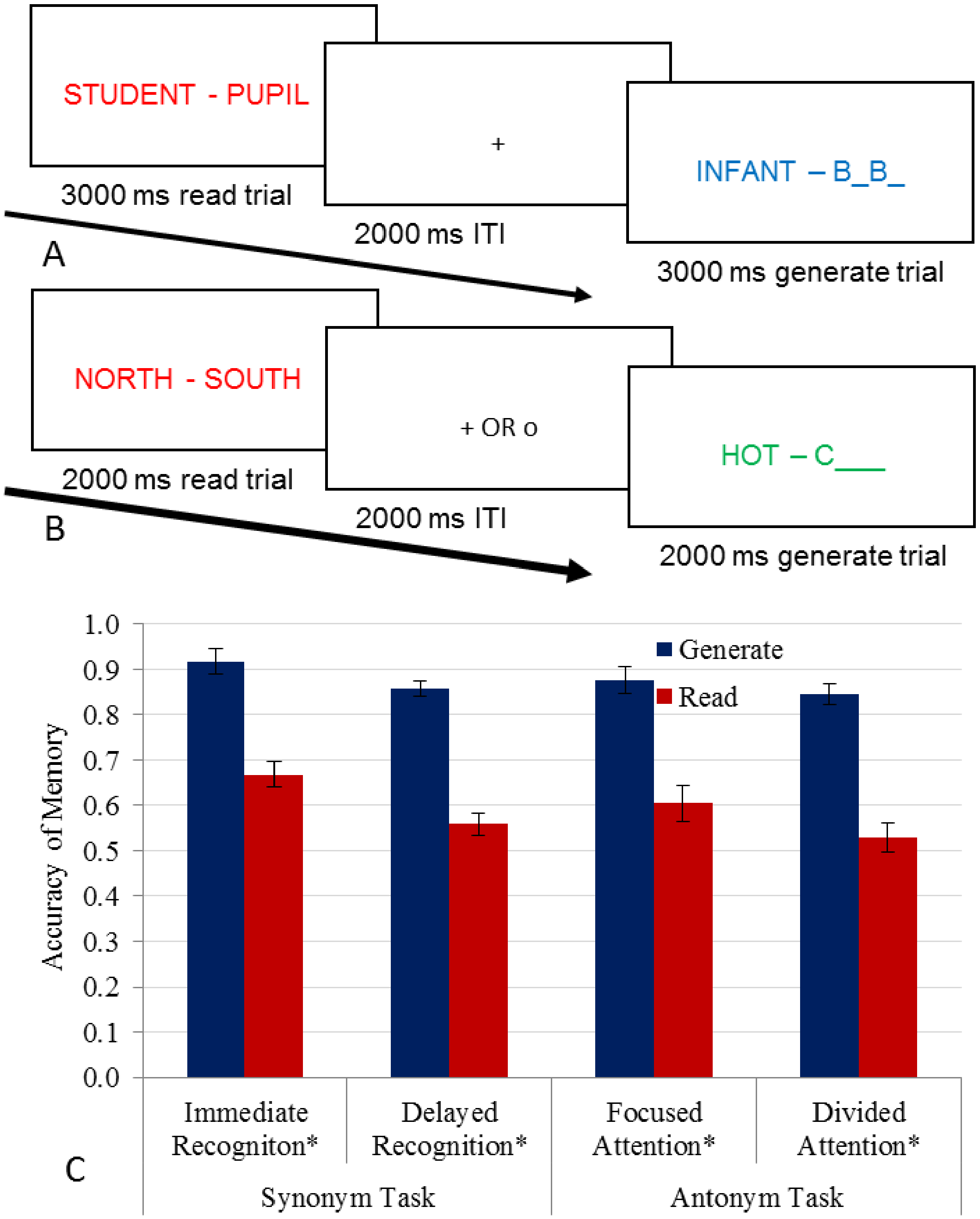

Figure 1.1 – (A) Synonym encoding task for Experiments 1.1A and 1.1B. (B) Antonym encoding task for Experiments 1.2A and 1.2B. (C) Behavioral data for Experiments 1.1A, 1.1B, 1.2A, and 1.2B.

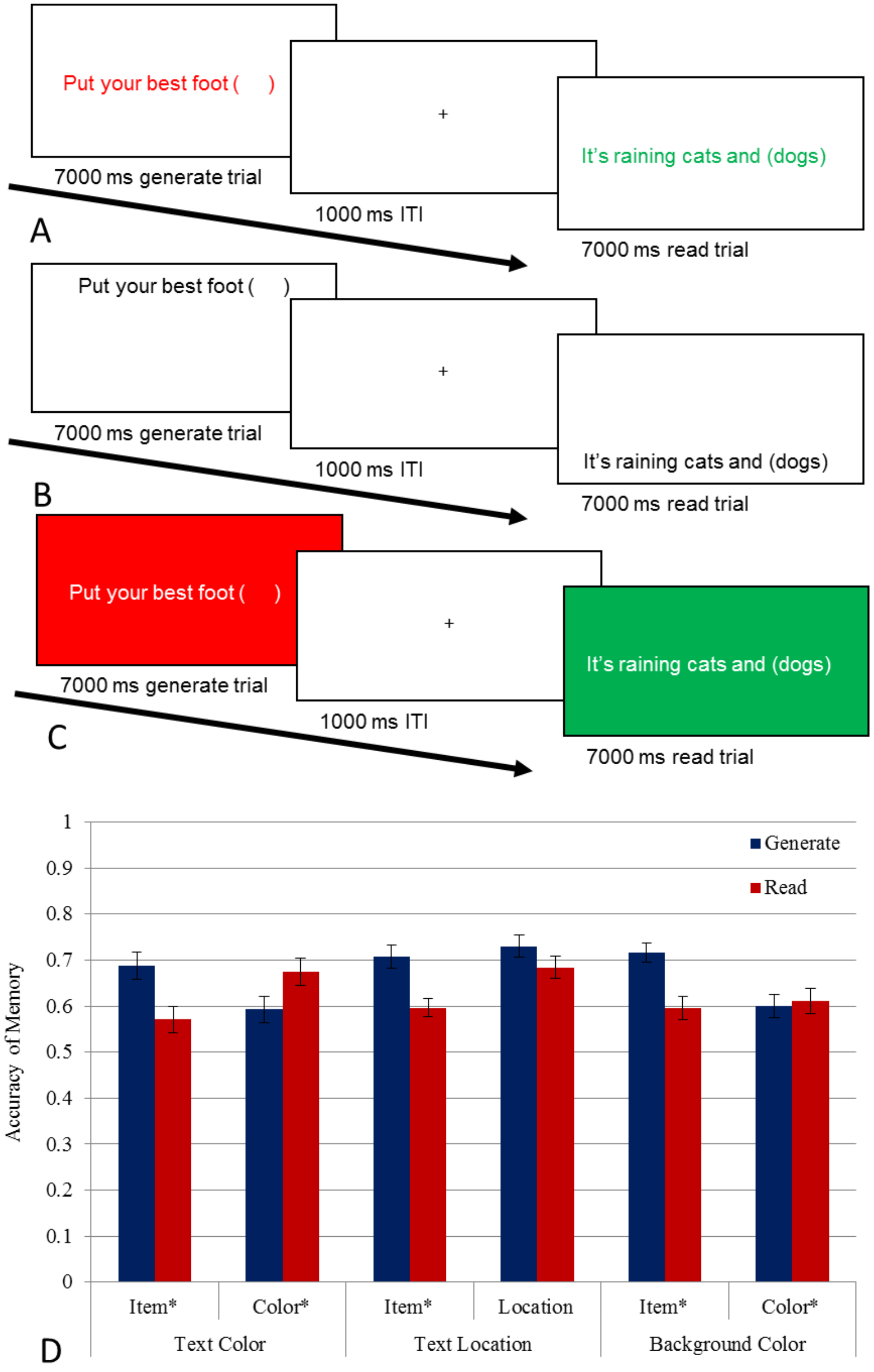

Figure 1.2 – (A) Idiom encoding task for Experiment 1.3A. (B) Idiom encoding task for Experiment 1.3B. (C) Idiom encoding task for Experiment 1.3C. (D) Item and source memory accuracy for Experiments 1.3A-1.3C.

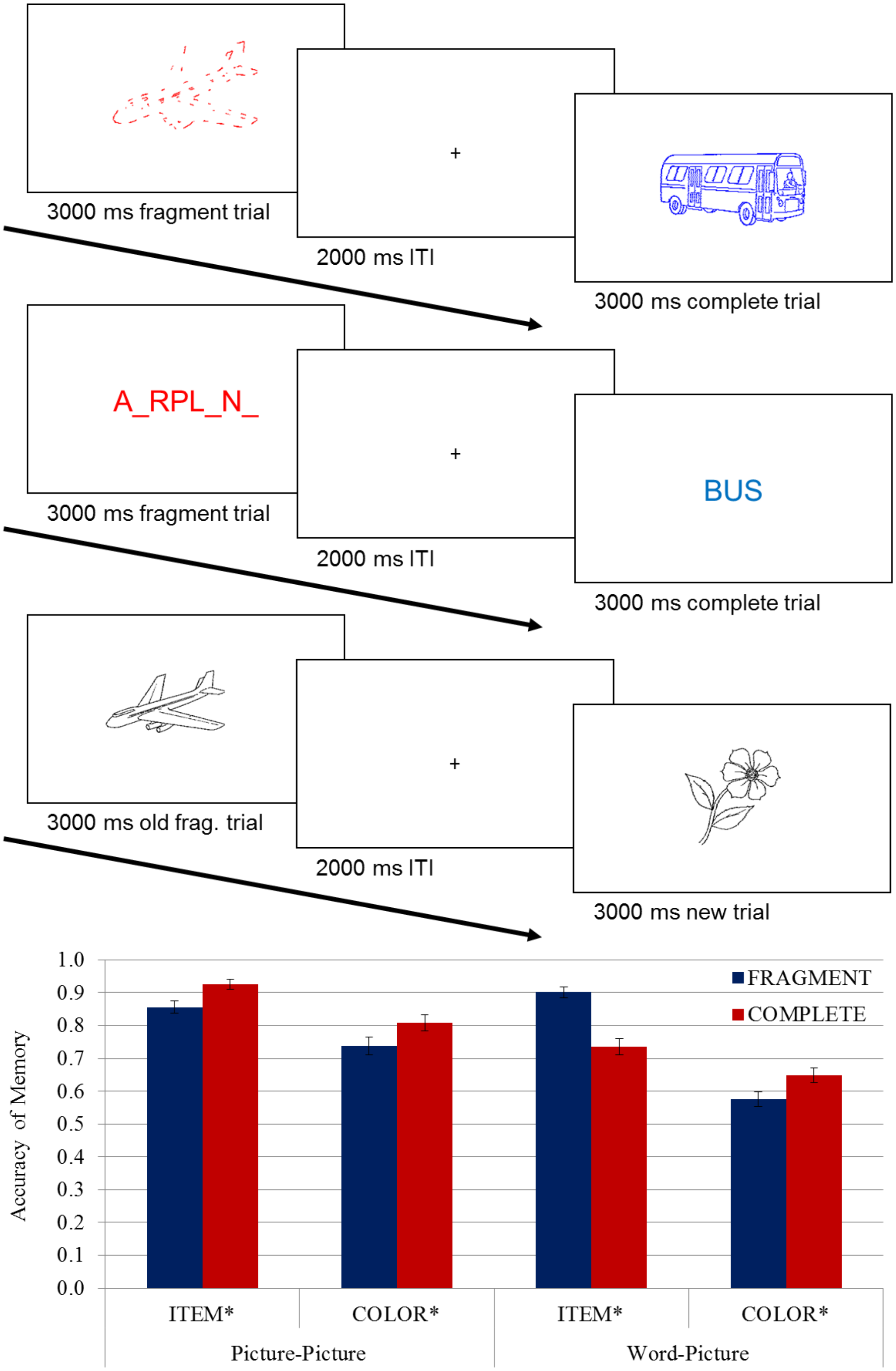

Figure 1.3 – (A) Encoding task for Experiment 1.4A. (B) Encoding task for Experiment 1.4B. (C) Recognition task for Experiments 1.4A and 1.4B. (D) Item and source memory accuracy for Experiments 1.4A and 1.4B.

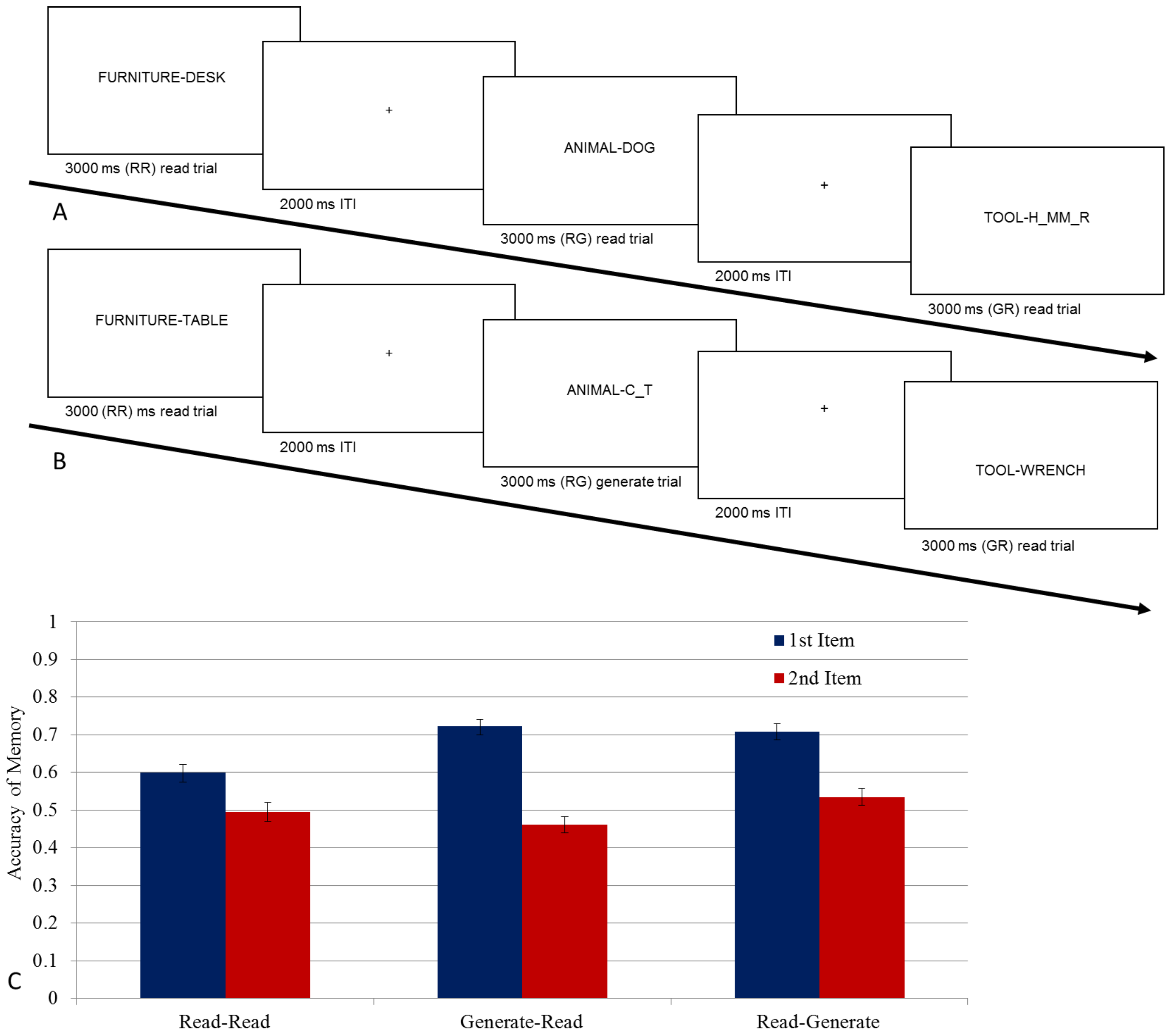

Figure 1.4 – (A) Encoding task for Experiment 1.5 study session 1. (B) Encoding task for Experiment 1.5 study session 2. (C) Behavioral data for Experiment 1.5.

Appendices

Synonym Immediate and Delayed Recognition Experiments (1.1A; 1.1B)			
Read Items		*Generate Items*	
ACADEMIC – SCHOLAR	HEATER - FURNACE	ACADEMIC - SCH_L_R	HEATER - F_RN_C_
AIR – OXYGEN	HEN - CHICKEN	AIR - _XYG_N	HEN - CH_CK_N
AMMUNITION – BULLET	HOMICIDE - MURDER	AMMUNITION - B_LL_T	HOMICIDE - M_RD_R
ATLAS – MAP	ICON - SYMBOL	ATLAS - M_P	ICON - SYMB_L
AUTUMN – FALL	ILLNESS - DISEASE	AUTUMN - F_LL	ILLNESS - D_S_ _S_
BASEMENT – CELLAR	INDICATION - SIGNAL	BASEMENT - C_LL_R	INDICATION - S_GN_L
BEAST – ANIMAL	INFANT - BABY	BEAST - _N_M_L	INFANT - B_BY
BELLY – STOMACH	INFIRMARY - HOSPITAL	BELLY - ST_M_CH	INFIRMARY - H_SP_T_L
BLAZE – FIRE	INFORMATION - NEWS	BLAZE - F_R_	INFORMATION - N_WS
BORDER – EDGE	JET - PLANE	BORDER - _DG_	JET - PL_N_
BREEZE – WIND	KINGDOM - EMPIRE	BREEZE - W_ND	KINGDOM - _MP_R_
BUG – INSECT	LAMP - LANTERN	BUG - _NS_CT	LAMP - L_NT_RN
BUNNY – RABBIT	LIMB - BRANCH	BUNNY - R_BB_T	LIMB - BR_NCH
CASTLE – PALACE	LOCOMOTIVE - TRAIN	CASTLE - P_L_C_	LOCOMOTIVE - TR_ _N
CATASTROPHE – DISASTER	MEDICINE - DRUG	CATASTROPHE - D_S_ST_R	MEDICINE - DR_G
CATHEDRAL – CHURCH	MIND - BRAIN	CATHEDRAL - CH_RCH	MIND - BR_ _N
CHILLY – COLD	MISTAKE - ACCIDENT	CHILLY - C_LD	MISTAKE - _CC_D_NT
CITRUS – ORANGE	NAP - SLEEP	CITRUS - _R_NG_	NAP - SL_ _P
CLIENT – CUSTOMER	NOISE - SOUND	CLIENT - C_ST_M_R	NOISE - S_ _ND
CLIMATE – WEATHER	NOVEL - BOOK	CLIMATE - W_ _TH_R	NOVEL - B_ _K
COIN – TOKEN	OCCUPATION - JOB	COIN - T_K_N	OCCUPATION - J_B
CONFLICT – BATTLE	OVERPASS - BRIDGE	CONFLICT - B_TTL_	OVERPASS - BR_DG_
CORPORATION – COMPANY	PACE - STRIDE	CORPORATION - C_MP_NY	PACE - STR_D_
COUNTRY – NATION	PARCEL - PACKAGE	COUNTRY - N_T_ _N	PARCEL - P_CK_G_
DECK – PORCH	PERIODICAL - MAGAZINE	DECK - P_RCH	PERIODICAL - M_G_Z_N_
DIAGRAM – CHART	PERSPIRATION - SWEAT	DIAGRAM - CH_RT	PERSPIRATION - SW_ _T
DIARY – JOURNAL	PHYSICIAN - DOCTOR	DIARY - J_ _RN_L	PHYSICIAN - D_CT_R
DINNER – SUPPER	POUCH - POCKET	DINNER - S_PP_R	POUCH - P_CK_T
DISH – PLATE	PRECIPITATION - RAIN	DISH - PL_T_	PRECIPITATION - R_ _N
DOORWAY – ENTRANCE	PROFESSOR - TEACHER	DOORWAY - _NTR_NC_	PROFESSOR - T_ _CH_R
EMPLOYEE – WORKER	PUB - B_R	EMPLOYEE - W_RK_R	PUB - B_R
EXAMPLE – SPECIMEN	QUANTITY - VOLUME	EXAMPLE - SP_C_M_N	QUANTITY - V_L_M_
EXHAUSTION – FATIGUE	ROCKET - MISSILE	EXHAUSTION - F_T_G_ _	ROCKET - M_SS_L_
FLAVOR – TASTE	SACK - BAG	FLAVOR - T_ST_	SACK - B_G
FLESH – MEAT	SCENT - SMELL	FLESH - M_ _T	SCENT - SM_LL
FLUID – LIQUID	SECTION - SEGMENT	FLUID - L_Q_ _D	SECTION - S_GM_NT
FOREIGNER – STRANGER	SHORE - COAST	FOREIGNER - STR_NG_R	SHORE - C_ _ST
FREEWAY – HIGHWAY	STAGE - PLATFORM	FREEWAY - H_GHW_Y	STAGE - PL_TF_RM
FUNGUS – MOLD	STATUE - MONUMENT	FUNGUS - M_LD	STATUE - M_N_M_NT
GARBAGE – WASTE	STREET - ROAD	GARBAGE - W_ST_	STREET - R_ _D
GLUE – PASTE	STUDENT - PUPIL	GLUE - P_ST_	STUDENT - P_P_L
GRASP – GRIP	SUPERVISOR - BOSS	GRASP - GR_P	SUPERVISOR - B_SS
GRASS – LAWN	THREAD - STRING	GRASS - L_WN	THREAD - STR_NG
GRAVE – TOMB	TOWN - VILLAGE	GRAVE - T_MB	TOWN - V_LL_G_
GRIN – SMILE	TOXIN - POISON	GRIN - SM_L_	TOXIN - P_ _S_N
HALLWAY – CORRIDOR	VICTOR - CHAMPION	HALLWAY - C_RR_D_R	VICTOR - CH_MP_ _N
HARBOR – PORT	VOCALIST - SINGER	HARBOR - P_RT	VOCALIST - S_NG_R
HARM – INJURY	WRITER - AUTHOR	HARM - _NJ_RY	WRITER - _ _TH_R

Appendix 1.1 – Stimuli for Experiments 1.1A and 1.1B.

Antonym Focused and Divided Attention Experiments (1.2A; 1.2B)			
Read Items		*Generate Items*	
absent – present	inside - outside	absent - p____	inside - o____
agree – disagree	internal - external	agree - d____	internal - e____
alive – dead	last - first	alive - d____	last - f____
alseep – awake	late - early	asleep - a____	late - e____
always – never	left - right	always - n____	left - r____
backward – forward	less - more	backward - f____	less - m____
bad – good	life - death	bad - g____	life - d____
before – after	long - short	before - a____	long - s____
bent – straight	lost - found	bent - s____	lost - f____
better – worse	love - hate	better - w____	love - h____
big – small	low - high	big - s____	low - h____
bride – groom	major - minor	bride - g____	major - m____
brother – sister	mom - dad	brother - s____	mom - d____
ceiling – floor	more - less	ceiling - f____	more - l____
cheap – expensive	near - far	cheap - e____	near - f____
clean – dirty	noisy - quiet	clean - d____	noisy - q____
crooked – straight	north - south	crooked - s____	north - s____
cry – laugh	over - under	cry - l____	over - u____
dangerous – safe	pleasure - pain	dangerous - s____	pleasure - p____
dark – light	pretty - ugly	dark - l____	pretty - u____
day – night	push - pull	day - n____	push - p____
dead – alive	question - answer	dead - a____	question - a____
deep – shallow	remember - forget	deep - s____	remember - f____
depart – arrive	rich - poor	depart - a____	rich - p____
dry – wet	rise - fall	dry - w____	rise - ____
dusk – dawn	shallow - deep	dusk - d____	shallow - d____
early – late	singular - plural	early - l____	singular - p____
east – west	sit - stand	east - w____	sit - s____
enter – exit	smile - frown	enter - e____	smile - f____
entrance – exit	smooth-rough	entrance - e____	smooth - r____
fast – slow	sober - drunk	fast - s____	sober - d____
few – many	soft - hard	few - m____	soft - h____
first – last	stale - fresh	first - l____	stale - f____
float – sink	strong - weak	float - s____	strong - w____
friend – enemy	summer-winter	friend - e____	summer - w____
full – empty	teach - learn	full - e____	teach - l____
higher – lower	thick - thin	higher - l____	thick - t____
horizontal – vertical	top - bottom	horizontal - v____	top - b____
hot – cold	up - down	hot - c____	up - d____
increase – decrease	winner - loser	increase - d____	winner - l____

Appendix 1.2 – Stimuli for Experiments 1.2A and 1.2B.

Idiom Text Color, Text Location, and Background Color Experiments (1.3A; 1.3B; 1.3C) – Part 1	
Read Items	*Generate Items*
a penny saved is a penny (earned)	a penny saved is a penny ( )
a picture is worth a thousand (words)	a picture is worth a thousand ( )
all work and no play makes Jack a dull (boy)	all work and no play makes Jack a dull ( )
along for the (ride)	along for the ( )
back to the drawing (board)	back to the drawing ( )
bark up the wrong (tree)	bark up the wrong ( )
beauty is in the eye of the (beholder)	beauty is in the eye of the ( )
beauty is only skin (deep)	beauty is only skin ( )
beggars can't be (choosers)	beggars can't be ( )
bend over (backwards)	bend over ( )
better safe than (sorry)	better safe than ( )
breathe down his (neck)	breathe down his ( )
bring home the (bacon)	bring home the ( )
chip on his (shoulder)	chip on his ( )
climb on the band (wagon)	climb on the band ( )
cost an arm and a (leg)	cost an arm and a ( )
diamond in the (rough)	diamond in the ( )
don't count your chickens before they've (hatched)	don't count your chickens before they've ( )
don't judge a book by the (cover)	don't judge a book by the ( )
dose of his own (medicine)	dose of his own ( )
Elvis has left the (building)	Elvis has left the ( )
every cloud has a silver (lining)	every cloud has a silver ( )
facts of (life)	facts of ( )
get down off your high (horse)	get down off your high ( )
grab the bull by the (horns)	grab the bull by the ( )
hard nut to (crack)	hard nut to ( )
his bark is worse than his (bite)	his bark is worse than his ( )
hit the nail on the (head)	hit the nail on the ( )
Houston we have a (problem)	Houston we have a ( )
it's no use crying over spilt (milk)	it's no use crying over spilt ( )
it's not over until the fat lady (sings)	it's not over until the fat lady ( )
It’s raining cats and (dogs)	It’s raining cats and ( )
just in the nick of (time)	just in the nick of ( )
just what the doctor (ordered)	just what the doctor ( )
keep an ace up your (sleeve)	keep an ace up your ( )
kill two birds with one (stone)	kill two birds with one ( )
last but not (least)	last but not ( )
lay his cards on the (table)	lay his cards on the ( )
leave a bad taste in his (mouth)	leave a bad taste in his ( )
let the cat out of the (bag)	let the cat out of the ( )

Idiom Text Color, Text Location, and Background Color Experiments (1.3A; 1.3B; 1.3C) – Part 2	
Read Items	*Generate Items*
lie through one's (teeth)	lie through one's ( )
light at the end of the (tunnel)	light at the end of the ( )
like a fish out of (water)	like a fish out of ( )
like taking candy from a (baby)	like taking candy from a ( )
looking for a needle in a (haystack)	looking for a needle in a ( )
new kid on the (block)	new kid on the ( )
on the tip of his (tongue)	on the tip of his ( )
once in a blue (moon)	once in a blue ( )
one man's trash is another man's (treasure)	one man's trash is another man's ( )
out in left (field)	out in left ( )
out of sight, out of (mind)	out of sight, out of ( )
out of thin (air)	out of thin ( )
pass with flying (colors)	pass with flying ( )
put on your thinking (cap)	put on your thinking ( )
put the pedal to the (metal)	put the pedal to the ( )
put your best foot (forward)	put your best foot ( )
roll out the red (carpet)	roll out the red ( )
Rome was not built in a (day)	Rome was not built in a ( )
run into a brick (wall)	run into a brick ( )
saved by the (bell)	saved by the ( )
skate on thin (ice)	skate on thin ( )
skeleton in the (closet)	skeleton in the ( )
spill the (beans)	spill the ( )
stir up a hornets (nest)	stir up a hornets ( )
talk a mile a (minute)	talk a mile a ( )
take his breath (away)	take his breath ( )
take with a grain of (salt)	take with a grain of ( )
that's the way the cookie (crumbles)	that's the way the cookie ( )
that's the way the wind (blows)	that's the way the wind ( )
the early-bird catches the (worm)	the early-bird catches the ( )
the ends justifies the (means)	the ends justifies the ( )
two peas in a (pod)	two peas in a ( )
up the creek without a (paddle)	up the creek without a ( )
wake up on the wrong side of the (bed)	wake up on the wrong side of the ( )
walk a mile in someone else's (shoes)	walk a mile in someone else's ( )
where there's smoke there's (fire)	where there's smoke there's ( )
wipe the smile off his (face)	wipe the smile off his ( )
wipe the smile off his (face)	wipe the smile off his ( )
x marks the (spot)	x marks the ( )
you can't make an omelet without breaking a few (eggs)	you can't make an omelet without breaking a few ( )

Appendix 1.3 – Stimuli for Experiments 1.3A – 1.3C.

Picture Fragment Completion Experiments (1.4A; 1.4B)			
Read Items		*Generate Items*	
Airplane	garbage can	_ _rpl_n_	g_rb_g_ c_n
Anchor	glasses	_nch_r	gl_ss_s
Apple	guitar	_ppl_	g_ _t_r
Arm	hammer	_rm	h_mm_r
Arrow	heart	_rr_w	h_ _rt
Asparagus	helicopter	_sp_r_g_s	h_l_c_pt_r
Axe	key	_x_	k_y
banana	kite	b_n_n_	k_t_
baseball bat	knife	b_s_b_ll b_t	kn_f_
basket	ladder	b_sk_t	l_dd_r
bed	lamp	b_d	l_mp
bell	leaf	b_ll	l_ _f
belt	leg	b_lt	l_g
bicycle	light bulb	b_cycl_	l_ght b_lb
bird	lion	b_rd	l_ _n
book	lips	b_ _k	l_ps
boot	lock	b_ _t	l_ck
bottle	mitten	b_ttl_	m_tt_n
bowl	monkey	b_wl	m_nk_y
bread	motorcycle	br_ _d	m_t_rcycl_
broom	mouse	br_ _m	m_ _s_
bus	mushroom	b_s	m_shr_ _m
butterfly	onion	b_tt_rfly	_n_ _n
cake	pen	c_k_	p_n
camel	piano	c_m_l	p_ _n_
candle	pineapple	c_ndl_	p_n_ _ppl_
car	pumpkin	c_r	p_mpk_n
carrot	rabbit	c_rr_t	r_bb_t
cat	ruler	c_t	r_l_r
chair	sailboat	ch_ _r	s_ _lb_ _t
comb	sandwich	c_mb	s_ndw_ch
couch	scissors	c_ _ch	sc_ss_rs
cow	toaster	c_w	t_ _st_r
dog	traffic light	d_g	tr_ff_c l_ght
door	train	d_ _r	tr_ _n
ear	umbrella	_ _r	_mbr_ll_
elephant	watch	_l_ph_nt	w_tch
fish	whistle	f_sh	wh_stl_
flower	windmill	fl_w_r	w_ndm_ll
frog	window	fr_g	w_nd_w

Appendix 1.4 – Stimuli for Experiments 1.4A and 1.4B.

Category Retrieval Blocking Experiment (1.5)

Category	*Read – Ex1*	*Generate – Ex1*	*Read – Ex2*	*Generate – Ex2*
appliance	stove	st_v_	blender	bl_nd_r
beverage	coffee	c_ff_ _	milk	m_lk
bird	robin	r_b_n	sparrow	sp_rr_w
candy	chocolate	ch_c_l_t_	lollipop	l_ll_p_p
cheese	cheddar	ch_dd_r	swiss	sw_ss
clergymen	priest	pr_ _st	bishop	b_sh_p
clothing	socks	s_cks	shirt	sh_rt
color	green	gr_ _n	yellow	y_ll_w
crime	robbery	r_bb_ry	murder	m_rd_r
dance	waltz	w_ltz	tango	t_ng_
dessert	cupcake	c_pc_k_	pudding	p_dd_ng
disaster	hurricane	h_rr_c_n_	tornado	t_rn_d_
disease	cancer	c_nc_r	flu	fl_
distance	mile	mile	yard	y_rd
dog	labrador	l_br_d_r	poodle	p_ _dl_
drug	cocaine	c_c_ _n_	ecstasy	ecst_sy
dwelling	house	h_ _s_	cabin	c_b_n
electronic	television	t_l_v_s_ _n	computer	c_mp_t_r
emotion	anger	ang_r	happiness	h_pp_n_ss
fabric	cotton	c_tt_n	wool	w_ _l
fish	salmon	s_lm_n	trout	tr_ _t
flavor	salty	s_lty	sweet	sw_ _t
flower	rose	r_s_	tulip	t_l_p
fruit	mango	m_ng_	lemon	l_m_n
fuel	gasoline	g_s_l_n_	petroleum	p_tr_l_ _m
furniture	table	t_bl_	desk	d_sk
gem	diamond	d_ _m_nd	emerald	em_r_ld
grain	rice	r_c_	wheat	wh_ _t
hat	bonnet	b_nn_t	sombrero	s_mbr_r_
herb	basil	b_s_l	parsley	p_rsl_y
insect	mosquito	m_sq_ _t_	ant	_nt
instrument	clarinet	cl_r_n_t	drum	dr_m
jewelry	ring	r_ng	necklace	n_ckl_c_
makeup	lipstick	l_pst_ck	mascara	m_sc_r_
math	calculus	c_lc_l_s	geometry	g_ _m_try
metal	copper	c_pp_r	platinum	pl_t_n_m
money	dollar	d_ll_r	nickel	n_ck_l
monster	mummy	m_mmy	vampire	v_mp_r_
month	March	M_rch	October	Oct_b_r
music	jazz	j_zz	classical	cl_ss_c_l
occupation	lawyer	l_wy_r	dentist	d_nt_st
organ	lung	l_ng	kidney	k_dn_y
planet	Mars	M_rs	Jupiter	J_p_t_r
relative	uncle	uncl_	sister	s_st_r
reptile	snake	sn_k_	lizard	l_z_rd
rodent	rat	r_t	hamster	h_mst_r
science	chemistry	ch_m_stry	biology	b_ _l_gy
sense	smell	sm_ll	touch	t_ _ch
shape	circle	c_rcl_	square	sq_ _r_
shoe	sneaker	sn_ _k_r	sandal	s_nd_l
sport	soccer	s_cc_r	baseball	b_s_b_ll
tool	hammer	h_mm_r	wrench	wr_nch
toy	puzzle	p_zzl_	doll	toy-d_ll
tree	redwood	r_dw_ _d	maple	m_pl_
utensil	fork	f_rk	spoon	sp_ _n
vegetable	lettuce	l_tt_c_	carrot	c_rr_t
vehicle	bicycle	b_cycl_	car	c_r
weapon	sword	sw_rd	gun	g_n
weather	sun	s_n	rain	r_ _n
weight	pound	p_ _nd	kilogram	k_l_gr_m

Appendix 1.5 – Stimuli for Experiment 1.5.

Chapter 3: The Universality of the Generation Effect

Experiment 2.1 (Idiom Text Color)

Cross-cultural Differences in Learning Style

The positive generation effect on item memory has been consistent, robust, and convincing, benefitting retrieval by nearly 10 percent as compared to passive study. Outside of the United States, the generation effect has been well-documented in European and North American countries, appearing in France (Taconnat & Isingrini, 2004), Sweden (Lundstrom et al., 2003), Russia (Voskresenskaia, 2010), Poland (Nieznański, 2012), Canada (MacLeod et al., 2012), and other countries. However, the universality of this effect among East Asian populations remains untested. Vast differences in learning styles between East Asian and Western European (and American) cultures have major implications for the effects of active generation.

Tweed and Lehman (2002) argued that Western thought stresses a Socratic learning method based on questioning and evaluating self-directed knowledge. In contrast, Eastern thought stresses a Confucian learning method based on essential knowledge, pragmatic information, and truth learned through collective analysis. It is important to note that while some researchers have mischaracterized this distinction as purely deep versus shallow, Confucian learning does stress effortful learning in combining memorization with understanding (Tweed & Lehman, 2002). Regardless, it appears that the act of self-generating information, reminiscent of the Socratic learning method, may be a more natural practice in America.

The shaping of these Socratic and Confucian learning styles begins early in life. Wang and Brockmeier (2002) observed parent-child memory sharing between cultures. American parents tended to co-recreate stories with their children, emphasizing elaboration and embellishment of self-focused and interesting activities, while Chinese parents stressed the repetition of mundane, socially relevant activities. The influence of these different learning styles on memory is apparent when investigating earliest childhood memories, as American participants recall more specific, self-focused, elaborative, and emotional memories, while Chinese participants recall more skeletal, relationship-centered, routine-related, and unemotional memories (Conway, Wang, Hanyu, & Haque, 2005; Wang & Ross, 2005).

Given this discrepancy in learning style, the present study assessed the universality of the effect of self-generation on memory for both item and context information. To our knowledge, this is the first study to evaluate cross-cultural influences on the generation effect. One possibility is that the generation effect is easily assimilated by Americans because the technique exploits a natural Socratic learning style. East Asians might find the technique less familiar and thus not easily adopt it. By this view, Americans may exhibit stronger positive and negative generation effects (as a product of a potential item-context tradeoff) than East Asians. Yet, another possibility is that the East Asians will be sensitive to the powerful effects of generation, find it to be an effective encoding strategy, and thus exhibit generation effects similar to Americans. In this first experiment, American and Chinese individuals were presented culture-based idioms in either red or green color and asked to generate or simply read the last word of each idiom. Memory for these words and the colors in which they were presented was assessed.

Materials and Methods

Participants

Fifty UC Berkeley undergraduate students participated 1 one hour of research participation credit for partial fulfillment of a psychology course requirement. Forty-seven undergraduate students from Beijing University and Tsinghua University in Beijing, China participated in exchange for ¥15 RMB (approximately 2 US dollars).

Materials

Stimuli consisted of 40 idioms commonly used in their respective language. Half of the stimuli were presented in the read condition, such that idioms were presented in their complete form with the last word bounded by parentheses (e.g., *a penny saved is a penny (earned)*). The other half were presented in the generate condition, such that the last word was missing and replaced by a blank space bounded by parentheses (e.g., *a penny saved is a penny (   )*). We will refer to the last words in the idioms as the target words. The idioms were very familiar, as pilot studies showed that individuals from both countries who were presented with their respective idioms could generate the last word with an accuracy level greater than 98%. In both conditions, the target word was marked by parentheses. Half of the idioms were presented in green, and the other half in red. Both encoding strategy (generate vs. read) and source (green vs. red) were manipulated within participants and counterbalanced such that each idiom appeared in each possible combination of conditions with equal frequency across participants. American idioms were between 3 and 10 words in length with target words consisting of 3 to 9 letters. Chinese idioms were between 4 and 12 characters in length and all targets were represented as one character.

A distractor task was presented between the study and test phase, which consisted of having individuals complete up to 162 simple math problems (addition, subtraction, multiplication, and division) for a 3-minute period. Thereafter, a recognition test was administered in which 80 words (40 target words, 40 new words) were presented in a random order. New words came from the last words of idioms not presented for study. Stimuli appeared as old and new with equal frequency across participants.

Procedure

Participants gave informed consent and were then seated in front of a computer monitor. They were instructed that they would be presented with idioms and that some of them would have the last word missing. They were also told that some of the idioms would be presented in red and others in green. Regardless of encoding condition (read or generate), participants were asked to write down the last word of each idiom. This ensured that the target word was correctly identified, enabling the elimination of any incorrect words from further analysis. Participants were also instructed to remember both the idiom and its color for a later memory test. Two practice trials were presented (1 read and 1 generate) to ensure that participants understood the task. Participants were then presented a series of 40 randomly ordered read and generate idioms. Each study trial began with a 1-second fixation interval followed by a 7-second presentation of an idiom (Figure 2.1A, 2.1B). Following the encoding phase, participants performed the 3-minute math distractor task.

For the recognition test, participants viewed a series of 80 randomly ordered words (40 target words, 40 new words) in black font. Item and source recognition memory were tested in a 3-alternative, multiple-choice test in which participants decided for each test word whether it was old and previously presented in red (R), old and previously presented in green (G), or new (N).

The recognition test was self-paced with the next test trial initiated after each recognition response.

Results

Item recognition performance (see Figure 2.1C) was based on responses of "old" to target words, regardless of source (i.e., color memory) accuracy. We subjected item recognition performance to a 2 x 2 ANOVA with encoding condition (generate vs. read) and cultural groups as variables. There was a main effect of encoding type, with the generation condition producing significantly better item recognition than the read condition ($F(1,95) = 36.43$, $p < .001$). While there was a main effect for culture ($F(1,95) = 6.11$, $p = .02$), the positive generation effect was comparable across cultures as the culture x encoding condition interaction was not significant ($F(1,95) = .01$, $p = .91$). The positive generation effect was significant in each culture. Specifically, American participants correctly recognized 69% of generated items and 57% of read items, $t(49) = 4.17$, $p < .001$, and Chinese participants correctly recognized 61% of generated items and 49% of read items, $t(47) = 4.38$, $p < .001$, which amounted to a boost of 12% in item recognition for both groups as a result of generating target words. False alarm rates (i.e., identifying a new item as "old") were comparable across groups (10% for USA participants, 12% for Chinese participants).

As shown in Figure 2.1C, participants exhibited negative generation effects for source (color) memory ($F(1,95) = 12.40$, $p = .001$). As with item recognition, there was a main effect for cultural group ($F(1,95) = 4.54$, $p = .04$), but no encoding condition x cultural group interaction ($F(1,95) = .02$, $p = .89$). Simple effects showed significant negative generation effects for both cultures. Among American participants, color accuracy was 59% in the generate condition and 68% in the read condition, $t(49) = 2.65$, $p = .01$, while for Chinese participants, color accuracy was 52% in the generate condition and 61% in the read condition, $t(47) = 2.35$, $p = .02$, a 9% drop in source memory for generated words compared to read words in both cultural groups.

Experiment 2.2 (Idiom Location)

Cross-cultural Differences in Cognition

Findings from the first experiment demonstrated comparable generation effects between American and Chinese individuals. Specifically, both groups exhibited positive generation effects for item memory and negative generation effects for color memory. Yet, as mentioned earlier, memory for some contextual features such as the spatial location of study items often fail to show negative generation effects (Marsh, 2006; Mulligan, 2004). Mulligan (2011) argued that generation impairs memory for intrinsic contextual features, while leaving extrinsic contextual features unaffected. It is possible, however, that cultural differences in cognition, such as field-dependence, lead to different types of contextual features being processed either intrinsically or extrinsically.

According to Markus and Kitayama (1991), the East-Asian definition of the self is construed as interdependent with others and leads to a holistic cognitive style in which one constantly scans the environment for information (field dependence). As described by Nisbett and colleagues, East Asians are "…holistic, attending to the entire field and assigning causality to it, making relatively little use of categories and formal logic" (Nisbett, Peng, Choi, & Norenzayan, 2001, page 291). In contrast, the American definition of the self is construed as independent of others, resulting in a more analytic cognitive style in which one focuses on target objects at the expense of scanning the environment (field independence). Nisbett and colleagues describe this Western analytic nature as "…paying attention primarily to the object and the categories to which it belongs (Nisbett, Peng, Choi, & Norenzayan, 2001, page 291). For example, when asked to photograph a portrait of another person, American participants took close-up shots, capturing only the individual, whereas Japanese participants took more inclusive photographs, allowing for greater presence of background and context (Nisbett & Masuda, 2003).

Numerous studies have illustrated these differences in field dependence. In one experiment, participants viewed a box with a short line drawn from the top, and were asked to redraw the line to either its absolute or relative length in a different sized box (Kitayama, Duffy, Kawamura, & Larsen, 2003). While American participants made smaller errors in the absolute condition, Chinese participants made smaller errors in the relative condition. In a later neuroimaging study, Hedden, Ketay, Aron, Markus, and Gabrieli (2008) revealed that participants had greater parietal and frontal lobe activation when performing their culturally more difficult task, indicating the need for more cognitive control. Further, attention and memory differences occur when viewing focal objects surrounded by complex scenes. Masuda and Nisbett (2006) found that Japanese participants noticed fewer focal and more background changes in a change blindness study. Masuda and Nisbett (2001) also found that Japanese participants were faster and more accurate when recognizing focal objects paired with previously presented backgrounds as compared with novel backgrounds, whereas American participants were unaffected by background status. Extending these findings, eye-tracking revealed that not only did American participants look at the focal object more than 100 milliseconds sooner than did Asian participants, after 500 milliseconds, American participants made longer fixations on the focal object, while Asian participants made more saccadic eye movements to the background (Chua, Boland, & Nisbett, 2005). Even at the neural level, Gutchess, Welsh, Boduroĝlu, and Park (2006) found that Americans had greater activity in object processing regions of the brain, including bilateral middle temporal gyrus, left angular gyrus, and right supramarginal gyrus. As far as location is concerned, it is argued that Chinese people truly internalize location, as in the past people often identified the self as where they came from (Hsu, 1981).

Given these cross-cultural differences in the way in which East-Asians and Americans process focal objects in relationship to the environment, cultural differences for the way in which generation influences location memory may exist. In the first set of experiments, there was a negative generation effect for memory for color. Mulligan (2011) argued for an intrinsic/extrinsic TAP account of the generation effect in which generation promotes conceptual processing, benefiting later item recognition. Passive study, on the other hand, promotes perceptual processing, which benefits memory for intrinsic contextual details such as font color and leaves extrinsic contextual details such as location unaffected. While location is likely processed as an extrinsic contextual detail among American participants, it may be processed intrinsically among Chinese participants. To the extent that Chinese individuals process location as an intrinsic contextual detail, an intrinsic/extrinsic TAP account (Mulligan, 2011) predicts a negative generation effect for location similar to that of color. Experiment 2.2 therefore sought to test whether a negative generation effect exists for location memory among Chinese participants in the absence of such an effect among American participants.

Materials and Methods

Participants

Forty-eight UC Berkeley undergraduate students participated for 1 hour of research participation credit for partial fulfillment of a psychology course requirement. Thirty-four undergraduate students from Beijing University and Tsinghua University in Beijing, China participated in exchange for ¥15 RMB (approximately 2 US dollars).

Materials

All materials were identical to Experiment 2.1, except that location, rather than color, was manipulated for the source memory test. Half of the idioms were presented on the top of the screen, and the other half were presented on the bottom of the screen (Figures 2.2A, 2.2B). Both encoding strategy (generate vs. read) and location (top vs. bottom) were manipulated within participants and counterbalanced so that each idiom appeared in each possible combination of conditions with equal frequency.

Procedure

The procedure was identical to that of Experiment 2.1, except that participants were instructed that some of the idioms would be presented at the top of the computer screen, and the others at the bottom of the computer screen. Participants were instructed to remember both the idiom and its location for a later memory test. Item and source memory were assessed using a 3-alternative, multiple-choice test in which participants were presented test words in the middle of the screen and decided whether each word was old and had been previously presented on the top half of the screen (T), old and previously presented on the bottom half (B), or was a new word (N).

Results

Figure 2.2C displays generation effects for item and source (spatial location) recognition. As in Experiment 2.1, there was an overall positive generation effect for item recognition ($F(1,80) = 44.24$, $p < .001$). American participants correctly recognized 71% of generated items and 60% of read items, $t(47) = 5.36$, $p < .001$. Chinese participants correctly recognized 58% of generated items and 46% of read items, $t(33) = 4.12$, $p < .001$. Both groups exhibited comparable boosts in performance as a result of generating target words (USA participants = 11% boost, Chinese participants = 12% boost). False alarm rates (i.e., identifying a new item as “old”) were comparable across groups (6% for USA participants, 9% for Chinese participants). Again, the main effect of group ($F(1,80) = 14.80$, $p < .001$) was significant, while the condition type x group interaction ($F(1,80) = .09$, $p = .76$) was not.

The pattern of performance for source memory of spatial location was entirely different from the findings of color memory observed in Experiment 2.1. For American participants, there was a nonsignificant positive generation effect, as source accuracy was 73% in the generate condition and 68% in the read condition $t(47) = 1.80$, $p = .08$. However, Chinese participants exhibited a significant negative generation effect, with source accuracies of 66% in the generate condition and 75% in the read condition $t(33) = 2.56$, $p = .02$. This pattern was confirmed by a significant encoding condition x cultural group interaction ($F(1,80) = 10.34$, $p < .01$) and nonsignificant main effects for encoding condition ($F(1,80) = 1.14$, $p = .29$) and group ($F(1,80) < .01$, $p = .98$).

Discussion

In general, American participants exhibited better overall item memory than Chinese participants. As it was not entirely possible to control for the exact target words used across cultures, such effects may be attributable to item effects. More importantly, there was a strong, consistent positive generation effect for item memory for both American and East-Asian participants, demonstrating the universal benefit of active generation as a powerful and robust mnemonic technique. Thus, despite potential differences in learning styles, active generation enhanced item recognition performance.

Interestingly, there were some differences between groups in the manner in which contextual information was remembered. Across cultures, a negative generation effect was observed for color memory. Yet, memory for the spatial location of items differed between cultures as a function of active generation. Among American participants, generation had no significant effect on location memory, a finding that has been previously observed (Mulligan, 2004; Mulligan et al., 2006). Among Chinese participants, however, generation significantly impaired location memory to a similar degree as color memory. To our knowledge, a negative generation effect for spatial context has never been reported. This finding, however, helps to explain the inconsistency of the generation effect that has been observed for location memory. As stated by Mulligan (2004), a TAP account predicts that active generation promotes conceptual processing, whereas reading promotes perceptual processing. In turn, generation benefits performance on conceptual retrieval tasks such as item recognition. However, generation impairs performance on perceptual tasks such as the retrieval of intrinsic contextual information. Memory for extrinsic contextual information, on the other hand, is unaffected (Mulligan, 2011). Among both cultures, color is likely an intrinsic contextual detail, explaining why color memory may benefit from perceptual processing during encoding. This story is entirely different for location, however. American participants are field-independent, ignoring the environment when analyzing a focal object. For this reason, American participants likely process location as an extrinsic contextual detail. However, Chinese participants are more field-dependent (Markus & Kitayama, 1991) and may process location as an intrinsic contextual detail, similar to the way in which both groups process color information, resulting in a negative generation effect.

Finally, this study demonstrated that while the similarities in cognition between cultures greatly outweigh the differences, differences do exist. Even basic cognitive functions such as perceptual memory appear to be influenced by culture. Interestingly, these differences likely occur during encoding. The generation effects were calculated by comparing generate versus read conditions within each culture. Therefore, unless one argues that the qualitative manner in which information is retrieved was affected by the way in which it was initially encoded, any observed effects cannot be the product of cultural differences in representational or retrieval biases, as these were held constant.

Figures

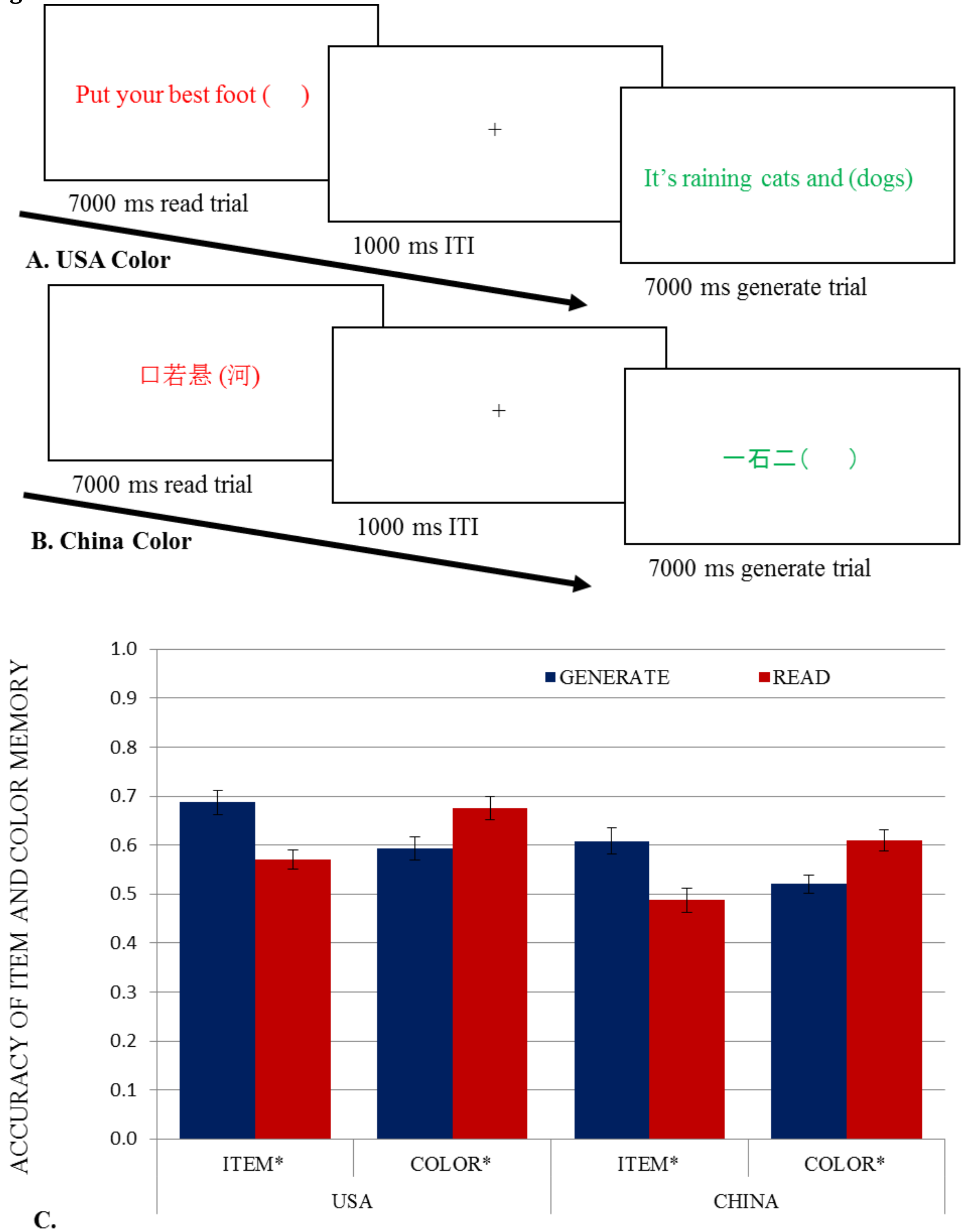

Figure 2.1 – (A) Encoding task for Experiment 2.1 (USA). (B) Encoding task for Experiment 2.1 (China). (C) Behavioral results for Experiment 2.1 (USA and China).

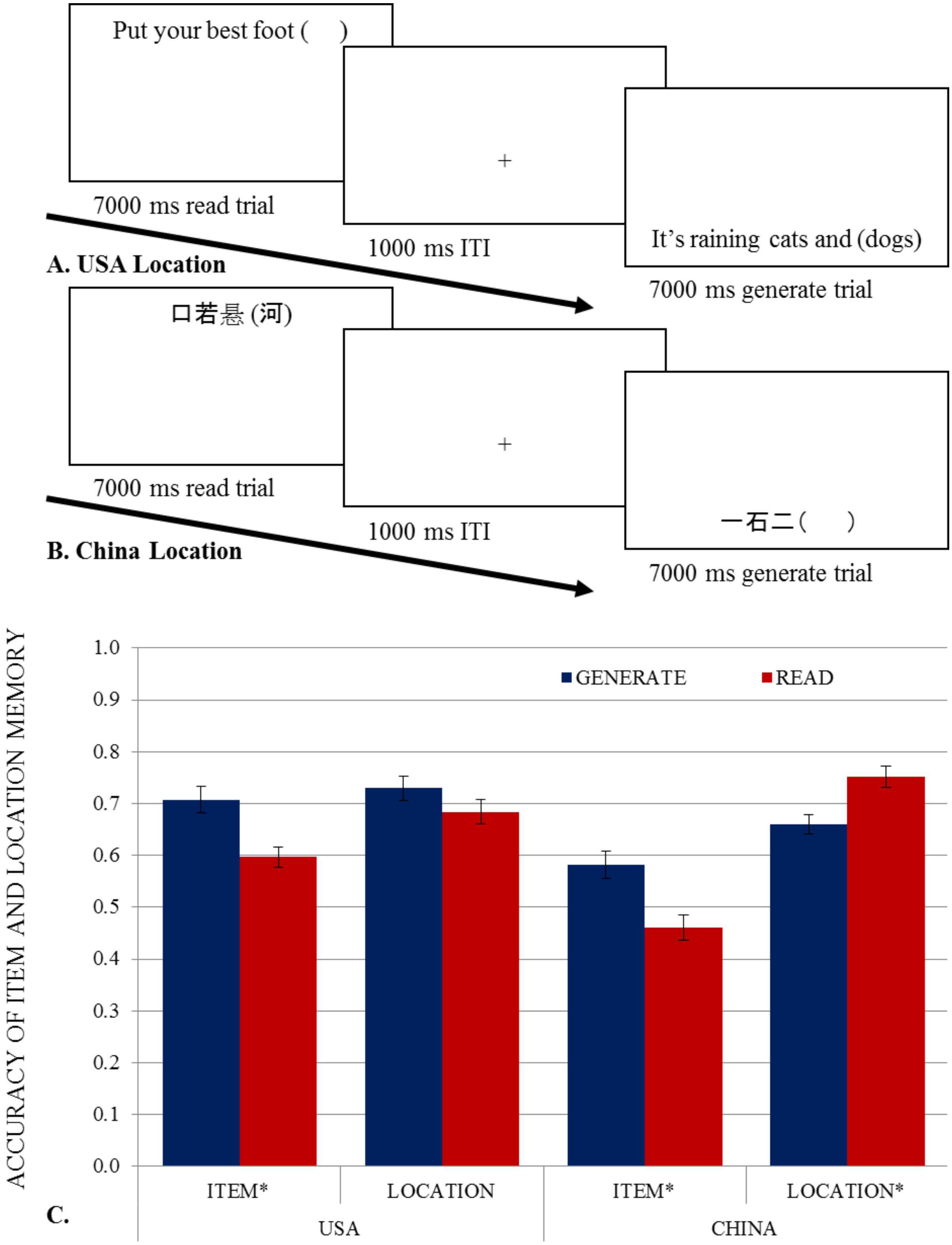

Figure 2.2 – (A) Encoding task for Experiment 2.2 (USA). (B) Encoding task for Experiment 2.2 (China). (C) Behavioral results for Experiment 2.2 (USA and China).

Appendices

Idiom Text Color and Location Experiments - English (2.1; 2.2) – Part 1	
Read Items	*Generate Items*
a penny saved is a penny (earned)	a penny saved is a penny ( )
a picture is worth a thousand (words)	a picture is worth a thousand ( )
all work and no play makes Jack a dull (boy)	all work and no play makes Jack a dull ( )
along for the (ride)	along for the ( )
back to the drawing (board)	back to the drawing ( )
bark up the wrong (tree)	bark up the wrong ( )
beauty is in the eye of the (beholder)	beauty is in the eye of the ( )
beauty is only skin (deep)	beauty is only skin ( )
beggars can't be (choosers)	beggars can't be ( )
bend over (backwards)	bend over ( )
better safe than (sorry)	better safe than ( )
breathe down his (neck)	breathe down his ( )
bring home the (bacon)	bring home the ( )
chip on his (shoulder)	chip on his ( )
climb on the band (wagon)	climb on the band ( )
cost an arm and a (leg)	cost an arm and a ( )
diamond in the (rough)	diamond in the ( )
don't count your chickens before they've (hatched)	don't count your chickens before they've ( )
don't judge a book by the (cover)	don't judge a book by the ( )
dose of his own (medicine)	dose of his own ( )
Elvis has left the (building)	Elvis has left the ( )
every cloud has a silver (lining)	every cloud has a silver ( )
facts of (life)	facts of ( )
get down off your high (horse)	get down off your high ( )
grab the bull by the (horns)	grab the bull by the ( )
hard nut to (crack)	hard nut to ( )
his bark is worse than his (bite)	his bark is worse than his ( )
hit the nail on the (head)	hit the nail on the ( )
Houston we have a (problem)	Houston we have a ( )
it's no use crying over spilt (milk)	it's no use crying over spilt ( )
it's not over until the fat lady (sings)	it's not over until the fat lady ( )
its raining cats and (dogs)	its raining cats and ( )
just in the nick of (time)	just in the nick of ( )
just what the doctor (ordered)	just what the doctor ( )
keep an ace up your (sleeve)	keep an ace up your ( )
kill two birds with one (stone)	kill two birds with one ( )
last but not (least)	last but not ( )
lay his cards on the (table)	lay his cards on the ( )
leave a bad taste in his (mouth)	leave a bad taste in his ( )
let the cat out of the (bag)	let the cat out of the ( )

Idiom Text Color and Location Experiments - English (2.1; 2.2) – Part 2	
Read Items	*Generate Items*
lie through one's (teeth)	lie through one's ( )
light at the end of the (tunnel)	light at the end of the ( )
like a fish out of (water)	like a fish out of ( )
like taking candy from a (baby)	like taking candy from a ( )
looking for a needle in a (haystack)	looking for a needle in a ( )
new kid on the (block)	new kid on the ( )
on the tip of his (tongue)	on the tip of his ( )
once in a blue (moon)	once in a blue ( )
one man's trash is another man's (treasure)	one man's trash is another man's ( )
out in left (field)	out in left ( )
out of sight, out of (mind)	out of sight, out of ( )
out of thin (air)	out of thin ( )
pass with flying (colors)	pass with flying ( )
put on your thinking (cap)	put on your thinking ( )
put the pedal to the (metal)	put the pedal to the ( )
put your best foot (forward)	put your best foot ( )
roll out the red (carpet)	roll out the red ( )
rome was not built in a (day)	rome was not built in a ( )
run into a brick (wall)	run into a brick ( )
saved by the (bell)	saved by the ( )
skate on thin (ice)	skate on thin ( )
skeleton in the (closet)	skeleton in the ( )
spill the (beans)	spill the ( )
stir up a hornets (nest)	stir up a hornets ( )
talk a mile a (minute)	talk a mile a ( )
take his breath (away)	take his breath ( )
take with a grain of (salt)	take with a grain of ( )
that's the way the cookie (crumbles)	that's the way the cookie ( )
that's the way the wind (blows)	that's the way the wind ( )
the early-bird catches the (worm)	the early-bird catches the ( )
the ends justifies the (means)	the ends justifies the ( )
two peas in a (pod)	two peas in a ( )
up the creek without a (paddle)	up the creek without a ( )
wake up on the wrong side of the (bed)	wake up on the wrong side of the ( )
walk a mile in someone else's (shoes)	walk a mile in someone else's ( )
where there's smoke there's (fire)	where there's smoke there's ( )
wipe the smile off his (face)	wipe the smile off his ( )
x marks the (spot)	x marks the ( )
you can't make an omelet without breaking a few (eggs)	you can't make an omelet without breaking a few ( )

Appendix 2.1 –Stimuli for Experiments 2.1 and 2.2 (English).

Idiom Text Color and Location Experiments - Mandarin (2.1; 2.2) – Part 1

Read Items	*Generate Items*
一朝被蛇咬，三年怕井 (绳)	一朝被蛇咬，三年怕井 ( )
一石二(鸟)	一石二( )
一筹莫(展)	一筹莫( )
一针见(血)	一针见( )
万事具备,只欠东(风)	万事具备,只欠东( )
三天打鱼，两天晒(网)	三天打鱼，两天晒( )
不入虎穴，焉得虎 (子)	不入虎穴，焉得虎 ( )
不听老人言，吃亏在眼 (前)	不听老人言，吃亏在眼 ( )
不是省油的(灯)	不是省油的( )
不给规矩，不成方 (圆)	不给规矩，不成方 ( )
不见真佛不烧(香)	不见真佛不烧( )
不食人间烟(火)	不食人间烟( )
书到用时方恨 (少)	书到用时方恨 ( )
人往高处走，水往低处 (流)	人往高处走，水往低处 ( )
人无远虑，必有近 (忧)	人无远虑，必有近 ( )
以卵击石，自不量 (力)	以卵击石，自不量 ( )
便宜没好(货)	便宜没好( )
倾家荡(产)	倾家荡( )
倾盆大(雨)	倾盆大( )
冤有头，债有(主)	冤有头，债有( )
冰冻三尺，非一日之(寒)	冰冻三尺，非一日之( )
刀子嘴，豆腐(心)	刀子嘴，豆腐( )
初出茅(庐)	初出茅( )
功成名(就)	功成名( )
匪夷所(思)	匪夷所( )
千里之行，始于足 (下)	千里之行，始于足 ( )
又想马儿跑，又想马儿不吃 (草)	又想马儿跑，又想马儿不吃 ( )
口若悬(河)	口若悬( )
各打五十大(板)	各打五十大( )
君子报仇，十年不 (晚)	君子报仇，十年不 ( )
大树底下好乘 (凉)	大树底下好乘 ( )
大水冲了龙王(庙)	大水冲了龙王( )
大海捞(针)	大海捞( )
天无绝人之 (路)	天无绝人之 ( )
失败乃成功之 (母)	失败乃成功之 ( )
如履薄(冰)	如履薄( )
实践出真 (知)	实践出真 ( )
对症下(药)	对症下( )
尺有所短，寸有所 (长)	尺有所短，寸有所 ( )
强扭的瓜果不 (甜)	强扭的瓜果不 ( )

Idiom Text Color and Location Experiments - Mandarin (2.1; 2.2) – Part 2	
Read Items	*Generate Items*
擒贼先擒 (王)	擒贼先擒 ( )
早起的鸟儿有虫(吃)	早起的鸟儿有虫( )
明人不做暗 (事)	明人不做暗 ( )
明枪好躲，暗箭难 (防)	明枪好躲，暗箭难 ( )
有志者， 事竟 (成)	有志者， 事竟 ( )
有钱能使鬼推 (磨)	有钱能使鬼推 ( )
杞人忧(天)	杞人忧( )
柳暗花明又一(村)	柳暗花明又一( )
横看成岭侧成(峰)	横看成岭侧成( )
江山易改， 本性难 (移)	江山易改， 本性难 ( )
洗心革(面)	洗心革( )
物以类聚 人以群 (分)	物以类聚 人以群 ( )
狗嘴吐不出象(牙)	狗嘴吐不出象( )
狗眼看人(低)	狗眼看人( )
玉不琢， 不成 (器)	玉不琢， 不成 ( )
留得青山在， 不怕没柴 (烧)	留得青山在， 不怕没柴 ( )
百般滋味在心(头)	百般滋味在心( )
真相大(白)	真相大( )
眼不见，心不(烦)	眼不见，心不( )
睁着眼睛说瞎(话)	睁着眼睛说瞎( )
福无双至， 祸不单 (行)	福无双至， 祸不单 ( )
绳锯木断，水滴石 (穿)	绳锯木断，水滴石 ( )
聪明反被聪明 (误)	聪明反被聪明 ( )
若要人不知， 除非己莫 (为)	若要人不知， 除非己莫 ( )
行云流 (水)	行云流 ( )
赔了夫人又折 (兵)	赔了夫人又折 ( )
这山望着那山 (高)	这山望着那山 ( )
逆水行舟， 不进则 (退)	逆水行舟， 不进则 ( )
逢场作(戏)	逢场作( )
隔行如隔 (山)	隔行如隔 ( )
飞蛾扑火，自取灭 (亡)	飞蛾扑火，自取灭 ( )
饥不择(食)	饥不择( )
饭后百步走，活到九十 (九)	饭后百步走，活到九十 ( )
麻雀虽小，五脏俱 (全)	麻雀虽小，五脏俱 ( )

Appendix 2.2 –Stimuli for Experiments 2.1 and 2.2 (Mandarin).

Chapter 4: Mechanisms Underlying the Generation Effect

Introduction

As previously stated, psychological theories have suggested that the generation effect is driven by a host of internally mediated, top-down processes such as conceptual analysis (Jacoby, 1983), semantic integration (McElroy, 1987), item distinctiveness (Begg et al., 1989; Hunt & McDaniel, 1993; Kinoshita, 1989), and selective attention (Jurica & Shimamura, 1999; Tyler et al., 1979). Such processes may be defined more distinctly by addressing the neural processes that drive the generation effect. Yet despite extensive behavioral analyses (Bertsch et al., 2007), no published study, to our knowledge, has assessed the neural correlates of the generation effect. Candidate structures that could potentially drive this active encoding effect include those involved in top–down executive processing. For example, semantic retrieval and conceptual analysis, which lead to elaborative, long-lasting memory traces (Craik & Lockhart, 1972), have been linked to activity in the left inferior frontal gyrus (IFG) (Baker, Sanders, Maccotta, & Buckner, 2001; Bookheimer, 2002; Poldrack et al., 1999). Other prefrontal regions, particularly in the dorsolateral prefrontal cortex (dlPFC), such as the middle frontal gyrus (MFG), have been associated with other executive control processes presumed to interact dynamically with posterior regions (Miller & Cohen, 2001; Shimamura, 2000, 2008). For example, dlPFC regions have been associated with a variety of working memory processes that lead to long–term memory formation (Paller and Wagner, 2002), such as refreshing perceptual features, maintaining items in memory, manipulating information, and selecting items for retrieval (Cohen et al., 1997; D'Esposito et al., 1997; D'Esposito, Postle, Ballard, & Lease, 1999; Johnson et al., 2005; Postle, 2006; Raye, Johnson, Mitchell, Reeder, & Greene, 2002; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997).

To the extent that the generation effect is mediated by item distinctiveness, it may be that posterior regions involved in verbal or item analysis, such as the left middle temporal gyrus (MTG) and lateral occipital cortex (LOC) (Binder, Desai, Graves, & Conant, 2009; Cabeza & Nyberg, 2000; Malach et al., 1995) also become particularly involved. Additionally, one might predict increased activation in the anterior cingulate cortex (ACC), which is involved in conflict monitoring (van Veen, Cohen, Botvinick, Stenger, & Carter, 2001) and verbal generation (Barch, Braver, Sabb, & Noll, 2000). Finally, with respect to monitoring internally or cognitively mediated processing, the generation effect may map onto activation related to the so-called default mode network (DMN), initially observed during periods of "rest," such as between stimulus presentations (Raichle et al., 2001). The DMN is a set of brain regions that includes the dorsal medial prefrontal cortex (dMPFC), ventral medial prefrontal cortex (vMPFC), posterior cingulate cortex (PCC), inferior parietal lobule (IPL), precuneus (PrC), retrosplenial cortex (Rsp), lateral temporal cortex (LTC), and hippocampal formation. Upon further analysis, this network has been associated with various internally mediated processes, such as episodic recollection, prospective memory, and perspective taking (Buckner, Andrews-Hanna, & Schacter, 2008; Buckner & Carroll, 2007; Spreng, Mar, & Kim, 2009). Given the view that the generation effect is involved in internally mediated processing, one might expect greater DMN activation during encoding for generate versus read items.

With respect to long-term memory processes, activity in the IFG during encoding has been particularly associated with successful retrieval (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Paller & Wagner, 2002; Wagner et al., 1998). Specifically, the IFG is more active during encoding for items subsequently remembered compared to those subsequently forgotten. This effect is robust and has been observed in a variety of tasks and conditions (Paller & Wagner, 2002). In addition to the IFG, generation may increase activity in other areas also associated with this *subsequent memory effect*, including the frontal operculum (FOP), fusiform gyrus (FG), inferior temporal gyrus (ITG), cingulate gyrus, dorsal posterior parietal cortex (dPPC), and LOC (Cansino, Maquet, Dolan, & Rugg, 2002; Kirchhoff, Wagner, Maril, & Stern, 2000; Uncapher & Wagner, 2009; Wagner et al., 1998).

In the present study, we employed a prototypical memory paradigm used to assess the generation effect. Participants were shown related word pairs in the form of a cue word and word fragment (e.g., *QUARREL–F_GHT*) and asked to complete the second word in each pair. These encoding trials were compared to trials in which participants simply read related pairs (e.g., *QUARREL–FIGHT*) (Figure 3.1A). At test, old/new recognition memory for the second word in each pair was assessed with confidence ratings (high vs. low) (Figure 3.1B). Participants were scanned during both study and test phases to identify the neural substrates underlying the generation effect.

Materials and Methods

Participants

Twenty-four healthy individuals (13 females, 11 males, mean age = 23 years, range = 18–32 years; all right-handed, native English speakers) participated in the study. Informed consent was obtained according to guidelines approved by the UC Berkeley Office for the Protection of Human Subjects. No participants reported any history of neuropsychiatric disorder or recent use of psychoactive medication. Participants were compensated $12 per hour.

Design and Materials

A total of 200 cue-target synonym word pairs were constructed (e.g., *GARBAGE–WASTE*). One hundred items were presented at study and again at test, while the other 100 items were used as lures at test. Target words were obtained from the MRC Psycholinguistic Database (Wilson, 1988) and consisted of a mean word length of 5.39 letters (range = 3–8 letters), and a mean frequency of 54.32 (range = 1–314) (Kucera & Francis, 1982). During encoding, target words were presented in fragmented form (generate condition; e.g., *GARBAGE–W_ST_*) or in complete form (read condition; e.g., GARBAGE–WASTE). Fragments were created by removing each vowel (unless it began a word) and replacing it with an underline score. The encoding strategy (read vs. generate) and mnemonic status (old vs. new) of each word were counterbalanced across participants.

Behavioral Procedure

The study phase was presented in 2 separate scanning blocks, each consisting of a randomized presentation of 25 generate and 25 read trials. For each study trial, the stimulus (either intact or fragmented pairs) was shown for 3 seconds which was followed by a 500-millisecond blank screen and a jittered fixation cross (4–8 seconds). Participants were instructed to make a keypress response when they could identify the second word in each pair (i.e., the target word). This procedure encouraged comparable processing across study conditions, except that fragmented items had to be generated (Figure 3.1A).

Following the study set, a 3–minute filled retention interval was presented. During this interval, participants were shown 24 simple math equations (e.g., $3 + 5 = 8$) and determined whether the answer was true or false. Thereafter, old/new recognition memory was assessed using the 50 target items and 50 new items. New items were target words from unused word pairs. For each test trial, a word was presented for 500 milliseconds, followed by a 3-second blank screen, and a jittered response interval (4-8 seconds) (Figure 3.1B). Participants determined whether a test word was old or new while indicating their confidence (high or low) for each response during the inter-trial interval (ITI). They were instructed to respond old with high confidence (HC) only if they were absolutely certain that the test item was presented during the study phase. Thus, we interpret such HC hits to reflect strong recollective responses. Upon completion of the first study-test block, the behavioral procedure was repeated with a different set of cue-target pairs.

fMRI Acquisition

A 3T Siemens (Erlangen, Germany) Trio scanner housed at the UC Berkeley Brain Imaging Center was used to acquire T1-weighted anatomical images and T2*-weighted echo-planar images (EPIs) [repetition time (TR) = 2000 milliseconds; echo time (TE) = 22 milliseconds; flip angle = 90º; matrix = 128x128; FOV = 220mm; 1.7x1.7 in-plane resolution] with GRAPPA [acceleration factor3]. For functional scans, EPIs consisted of 37 axial slices, 2.5mm thick, oriented to the anterior–posterior commissure (AC–PC), and were acquired in an interleaved order which resulted in whole brain coverage. A total of 155 volumes (run duration = 310 seconds) were collected during each of 2 encoding runs and 255 volumes (run duration = 510 seconds) were collected during each of 2 retrieval runs. The first 5 volumes of each run were used for magnetization preparation and were removed from future analyses, resulting in 150 and 250 volumes for each encoding and retrieval session, respectively. For registration purposes, a high resolution magnetization-prepared rapid-acquisition gradient echo (MPRAGE) volume [TR = 2300 milliseconds; TE = 2.98; matrix = 256x256; FOV = 256; sagittal plane; slice thickness=1 mm; 160 slices] and a gradient-echo multislice (GEMS) volume [TR = 250 milliseconds; TE = 3; matrix = 256x256; FOV = 220; 3mm slice thickness, 28 slices] were collected. Due to movement artifacts, 8 of the 96 runs were excluded from data analysis.

fMRI Data Analysis

All data processing and analyses were performed using the FMRIB Software Library (FSL) toolbox v4.1.4 (http://www.fmrib.ox.ac.uk/fsl; S. M. Smith et al., 2004). During preprocessing, BET (brain extraction tool) was applied to each participant’s data to separate brain tissue from skull and dura using a mask of the brain from the first volume, which was used for subsequent volumes. Images were then spatially smoothed using a 5mm full width at half maximum (FWHM) Gaussian kernel. To remove low frequency artifacts, highpass temporal filtering was performed with the local Gaussian-weighted fit of a running line. Motion Correction using FMRIB’s Linear Image Registration Tool (MCFLIRT) corrected for motion by aligning images to the middle slice with rigid body transformation. Sinc interpolation (Hanning windowed) shifted each slice in the volume in reference to the middle of the TR period. Next, FLIRT (FMRIB’s Linear Image Registration Tool) registered subject’s EPIs to their skull-stripped high resolution T1-weighted images, which were then registered to standard Montreal Neurological Institute (MNI) space (FSL’s MNI152 template), both of which were combined to transform the EPI's and statistical maps into standard space.

At the first level of analysis, a multilevel, mixed effects general linear model was run using FILM (FMRIB’s Improved Linear Model). Each individual run (2 encoding and 2 retrieval runs per participant) was modeled in individual subject space. Next, each resulting statistical map was registered to standard space. Regressors of interest were obtained by convolving stimulus onset times with FSL's canonical (gamma) hemodynamic response function and temporal derivative. Trials in which the participant failed to respond, including those trials in which the participant was unable to identify the target word at encoding, were included in the model as regressors of no interest. Finally, motion parameters were added as a confound variable and temporal autocorrelation was removed through prewhitening.

At the second level of analysis, each subject's 2 encoding runs were combined, as were each subject's 2 retrieval runs, using one-sample t-tests. These runs were treated as fixed effects. At the third level, statistical maps were created at the group level for each contrast using FLAME (FMRIB's Local Analysis of multilevel GLM Mixed Effects). The whole-brain family-wise error was corrected to $p < .05$ using Gaussian Random Field theory with a cluster forming threshold of $Z > 2.3$. To assess the relationship between behavioral performance and neural activity, we applied 2 separate subject-specific covariate analyses. First, we used individual generation effect recollection benefit (generate HC hit rate – read HC hit rate) as a covariate of interest in an analysis of generation effect recollection activity (generate > read, HC hits). We used HC responses to isolate recollection responses and eliminate the confound of varying memory strength and remove possible guess trials. In addition, we used individual memory performance (hit – false alarm score) as a covariate of interest in an analysis of overall generation effect activity (generate > read, all items). Localizations of peak activations were identified by mapping images onto the Harvard-Oxford Cortical Atlas.

Results and Discussion

Behavioral Data

We confirmed the robust benefit afforded by the generation effect. Specifically, the generate condition produced a hit rate that was 22% greater than that for read items (generate hits = 87%, read hits = 65%, $t(23) = 9.97$, $p < .001$, false alarm rate = 21%; see Figure 3.1C, Table 3.1). The difference between the two conditions was even greater when performance was based only on high-confident hits (generate HC hits = 74%, read HC hits = 42%, $t(23) = 11.61$, $p < .001$, HC false alarm rate = 7%; see Figure 3.1C, Table 3.1). As mentioned above, an HC rating was made only when participants were absolutely certain that they had seen a test item during the study phase. Given our findings for HC hits, we can assert that the generation effect is particularly potent in driving strong recollective responses. During encoding, the ability to identity targets was high and not significantly different between generated and read targets (generated targets = 98%, read targets = 99%, $t(23) = 1.89$, $p = .07$). Mean latency to identify a target was longer for generated items than read items (generate = 843 milliseconds, read = 670 milliseconds, $t(23) = 6.58$, $p < .001$).

fMRI Data

We first assessed memory-related effects by contrasting activations during encoding for items that were subsequently remembered with those that were subsequently forgotten, collapsed across encoding condition. This contrast revealed significant activation in the left LOC. In a second analysis, we assessed items that elicited HC (i.e., strongly recollected) ratings. This contrast revealed significant activation in the left LOC, IFG, ITG, and right precentral gyrus. Thus, with respect to encoding effects, memory-related activity was particularly observed for items remembered with HC (i.e. strong recollections).

We were particularly interested in determining the neural processes that drive contrasts between generate and read conditions. We thus assessed the contrast of generate hits > read hits, which resulted in significant activation in IFG, MFG, LOC, PrC, ITG, intraparietal sulcus (IPS), and ACC (see Figure 3.2A, Table 3.2). The reverse contrast (read hits > generate hits) resulted in no significant activation differences. We next assessed neural activations associated with the generation effect for HC hits (generate > read, HC hits), which revealed activations in bilateral IFG, MFG, LOC, ITG, IPS, PrC and ACC (see Figure 3.2B, regions in red, Table 3.3). The reverse contrast (read > generate, HC hits) revealed activation in bilateral LOC and PrC, and left angular gyrus (AG) (see Figure 3.2B, regions in blue, Table 3.3).

Activations during retrieval were consistent with previous findings of the successful retrieval effect in which hits are compared with correction rejections (CR) (hits > CRs). In the present study, the successful retrieval effect was associated with increased activation in the left IFG, MFG, superior frontal gyrus (SFG), LTC, LOC, ACC, supramarginal gyrus (SMG), and AG (Figure 3.3A). This retrieval-based network was observed when contrasts were restricted to generated items (hits > CRs, generate items, Figure 3.3B) or to read items (hits > CRs, read items, Figure 3.3C). Direct comparisons of retrieval-based generated versus read items revealed no reliable differences.

To evaluate neural correlates of the generation effect with respect to behavioral performance, we performed a covariate analysis of recognition performance and regional neural responses associated with the generation effect. We used as our covariate of interest overall memory performance (hit rate – false alarm rate) and correlated it with the contrast of generate > read hits during encoding. With this analysis, we addressed the degree to which overall memory performance may be mediated by the magnitude of neural activations associated with the generation effect across individuals. As shown in Figure 3.4A, memory performance was significantly correlated with activity in the right parahippocampal gyrus (PHG), temporal fusiform cortex, MTG, AG, LOC, and PrC. Thus, the strength of activation within these regions elicited by self-generation at encoding predicted better memory performance. As the generation effect was particularly potent for HC hits, we performed a second covariate analysis in which the behavioral advantage of generation for HC hits (generate HC hit rate – read HC hit rate) was correlated with its neural counterpart, the contrast of generate HC hits > read HC hits. In this analysis, we found correlated activity in the paracingulate, frontal pole, left ACC, and right SFG (Figure 3.4B), suggesting a medial-frontal network underlying the behavioral benefit of generation for producing strong recollective responses (i.e. HC hits).

Discussion

The present findings addressed the neural correlates of the generation effect. Active generation was associated with a broad set of regions that included the IFG, MFG, ACC, PrC, IPS, ITG, and LOC. Significant prefrontal activity (IFG and MFG) confirmed the role of executive control processes important for establishing long-term memories. Thus, these findings mesh well with studies that have shown that these regions are particularly involved in stimulus refreshing, updating, and semantic access (D'Esposito et al., 1997; Johnson et al., 2005; Raye et al., 2002; Thompson-Schill et al., 1997). For example, previous studies have shown that these PFC regions are active when participants must refresh or re-activate recently presented words, drawings, or patterns (Johnson et al., 2005; Raye et al., 2002). The generation effect can thus be linked to related acts of refreshing and updating, which also involve internally mediated or generated information.

As suggested by theories of executive control (Miller & Cohen, 2001; Shimamura, 2000, 2008), prefrontal mechanisms act to modulate or control posterior cortical activity thus engaging a broad prefrontal-posterior network involved in selecting, maintaining, and manipulating information in working memory. In the present study, generation was associated with both PFC and posterior activity, particularly in regions involved in image generation (ITG) and object processing (LOC) (D'Esposito et al., 1997; Malach et al., 1995). Thus, the generation effect offers a useful analysis of the neural dynamics associated with executive or metacognitive monitoring and control (D'Esposito et al., 1999; Miller & Cohen, 2001; Postle, 2006; Shimamura, 2008).

Importantly, covariate analyses showed that memory performance could be predicted by the degree to which neural networks associated with the generation effect were active. Specifically, we found that overall memory performance was correlated with increased generate activity in the PHG, temporal fusiform cortex, MTG, AG, LOC, and PrC. In addition, the behavioral benefit of generating at encoding to produce subsequent HC hits was correlated with activity in medial anterior PFC regions known to be important for attending to internally generated versus externally perceived stimuli (Lagioia et al., 2011; Simons, Davis, Gilbert, Frith, & Burgess, 2006; Simons, Henson, Gilbert, & Fletcher, 2008). These findings link the generation effect to regional activations during encoding that are known to be critical for the establishment of long-term memories (Paller & Wagner, 2002). Generation increased both prefrontal activity and activity in posterior regions involved in verbal processing, object analysis, and visuospatial imagery. Additionally, participants who benefited the most from generation showed the greatest activation in regions known to be important for memory binding and retrieval, such as the PHG, AG, and PrC (Davachi, 2006).

Recently, Moss, Schunn, Schneider, McNamara, and VanLehn (2011) compared neural activity when participants reread, paraphrased, or explained biology texts. While self-explaining led to the greatest memory benefit, regional activity in ACC, bilateral superior parietal cortex, and left IFG also increased along with complexity of semantic processing. In the present study, different regions within the DMN were active when reading or generating items during encoding (IPL, PrC, dMPFC for generate > read, HC hits; IPL, PrC for read > generate, HC hits), suggesting that the DMN is responsible for internally driven processing, though different regions may mediate different top-down processes. It is possible that on some trials, active generation oriented participants to internally generated information arising from semantic analysis or conceptual processes, while reading kept participants less on-task and allowed for increased mind wandering. It is acknowledged that the DMN is associated with many internally mediate processes and that there may be regional specificity within the network depending on the particular process being engaged (Buckner & Carroll, 2007; Shimamura, 2011; Spreng et al., 2009).

At retrieval, successful recognition (hits > CRs) was associated with activation in lateral and medial PPC, two regions associated with memory recollection (Cabeza, 2008; Shimamura, 2011; Vilberg & Rugg, 2008). Interestingly, this pattern of activity was observed for both successfully retrieved generated and read items, and there were no differences during retrieval that differentiated remembered items between the two conditions. Within the confines of the encoding conditions used in the study, our findings suggest that a remembered item (hit or high-confident hit) elicits the same pattern of activation during retrieval regardless of whether it was previously generated or read.

With respect to mapping psychological theories of the generation effect onto our fMRI findings, it is clear that multiple brain regions are responsible for different aspects of the mnemonic benefit associated with the generation effect. Certainly, PFC regions involved with semantic analysis, refreshing, and updating are included. However, a host of posterior regions, such as the PHG, temporal fusiform cortex, MTG, AG, and LOC, is also involved. It is possible that active generation increases attention and cognitive effort (prefrontal and posterior cortical activation; Miller & Cohen, 2001; Shimamura, 2000, 2008), conceptual and semantic processing (IFG and MTG; Bookheimer, 2002; Poldrack et al., 1999), and item distinctiveness (LOC and ACC; Malach et al., 1995; van Veen et al., 2001). Perhaps one of the reasons memory researchers have not reached a consensus regarding the underlying mechanism of the generation effect is that active generation engages a large range of cognitive processes. Depending on the task at hand, active generation may promote increases in attention, cognitive effort, item distinctiveness, semantic processing, and conceptual processing. Indeed, our findings affirm the fact that these memory-related influences associated particularly with strong recollective responses are driven by a broad network of both PFC and posterior regions during encoding (Shimamura, 2010).

Tables

	Hit	False alarm	HC hit	HC false alarm
Generate	.87	.21	.74	.07
Read	.65	.21	.42	.07

Table 3.1 – Recognition accuracy for generate and read conditions.

Cluster Index	**BA**	**Z**	**x**	**y**	**z**
Generate Hit > Read Hit					
Anterior Cingulate Gyrus	24	4.73	0	0	28
Left Inferior Frontal Gyrus	48	5.44	-52	14	28
Right Inferior Frontal Gyrus	45	4.42	50	34	16
Left Inferior Temporal Gyrus	37	4.34	-46	-56	-16
Right Inferior Temporal Gyrus	37	4.70	46	-54	-10
Right Insular Cortex	48	3.10	32	0	10
Left Lateral Occipital Cortex	19	5.98	-24	-76	26
Right Lateral Occipital Cortex	19	6.13	28	-76	32
Left Middle Frontal Gyrus	44	4.78	-54	14	34
Right Middle Frontal Gyrus	45	4.50	52	24	26
Left Occipital Pole	18	5.56	-32	-90	8
Right Occipital Pole	18	5.71	34	-92	2
Left Precentral Gyrus	44	5.95	-44	4	24
Right Precentral Gyrus	48	5.17	42	8	26
Left Precuneous	7	3.23	-12	-62	42
Right Precuneous	7	3.72	18	-58	42
Left Superior Parietal Lobule	40	4.92	-38	-42	44
Right Superior Parietal Lobule	7	4.45	28	-56	48
Read Hit > Generate Hit					
No Significant Activations					

Table 3.2 – Brain regions active at encoding for subsequently remembered items. Generate hit > read hit; Read hit > generate hit. (MNI coordinates).

Cluster Index	**BA**	**Z**	**x**	**y**	**z**
HC Generate > HC Read					
Left Central Opercular Cortex	48	4.04	-46	6	2
Left Cingulate Gyrus	32	3.73	-4	40	18
Right Cingulate Gyrus	24	3.15	4	30	22
Left Frontal Orbital Cortex	47	4.14	-42	26	-6
Left Frontal Pole	47	3.42	-42	38	-14
Left Inferior Frontal Gyrus	45	5.25	-48	34	6
Right Inferior Frontal Gyrus	48	3.08	42	16	24
Left Inferior Temporal Gyrus	37	3.96	-58	-60	-20
Right Inferior Temporal Gyrus	37	5.7	54	-56	-14
Left Insular Cortex	48	4.38	-32	18	6
Left Lateral Occipital Cortex	19	6.07	-24	-76	28
Right Lateral Occipital Cortex	19	5.58	32	-72	26
Right Lingual Gyrus	18	3.32	10	-88	-6
Left Middle Frontal Gyrus	45	3.99	-44	30	26
Right Middle Frontal Gyrus	6	3.27	54	10	42
Left Occipital Fusiform Gyrus	19	3.67	-40	-74	-20
Right Occipital Fusiform Gyrus	19	3.47	30	-80	-4
Left Occipital Pole	18	6.11	-34	-94	10
Right Occipital Pole	18	5.5	34	-92	2
Left Paracingulate Gyrus	32	3.35	-4	16	48
Right Paracingulate Gyrus	32	3.67	12	32	28
Right Postcentral Gyrus	2	4.54	48	-28	48
Right Postcentral Gyrus	3	3.22	56	-20	46
Left Precentral Gyrus	44	6.06	-48	6	26
Right Precentral Gyrus	44	4.78	44	8	26
Left Precuneus	18	3.39	-16	-70	-30
Right Precuneus	19	3.35	24	-64	30
Left Superior Frontal Gyrus	32	3.99	-6	38	42
Left Superior Frontal Gyrus	8	3.6	-4	28	48
Left Superior Parietal Lobule	40	4.95	-36	-48	46
Right Superior Parietal Lobule	7	4.6	32	-54	48
Left Supramarginal Gyrus	40	4.67	-44	-44	46
Right Supramarginal Gyrus	2	3.81	44	-36	48
Left Temporal Occipital Fusiform Cortex	37	4.39	-44	-56	-16
Right Temporal Occipital Fusiform Cortex	37	5.04	44	-58	-12
HC Read > HC Generate					
Left Angular Gyrus	39	3.37	-48	-68	26
Left Lateral Occipital Cortex	19	3.38	-40	-84	36
Right Lateral Occipital Cortex	7	3.23	8	-68	36
Left Occipital Pole	19	3.66	-42	-68	36
Left Precuneus	23	3.43	-10	-68	26
Right Precuneus	7	3.23	8	-68	36
Right Superior Parietal Lobule	7	3.06	4	-64	48

Table 3.3 – Brain regions active at encoding for items subsequently remembered with HC. HC generate > HC read; HC read > HC generate. (MNI coordinates).

Figures

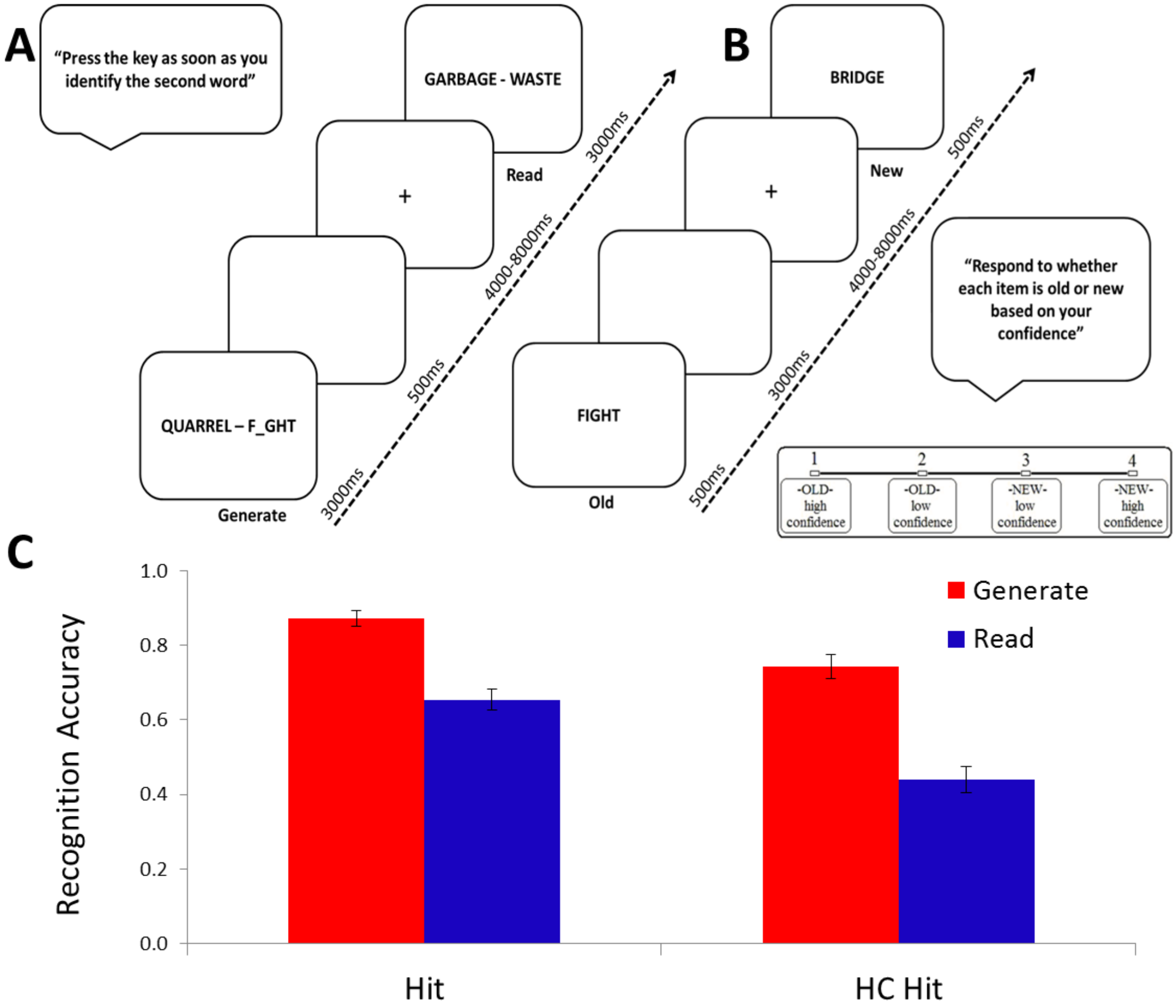

Figure 3.1 – Experimental design and behavioral data. (A) Experimental design for encoding phase and (B) retrieval phase. (C) Recognition accuracy for read and generate items. Hits are items correctly identified as old. HC hits are items correctly identified as old with HC.

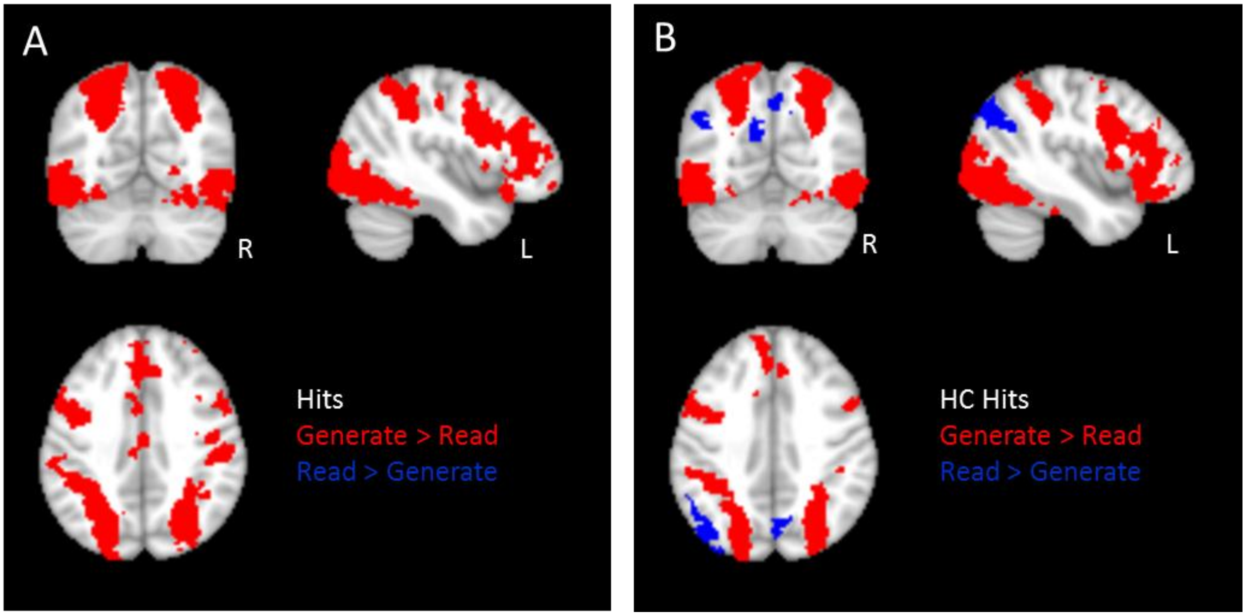

Figure 3.2 – Statistical activation maps for the generation effect during encoding. (A) Hits. Generate > read (red): Regional activations include bilateral IFG, MFG, LOC, PrC, ITG, IPS, ACC. Read > generate (blue): no significant activation. (B) HC hits. Generate > read (red): Regional activations include bilateral IFG, MFG, LOC, ITG, IPS, ACC, right PrC. Read > generate (blue): bilateral LOC, PrC, left AG.

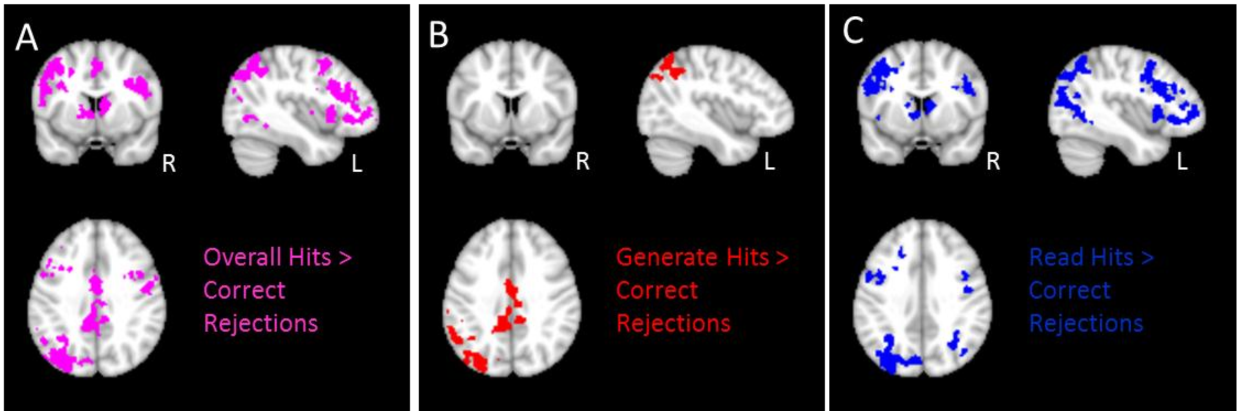

Figure 3.3 – Statistical activation maps during retrieval. (A) Overall hits > correct rejections. Regional activations include left IFG, MFG, SFG, ITG, MTG, LOC, ACC, SMG, AG. (B) Generate hits > correct rejections. Regional activations include left LOC, ACC, SMG, AG. (C) Read hits > correct rejections. Regional activations include left IFG, MFG, SFG, ITG, MTG, ACC, SMG, AG, PHG.

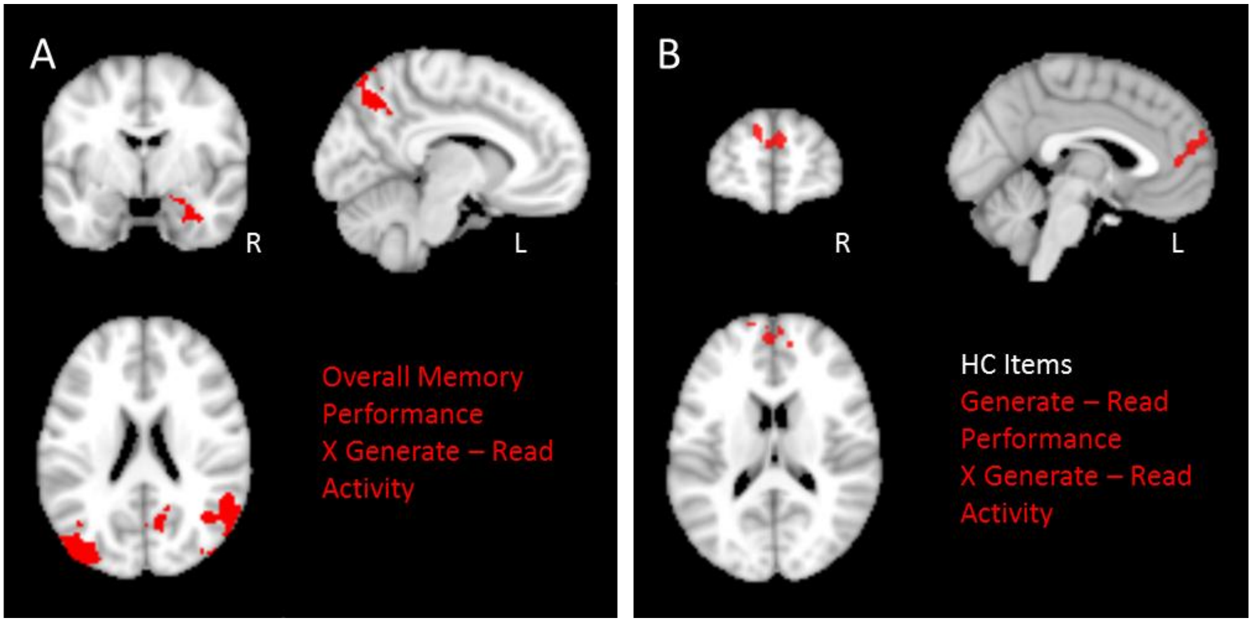

Figure 3.4 – Covariate Analyses. (A) Shown in red are regions related to the generation effect (generate > read, all items) that covaried with overall memory performance (hits – false alarms). Regional activations include PHG, MTG, AG, LOC, temporal fusiform cortex, PrC. (B) Shown in red are regions related to the generation effect (generate > read, HC items) that covaried with the behavioral generation effect (HC hits – false alarms). Regional activations include bilateral paracingulate cortex and frontal pole, left ACC, right SFG.

Appendices

Synonym fMRI Experiment (3) – Part 1			
Read Items		*Generate Items*	
ACADEMIC - SCHOLAR	DIARY - JOURNAL	ACADEMIC - SCH_L_R	DIARY - J_ _RN_L
AGREEMENT - CONTRACT	DINNER - SUPPER	AGREEMENT - C_NTR_CT	DINNER - S_PP_R
AIR – OXYGEN	DIRECTOR - LEADER	AIR - OXYG_N	DIRECTOR - L_ _D_R
AMMUNITION - BULLET	DIRT - DUST	AMMUNITION - B_LL_T	DIRT - D_ST
ARENA - STADIUM	DISH - PLATE	ARENA - ST_D_ _M	DISH - PL_T_
ASSOCIATION - CLUB	DOORWAY - ENTRANCE	ASSOCIATION - CL_B	DOORWAY - ENTR_NC_
ATLAS – MAP	DRAWING - SKETCH	ATLAS - M_P	DRAWING - SK_TCH
ATTORNEY - LAWYER	DRESS - GOWN	ATTORNEY - L_WY_R	DRESS - G_WN
AUTOMOBILE - CAR	EMPLOYEE - WORKER	AUTOMOBILE - C_R	EMPLOYEE - W_RK_R
AUTUMN - FALL	EXAM - TEST	AUTUMN - F_LL	EXAM - T_ST
BASEMENT - CELLAR	EXAMPLE - SPECIMEN	BASEMENT - C_LL_R	EXAMPLE - SP_C_M_N
BATHROOM - TOILET	EXHAUSTION - FATIGUE	BATHROOM - T_ _L_T	EXHAUSTION - F_T_G_ _
BEAST - ANIMAL	EXPLOSIVE - BOMB	BEAST - AN_M_L	EXPLOSIVE - B_MB
BELLY - STOMACH	FARM - RANCH	BELLY - ST_M_CH	FARM - R_NCH
BLADE – KNIFE	FAUCET - SINK	BLADE - KN_F_	FAUCET - S_NK
BLAZE – FIRE	FEE - TOLL	BLAZE - F_R_	FEE - T_LL
BLOCK – BRICK	FELINE - CAT	BLOCK - BR_CK	FELINE - C_T
BORDER – EDGE	FILM - MOVIE	BORDER - EDG_	FILM - M_V_ _
BREEZE – WIND	FIREARM - GUN	BREEZE - W_ND	FIREARM - G_N
BRIDE – WIFE	FLAVOR - TASTE	BRIDE - W_F_	FLAVOR - T_ST_
BUG – INSECT	FLESH - MEAT	BUG - INS_CT	FLESH - M_ _T
BUNNY - RABBIT	FLUID - LIQUID	BUNNY - R_BB_T	FLUID - L_Q_ _D
BURGLARY - ROBBERY	FOREIGNER - STRANGER	BURGLARY - R_BB_RY	FOREIGNER - STR_NG_R
CAP – HAT	FREEWAY - HIGHWAY	CAP - H_T	FREEWAY - H_GHW_Y
CARPET – RUG	FUNGUS - MOLD	CARPET - R_G	FUNGUS - M_LD
CASH – MONEY	GAME - MATCH	CASH - M_N_Y	GAME - M_TCH
CASSETTE - TAPE	GARBAGE - WASTE	CASSETTE - T_P_	GARBAGE - W_ST_
CASTLE - PALACE	GASH - CUT	CASTLE - P_L_C_	GASH - C_T
CATASTROPHE – DISASTER	GATHERING - MEETING	CATASTROPHE - D_S_ST_R	GATHERING - M_ _T_NG
CATHEDRAL - CHURCH	GLOBE - SPHERE	CATHEDRAL - CH_RCH	GLOBE - SPH_R_
CELEBRATION - PARTY	GLUE - PASTE	CELEBRATION - P_RTY	GLUE - P_ST_
CHECK – BILL	GOD - LORD	CHECK - B_LL	GOD - L_RD
CHIEF - CAPTAIN	GRASP - GRIP	CHIEF - C_PT_ _N	GRASP - GR_P
CHILD – KID	GRASS - LAWN	CHILD - K_D	GRASS - L_WN
CHILLY – COLD	GRAVE - TOMB	CHILLY - C_LD	GRAVE - T_MB
CITRUS - ORANGE	GRIN - SMILE	CITRUS - OR_NG_	GRIN - SM_L_
CLERGYMAN - PRIEST	GROUND - FLOOR	CLERGYMAN - PR_ _ST	GROUND - FL_ _R
CLIENT - CUSTOMER	GUTTER - SEWER	CLIENT - C_ST_M_R	GUTTER - S_W_R
CLIMATE - WEATHER	HALLWAY - CORRIDOR	CLIMATE - W_ _TH_R	HALLWAY - C_RR_D_R
COIL – SPRING	HANDBAG - PURSE	COIL - SPR_NG	HANDBAG - P_RS_
COIN – TOKEN	HARBOR - PORT	COIN - T_K_N	HARBOR - P_RT
COMPENSATION – PAYMENT	HARM - INJURY	COMPENSATION - P_YM_NT	HARM - INJ_RY
CONFLICT - BATTLE	HEATER - FURNACE	CONFLICT - B_TTL_	HEATER - F_RN_C_
CORPORATION – COMPANY	HEN - CHICKEN	CORPORATION - C_MP_NY	HEN - CH_CK_N
COUNTRY - NATION	HOLE - PIT	COUNTRY - N_T_ _N	HOLE - P_T
CREATION - PRODUCT	HOMICIDE - MURDER	CREATION - PR_D_CT	HOMICIDE - M_RD_R
DAD – FATHER	HONEY - SUGAR	DAD - F_TH_R	HONEY - S_G_R
DAWN - MORNING	ICON - SYMBOL	DAWN - M_RN_NG	ICON - SYMB_L
DECK – PORCH	ILLNESS - DISEASE	DECK - P_RCH	ILLNESS - D_S_ _S_
DIAGRAM - CHART	INDICATION - SIGNAL	DIAGRAM - CH_RT	INDICATION - S_GN_L

Synonym fMRI Experiment (3) – Part 2

Read Items		*Generate Items*	
INDIVIDUAL – PERSON	PROPRIETOR - OWNER	INDIVIDUAL - P_RS_N	PROPRIETOR - OWN_R
INFANT – BABY	PUB - BAR	INFANT - B_BY	PUB - B_R
INFIRMARY - HOSPITAL	QUANTITY - VOLUME	INFIRMARY - H_SP_T_L	QUANTITY - V_L_M_
INFORMATION - NEWS	QUARREL - FIGHT	INFORMATION - N_WS	QUARREL - F_GHT
JACKET – COAT	REFEREE - JUDGE	JACKET - C_ _T	REFEREE - J_DG_
JET – PLANE	RELATIVES - FAMILY	JET - PL_N_	RELATIVES - F_M_LY
JUNGLE – FOREST	RESIDENT - CITIZEN	JUNGLE - F_R_ST	RESIDENT - C_T_Z_N
KINGDOM – EMPIRE	REWARD - PRIZE	KINGDOM - EMP_R_	REWARD - PR_Z_
LAMP – LANTERN	RITUAL - CEREMONY	LAMP - L_NT_RN	RITUAL - C_R_M_NY
LEASE – RENT	ROCK - STONE	LEASE - R_NT	ROCK - ST_N_
LECTURER – SPEAKER	ROCKET - MISSILE	LECTURER - SP_ _K_R	ROCKET - M_SS_L_
LIMB – BRANCH	ROOF - CEILING	LIMB - BR_NCH	ROOF - C_ _L_NG
LOCOMOTIVE – TRAIN	ROUGH - TOUGH	LOCOMOTIVE - TR_ _N	ROUGH - T_ _GH
LODGE – CABIN	SACK - BAG	LODGE - C_B_N	SACK - B_G
LOOP – CIRCLE	SCENT - SMELL	LOOP - C_RCL_	SCENT - SM_LL
LOTION – CREAM	SECTION - SEGMENT	LOTION - CR_ _M	SECTION - S_GM_NT
LUMBER – WOOD	SERPENT - SNAKE	LUMBER - W_ _D	SERPENT - SN_K_
MAID – SERVANT	SHED - BARN	MAID - S_RV_NT	SHED - B_RN
MASS – WEIGHT	SHIP - BOAT	MASS - W_ _GHT	SHIP - B_ _T
MEDICINE – DRUG	SHORE - COAST	MEDICINE - DR_G	SHORE - C_ _ST
METROPOLIS – CITY	SHRINE - TEMPLE	METROPOLIS - C_TY	SHRINE - T_MPL_
MILITARY – ARMY	SHRUB - BUSH	MILITARY - _RMY	SHRUB - B_SH
MIND – BRAIN	SOFA - COUCH	MIND - BR_ _N	SOFA - C_ _CH
MISTAKE – ACCIDENT	SOLID - FIRM	MISTAKE - ACC_D_NT	SOLID - F_RM
MUG – CUP	SPOUSE - PARTNER	MUG - C_P	SPOUSE - P_RTN_R
NAP – SLEEP	SQUAD - CREW	NAP - SL_ _P	SQUAD - CR_W
NOISE – SOUND	STAGE - PLATFORM	NOISE - S_ _ND	STAGE - PL_TF_RM
NOVEL – BOOK	STARVATION - HUNGER	NOVEL - B_ _K	STARVATION - H_NG_R
OBJECTIVE – GOAL	STATUE - MONUMENT	OBJECTIVE - G_ _L	STATUE - M_N_M_NT
OCCUPATION – JOB	STOOL - CHAIR	OCCUPATION - J_B	STOOL - CH_ _R
OCEAN – SEA	STREAM - RIVER	OCEAN - S_ _	STREAM - R_V_R
OPPONENT – ENEMY	STREET - ROAD	OPPONENT - EN_MY	STREET - R_ _D
OVEN – STOVE	STUDENT - PUPIL	OVEN - ST_V_	STUDENT - P_P_L
OVERPASS – BRIDGE	SUPERVISOR - BOSS	OVERPASS - BR_DG_	SUPERVISOR - B_SS
PACE – STRIDE	TALK - SPEECH	PACE - STR_D_	TALK - SP_ _CH
PARCEL – PACKAGE	THREAD - STRING	PARCEL - P_CK_G_	THREAD - STR_NG
PATH – TRAIL	TOWN - VILLAGE	PATH - TR_ _L	TOWN - V_LL_G_
PERIODICAL - MAGAZINE	TOXIN - POISON	PERIODICAL - M_G_Z_N_	TOXIN - P_ _S_N
PERSPIRATION - SWEAT	TRENCH - DITCH	PERSPIRATION - SW_ _T	TRENCH - D_TCH
PHOTOGRAPH - PICTURE	TUNE - SONG	PHOTOGRAPH - P_CT_R_	TUNE - S_NG
PHYSICIAN – DOCTOR	UNIVERSITY - COLLEGE	PHYSICIAN - D_CT_R	UNIVERSITY - C_LL_G_
PIN – NEEDLE	VACATION - TRIP	PIN - N_ _DL_	VACATION - TR_P
POLICEMAN – OFFICER	VICTOR - CHAMPION	POLICEMAN - OFF_C_R	VICTOR - CH_MP_ _N
POND – LAKE	VISITOR - GUEST	POND - L_K_	VISITOR - G_ _ST
POSESSION - PROPERTY	VOCALIST - SINGER	POSESSION - PR_P_RTY	VOCALIST - S_NG_R
POUCH – POCKET	WARRIOR - SOLDIER	POUCH - P_CK_T	WARRIOR - S_LD_ _R
PRECIPITATION – RAIN	WEB - NET	PRECIPITATION - R_ _N	WEB - N_T
PRESENT – GIFT	WOMAN - LADY	PRESENT - G_FT	WOMAN - L_DY
PRISON – JAIL	WOUND - SCAR	PRISON - J_ _L	WOUND - SC_R
PROFESSOR – TEACHER	WRITER - AUTHOR	PROFESSOR - T_ _CH_R	WRITER - A_TH_R

Appendix 3.1 – Stimuli for Experiment 3.

Chapter 5: Discussion

The purpose of the collection of experiments contained within this dissertation is to improve our understanding of the generation effect. This included exploring boundaries and conditions of positive and negative generation effects within 2 cultures of contrasting cognitive styles to illustrate in which ways active generation influences memory for various types of information. Additionally, the neural mechanisms underlying the generation effect were investigated to help elucidate not only the effects of generation, but *why* these effects occur. Through a richer understanding of the influences and mechanisms of generation, these experiments also tested various theories of the generation effect.

Active learning, which includes techniques such as paraphrasing information, self-explaining, self-testing, and learning through experience, is a classic encoding strategy. Championed by educators and studied by cognitive psychologists for nearly 40 years, the true pattern of the consequences of active generation, and the underlying mechanisms of the generation effect have remained elusive. In 1978, Slamecka and Graf (1978) demonstrated the positive effects of active generation on verbal item information by having participants generate antonyms, synonyms, categories, and rhymes to cues. These effects have since been demonstrated under conditions of intentional and incidental learning, and cued and uncued recognition and recall (Bertsch et al., 2007). They have also been extended to the domains of arithmetic problems (McNamara & Healy, 2000; R. W. Smith & Healy, 1998), pictures (Kinjo & Snodgrass, 2000), actions (Zimmer et al., 2001), and arguments (Petty, 1981). Further, active generation has proven beneficial in older adults (Taconnat et al., 2006; Taconnat & Isingrini, 2004), patients with various traumatic brain injuries, (Lengenfelder et al., 2007) and even in patients with mild cognitive impairment or early stages of Alzheimer's Disease (Souliez et al., 1996).

Indeed, the experiments presented here demonstrate the power and versatility of the positive generation effect on item memory, which existed when employing various stimuli including synonyms, antonyms, idioms, pictures, and categories, when participants generated information covertly and overtly, and in front of a computer and in a scanner. Further, these positive generation effects persisted over a 24-hour delay and in the face of divided attention. The cross-cultural Idiom experiments also demonstrated that active generation may be a universally beneficial encoding strategy, as the generation effect was as strong in China as it was in the United States. This is interesting, as a Chinese Confucian learning style is less similar on its face to active generation than is an American Socratic learning style (Tweed & Lehman, 2002).

At the neural level, active generation was associated with a broad set of regions that included the IFG, MFG, ACC, PrC, IPS, ITG, and LOC. Prefrontal activity in the IFG and MFG confirmed the role of executive control processes (Miller & Cohen, 2001; Shimamura, 2000, 2008) that modulate posterior cortical activity, thus engaging a prefrontal-posterior network involved in selecting, maintaining, and manipulating information in working memory. Generation also increased activation in regions involved in image generation (ITG) and object processing (LOC) (D'Esposito et al., 1997; Malach et al., 1995). Further, memory performance was correlated with increased generate activity in the PHG, temporal fusiform cortex, MTG, AG, LOC, and PrC, regions known to be important for memory binding and retrieval (Davachi, 2006), and the behavioral benefit (generate HC hit rate – read HC hit rate) of generating at encoding was correlated with activity in medial anterior PFC regions known to be important for attending to internally generated versus externally perceived stimuli (Lagioia et al., 2011; Simons et al., 2006, 2008). The DMN was also involved, as different regions within the DMN were active when reading or generating items during encoding (IPL, PrC, dMPFC for generate > read, HC hits; IPL, PrC for read > generate, HC hits). It is possible that on some trials, active generation oriented participants to internally generated information arising from semantic analysis or conceptual processes, while reading kept participants less on-task and allowed for increased mind wandering (see Buckner & Carroll, 2007; Shimamura, 2011; Spreng et al., 2009). Interestingly, the successful retrieval effect (hits > CRs at retrieval), which was associated with activation in lateral and medial PPC (see Cabeza, 2008; Shimamura, 2011; Vilberg & Rugg, 2008), revealed no significant differences for items that were initially read or generated, suggesting that the benefits of generation act at encoding. These findings link the generation effect to regional activations during encoding that are known to be critical for the establishment of long-term memories (Paller & Wagner, 2002). Generation increased both prefrontal activity and activity in posterior regions involved in verbal processing, object analysis, and visuospatial imagery.

Even with the praise of educators and great efforts of psychological researchers, the exact reason as to why active generation improves memory remains unknown. Various theories have suggested that active generation increases cognitive effort (McFarland Jr. et al., 1980; Tyler et al., 1979), conceptual processing (Jacoby, 1983), item distinctiveness (Begg et al., 1989; Hunt & McDaniel, 1993; Kinoshita, 1989), semantic processing (McElroy, 1987; McElroy & Slamecka, 1982), the association between cue and target items (Hirshman & Bjork, 1988), and the relationship between target items (McDaniel et al., 1988). And, while the positive effects of generation are robust, there are limitations. The generation effect is reduced when the read and generate conditions are manipulated between rather than within subjects (Slamecka & Katsaiti, 1987), and vanishes when using stimuli without preexisting representations (Gardiner & Hampton, 1985; Nairne et al., 1985).

Perhaps the reason that there has been no consensus as to which of these presented theories drives the generation effect is because the effects of active generation are ubiquitous and engage a large range of cognitive processes. With respect to the fMRI findings, it is clear that multiple brain regions are responsible for different aspects of the mnemonic benefit associated with the generation effect. It is possible that active generation increases attention and cognitive effort (prefrontal and posterior cortical activation; Miller & Cohen, 2001; Shimamura, 2000, 2008), conceptual and semantic processing (IFG and MTG; Bookheimer, 2002; Poldrack et al., 1999), and item distinctiveness (LOC and ACC; Malach et al., 1995; van Veen et al., 2001). The benefits of active generation during encoding likely depend on the nature of the retrieval task, supporting a TAP account (see Blaxton, 1989; Jacoby, 1983). Essentially, the amount of overlap between the processes preferentially engaged by generation at encoding with later retrieval will drive the mnemonic benefit. Various encoding tasks can bias the engagement of relevant cognitive processes, promoting relative increases in attention, cognitive effort, item distinctiveness, semantic processing, and conceptual processing.

In spite of these results, active learning does not simply enhance memory across the board. Generation has been demonstrated to impair memory for contextual information such as temporal order (Nairne et al., 1991), color (Mulligan, 2004; Mulligan et al., 2006), and the person who presented information (Jurica & Shimamura, 1999). As with the positive generation effect, the results of this negative generation effect have been inconsistent. Location memory, for example, has had generation effects varying from positive to null (Marsh, 2006; Mulligan et al., 2006). Various theories have been proposed to explain these negative generation effects, or lack thereof, including item-context tradeoff accounts (Jurica & Shimamura, 1999; Nairne et al., 1991), TAP accounts (Mulligan, 2004, 2011; Mulligan et al., 2006), and accounts in which generation can enhance item-context relationships (Marsh et al., 2001).

The present experiments demonstrate negative generation effects not only for context memory, but also for item memory under certain conditions. When participants were presented with picture stimuli at both encoding and retrieval, generation impaired memory for item information. In addition, the Category Retrieval Blocking experiment demonstrated that while active generation enhanced memory for the generated items themselves, this benefit impaired memory for related non-generated items. This effect may operate in a way similar to that of retrieval-induced forgetting (Anderson et al., 1994; Bäuml, 2002). The Idiom experiments further demonstrated that generation negatively impacts color memory while failing to influence background color memory and location memory (see Mulligan, 2004; Mulligan et al., 2006). Interestingly, however, the cross-cultural Idiom experiments revealed cultural differences for the way in which context memory may be processed. While active generation impaired color memory and left location memory unaffected among American participants, among Chinese participants it impaired both.

Taken together, this collection of experiments supports a TAP account as adopted by Mulligan (2011). In this view, generation enhances memory for item information through increased conceptual processing, impairs memory for intrinsic contextual details through increased perceptual processing, and has no effect on memory for extrinsic contextual details. As seen in the fMRI experiment, active generation can recruit a broad range of cognitive processes, and its benefit depends on the overlap between these processes and those engaged during later retrieval. Generation effect experiments are typically constructed in such a way that generation promotes conceptual processing, while passive study promotes perceptual processing. As most standard tests of item recall and recognition are considered to be conceptual in nature, generation often benefits item memory. Consistent with this theory, the American Idiom experiments demonstrated a positive generation effect for item memory, a negative generation effect for text color memory (intrinsic contextual feature), and no generation effect for location memory (extrinsic contextual feature) or background color memory (extrinsic contextual feature). In contrast, Chinese participants maintained a positive generation effect for item memory and a negative generation effect for text color memory (still an intrinsic contextual feature) while demonstrating a negative generation effect for location memory (now an intrinsic contextual feature). As Chinese participants are more likely than American participants to process location as an intrinsic contextual detail due to a field-dependent cognitive style (Markus & Kitayama, 1991), these results fit comfortably within the proposed framework.

Further, the Picture Fragment Completion experiments demonstrated an instance of a negative generation effect on item memory. In these experiments, participants were tested with pictures, a recognition task that is more perceptual in nature than typical word recognition tasks. However, the type of stimuli presented during encoding impacted the way in which item information was accessed at test. When presented with pictures at study, participants capitalized on the consistent perceptual processing afforded by passive study, resulting in a negative generation effect for both item and color memory. When presented with words at study, however, this advantage of consistent perceptual processing of item information between study and test vanished, requiring participants to rely on conceptual features of the items instead.

Therefore, a positive generation effect on item memory was found, but was accompanied by a negative generation effect for color memory, as conceptual processing was likely of little utility for this task.

When considering this entire collection of results, Mulligan's (2011) TAP account appears to be the most viable explanation for the various positive and negative effects of generation. Negative generation effects were found for item, color and location memory, disputing an account that generation enhances item and context memory (Marsh et al., 2001). Under different circumstances, however, it is certainly plausible that active generation could benefit context memory to the extent that this information is targeted by the act of generation itself. Additionally, positive generation effects for item memory were paired with both negative and null generation effects for context memory in the Idiom experiments. The Picture Fragment Completion studies, on the other hand, paired a negative generation effect for item memory with a negative generation effect for context memory in the Picture-Picture experiment and a positive generation effect for item memory with a negative generation effect for context memory in the Word-Picture experiment. Given that positive and negative item and context memory generation effects could be independently manipulated, it appears unlikely that the negative generation effect for context memory is a necessary consequence of the positive generation effect for item memory. While these results argue against a strict tradeoff account (Jurica & Shimamura, 1999), it is likely that the majority of generation effect experiments do result in the processing of one type of information (i.e., conceptual processing or item information) at the expense of processing other types of information (i.e., perceptual processing or contextual information).

While the studies presented in this dissertation, backed by nearly 40 years of research showing the generation effect to yield nearly a 10% memory benefit (Bertsch et al., 2007), demonstrated the power of the generation effect through the use of synonyms, antonyms, idioms, categories and pictures, the utility of active generation as an encoding strategy outside of the laboratory is questionable. Generating the second word of a synonym pair or the last word of an idiom offers little value to the student who wants to learn a foreign language, understand history, or study for a science test. Therefore, future experiments should investigate ways in which active generation may be employed to enhance learning in real-world settings such as textbooks and classrooms.

While students may not dispute the value of active learning, Karpicke et al., (2009) found that college students tend to reread textbooks or notes rather than employ active learning strategies such as self-testing. To be sure, self-testing has great value. Self-testing allows students to recognize when they have sufficiently learned information (Karpicke and Roediger, 2008) and its memory benefit outweighs the benefit of repeated study sessions (Agarwal et al., 2008; Roediger III & Karpicke, 2006a), elaborative encoding (Karpicke & Blunt, 2011), and even active generation (Karpicke & Zaromb, 2010). While self-testing is powerful, the investigation of the generation effect in the classroom warrants attention. Generation activities can be incorporated into study materials more easily than self-testing, prompting more widespread use in studying. Active generation is also a useful strategy for initially encoding information, while self-testing can only capitalize on previously learned information.

Indeed, studies have found that generation enhances learning in education, and the errors students might make by generating incorrect information are not harmful if feedback is provided to correct those errors (Metcalfe & Kornell, 2007). Further, the benefits of generation can continue past the initial encoding phase, as students who generated words a second time showed a memory advantage over those who generated and then read words or simply read words twice

(MacLeod et al., 2012). Additionally, as students seem hesitant to take the initiative to test themselves, active generation can be easily adopted into classroom activities, textbooks, and study materials, especially during a time in which electronic resources are becoming more readily available. For example, answers to facts could be incomplete, bilingual word pairs could require generation, and key terms in textbooks could be fragmented. The areas of study in which active generation can enhance learning should be exhausted. Additionally, the optimal conditions of active learning should be investigated. Should people read first, followed by generation, followed by self-testing? Do these strategies depend on the type of the to-be-learned material?

Throughout this collection of experiments, active generation proved to be a powerful encoding strategy, engaging a wide range of cognitive processes and broad networks of brain activity. Seemingly an almost effortless task, generation enhanced item memory for various stimuli under several conditions. Active generation, however, can have limitations and consequences, as it was demonstrated to impair both item and context memory in certain situations. A TAP account (Mulligan, 2011) reasonably accounts for this pattern of positive and negative generation effects.

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