EXPLORING THE ROLE OF ATTENTION DURING IMPLICIT MEMORY RETRIEVAL

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ABSTRACT

JEFFREY P. LOZITO: EXPLORING THE ROLE OF ATTENTION DURING IMPLICIT MEMORY RETRIEVAL
(Under the direction of Neil W. Mulligan)

Implicit memory is memory for information that is not driven by conscious processing. This study investigated the role of attention during implicit memory retrieval across four experiments using a test-phase division of attention. Implicit retrieval is dissociable into perceptual and conceptual forms. Implicit retrieval is further dissociable into tests that involve stimulus identification or stimulus production. Several lines of research make predictions about implicit retrieval in general, and with respect to these two dissociations.

The present study used four implicit tests that can be classified according to each of these two dimensions. Experiment 1 used a perceptual identification test; Experiment 2 used a word-stem completion test; Experiment 3 used a category exemplar production test; and Experiment 4 used a category verification test. Attention was divided during the test-phase only with one of several secondary tasks. It was found that, across all experiments, none of the secondary tasks reduced levels of priming for any of the implicit tests. Further, implicit retrieval had no detrimental effects on performance for any of the secondary tasks. All of the above support the idea that implicit retrieval is automatic.

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CHAPTER I

INTRODUCTION

During the course of a typical day, how often is one forced to perform two tasks simultaneously? The ability to multi-task is increasingly becoming a part of our everyday lives. For example, how many times during the course of a day do you see someone driving while using a cellular phone? What happens when we engage in two tasks simultaneously? A common belief is that people cannot perform two tasks simultaneously as well as they could perform each task independently. Even jokes, such as saying that someone is unable to walk and chew gum at the same time, seem to corroborate such beliefs. Retrieving information from memory is something we continually do. Because it is sometimes done in conjunction with other tasks (e.g., maintaining a conversation with someone while simultaneously trying to remember who exactly they are!), it is important to understand the effects of distraction on remembering. The key question that will guide the rest of this paper is whether our memory is as effective when remembering something while simultaneously performing a second task (i.e., when one is distracted) compared to remembering when not distracted.

In the laboratory, the effects of distraction are studied across two conditions: divided attention (DA) and full attention (FA). In the DA condition, participants must simultaneously respond to two concurrent tasks. Performance in this condition is compared to the FA condition, where participants perform only one of the two tasks.

Dividing attention during memory encoding has a long tradition and the large, deleterious effects on subsequent performance are both well-documented and consistent

(Anderson & Craik, 1974; Baddeley, Lewis, Eldridge, Thompson, 1984; Craik, Govoni, Naveh-Benjamin, Anderson, 1996; Murdock, 1965). In a typical DA paradigm, participants study a list of items (e.g., words, pictures, or sentences). Some participants study items while simultaneously performing a secondary task (the DA condition) and others study with no secondary task (the FA condition). Typically the test is presented under FA; that is, attention is manipulated only during memory encoding.

In a typical study, Baddeley et al. (1984), in a series of nine experiments, used a variety of secondary tasks (e.g., a card-sorting task or a digit load task) and consistently documented the detrimental effects of dividing attention during encoding on free-recall, cued-recall, and recognition memory. Baddeley et al. (1984) also found graded effects of DA by comparing the effects of an easy secondary task (e.g., randomly placing a card into one of four piles) with the effects of a more challenging secondary task (e.g., placing a card into one of four piles based on its suit). While studying the list of words, participants simultaneously performed either the more or less challenging secondary task. Memory for the study items was worse following the more challenging secondary task.

Studies on the role of attention during episodic memory retrieval, however, are a more recent development in the literature, yielding inconsistent results. Specifically, some studies find large DA effects (e.g., Dodson & Johnson, 1996; Fernandes & Moscovitch, 2000, 2002, 2003; Gooding, Mayes, van Eijk, Meudell, & MacDonald, 1999; Gruppuso, Lindsay, & Kelley, 1997; Hicks & Marsh, 2000; Jacoby, 1991; Lozito & Mulligan, 2006; Mulligan & Hirshman, 1997; Rohrer & Pashler, 2003) whereas others do not (e.g., Anderson, Craik, Naveh-Benjamin, 1998; Cinan, 2003; Craik et al., 1996; Craik, Naveh-Benjamin, Ishaik, & Anderson, 2000; Logan & Delheimer, 2001; Naveh-Benjamin, Craik, Guez, Dori, 1998; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000a; Naveh-Benjamin, Craik, Perretta, & Tonev, 2000b; Naveh-Benjamin & Guez, 2000). In light of these empirical disparities, conclusions regarding the interplay between attention and episodic retrieval have also been inconsistent. In the following section of the paper, I will review this body of research and address the role of attention during episodic retrieval.

CHAPTER II

DIVIDED ATTENTION DURING EPISODIC RETRIEVAL

In a typical experiment, participants study a list of items (under FA conditions) and later take a memory test for those items. Some participants take the memory test while simultaneously performing a secondary task and others take the test with no secondary task. Baddeley et al. (1984) performed the first comprehensive study into the effects of dividing attention during memory retrieval. Unlike the effects of performing these tasks during encoding, Baddeley et al. found that, when performed concurrently with memory retrieval, neither secondary task affected memory performance. The finding of little or no decline in memory performance when attention is divided at retrieval is typical of numerous studies that examine this phenomenon (Craik et al., 1996; Craik et al. 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000a; Naveh-Benjamin et al., 2000b; Naveh-Benjamin & Guez, 2000).

From these results, Baddeley et al. (1984) concluded that retrieval processes are automatic and do not compete for attentional resources. Subsequent research has since disputed this claim (Craik et al., 1996; Naveh-Benjamin et al. 2000a; Naveh-Benjamin et al. 2000b). Craik et al. also had participants perform a concurrent task during memory retrieval. However, this study provided *two* assessments of the role of attention in memory retrieval: (1) the effects of a secondary task on memory performance and (2) the effects of memory retrieval on the secondary task (called *secondary task costs*). The secondary task used in this study was a continuous reaction time (CRT) task, which consists of four boxes arranged horizontally on a computer screen. At random, an asterisk appears in one of the four boxes and the participant indicates its location by pressing one of four keys. The response immediately starts the next trial, necessitating continuous responding.

Craik et al. found that the CRT task retrieval produced little or no decline in memory accuracy compared to memory retrieval in isolation. Thus, the results of Baddelely et al. (1984) were replicated for tests of free-recall, cued-recall, and recognition. However, when the attention demands of retrieval were measured through secondary task costs, large and consistent effects were found. That is, the responses on the CRT were longer when that task was carried out in conjunction with memory retrieval than when carried out by itself (Craik et al., 1996; see Naveh-Benjamin et al., 1998, for similar results). This is contrary to Baddeley et al.'s (1984) central claim that retrieval processes are automatic. The large secondary task costs imply that retrieval must require the use of attentional resources.

Craik et al. (1996) concluded that unlike encoding processes, which are susceptible to the disruptive effects of dividing attention, retrieval processes are obligatory (or "protected") and thus not hindered by dividing attention (Craik et al., 1996; Naveh-Benjamin et al., 2000b). That is, they argued that although retrieval is attention-demanding, success of retrieval is unaffected by competition for central processing resources because it takes precedence over other ongoing activities. In further support of this, Craik et al. (1996) instructed some participants to emphasize the memory test, other participants to emphasize the CRT task, and others to emphasize both equally. They found that the type of instructions had no effect on memory performance. That is, participants performed equivalently on the memory test regardless of how they were told to allocate their attentional efforts. This indicates that the allocation of attention resources during retrieval is not under the participant's control (Craik et al., 1996). This contrasts with the effects of dividing attention during encoding, where the same attentional focus instructions produced graded memory performance (with instructions to focus on encoding leading to highest memory performance, instructions to focus on the secondary task producing worst performance, and instructions to emphasize both equally leading to intermediate performance). This implies that, unlike encoding processes, retrieval processes are not under the control of participants (i.e., they are obligatory).

A recent study using positron emission tomography (PET) provides further evidence (Iidaka, Anderson, Kapur, Cabeza, & Craik, 2000; see also, Anderson et al., 2000). The behavioral methodology of this study was similar to that of Craik et al. (1996). It was found that under FA, memory retrieval processes selectively activated specific regions of the brain (including the right pre-frontal cortex, the right anterior-cingulate gyrus, and two areas in the right middle-frontal gyrus). Interestingly, DA did not reduce activation in these areas. These results seem consistent with the behavioral finding that dividing attention during retrieval had no effect on later memory performance and indicate that, even under DA, retrieval processes operate normally. This contrasts with the results from encoding where the secondary task reduced both memory performance and activation in brain regions selectively engaged by encoding processes.

Returning to behavioral measures, studies prior to Baddeley et al. (1984) reveals a similar pattern of results with respect to dividing attention during memory retrieval (Johnston, Greenberg, Fisher, & Martin, 1970; Johnston, Griffith, & Wagstaff, 1972; Johnston, Wagstaff, & Griffith, 1972; Martin, 1970; Martin & Kelly, 1974; Martin, Martson, & Kelly, 1973; Trumbo & Milone, 1971). All of these early examined secondary task costs to determine the attention requirements of the primary memory task (i.e., DA effects on memory retrieval were not measured). These studies, consistently found that memory retrieval produced large and robust secondary task costs, supporting the idea that memory retrieval requires attentional resources (e.g., Johnston et al., 1970; Martin, 1970; Trumbo & Milone, 1971).

A number of studies have supported the notion that episodic retrieval is obligatory. This has been shown for tests of free- and cued-recall (Craik et al. 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000a; Naveh-Benjamin et al., 2000b; Naveh-Benjamin & Guez, 2000) and for tests of recognition (Anderson et al., 1998; Baddeley et al., 1984; Craik et al., 1996; Dodson, Holland, & Shimamura, 1998; Jones & Jacoby, 2001; Koustaal, Schacter, & Brenner, 2001; Troyer & Craik, 2000; Whiting & Smith, 1997). Despite this, other studies have found large, deleterious effects of DA on levels of recall (Carrier & Pashler, 1995; Fernandes & Moscovitch, 2000, 2002, 2003; Gooding et al., 1999; Park, Smith, Dudley, & Lafronza, 1989; Rohrer & Pashler, 2003) and recognition (Carrier & Pashler, 1995; Dodson & Johnson, 1996; Fernandes & Moscovitch, 2000; Gooding et al., 1999; Gruppuso et al. 1997; Hicks & Marsh, 2000; Jacoby, 1991; Lozito & Mulligan, 2006; Mulligan & Hirshman, 1997), showing that, under certain circumstances, memory retrieval can be severely affected by dividing attention.

Fernandes & Moscovitch (2000, 2002, 2003; Fernandes, Moscovitch, Zeigler, & Grady, 2005) argued that material-specific interference effects occur when the primary memory test and secondary task utilize the same type of materials (e.g, words) because both tasks will draw on the same domain-specific representational systems. In one study, Fernandes et al. (2005) had participants a recognition test for a list of previously presented words while simultaneously engaging in one of two secondary tasks: (1) an animacy task in which participants were presented with a series of words, half of which represented living objects and half of which represented non-living objects; participants responded whenever a word representing a non-living object was presented or (2) a digit monitoring task in which participants were presented with a series of numbers, half of which were odd and half of which were even; participants had to respond whenever an odd digit was presented. The verbal secondary task severely impaired recognition memory. Critically, they found the numerical distracter task produced no memory interference (e.g., Fernandes et al., 2005). Fernandes and Moscovitch (2000, 2002, 2003; Fernandes et al.) argued the similarity in materials between the retrieval and secondary tasks induces competition for use of a word-specific representational system, which resulted in decrements to memory retrieval. According to this analysis, prior studies (e.g., Craik et al., 1996) failed to obtain DA effects because the primary and secondary tasks used different materials (e.g., a verbal memory test paired with any number of non-verbal secondary tasks, such as the CRT task). Thus the retrieval and secondary tasks failed to compete for the same domain-specific representational system.

Hicks and Marsh (2000) highlighted a different issue. They argued that the type of retrieval in which participants engage is the critical determinant of whether or not memory retrieval will be affected by a concurrent task. Hicks and Marsh appealed to the dual-process model of recognition memory. This model proposes that memory retrieval consists of two independent processes, recollection and familiarity that act as alternative bases for making recognition memory decisions (see Yonelinas, 2002, for a review). Recollection is viewed as consciously remembering both the specific test item and the context in which it occurred whereas familiarity is described as a feeling that an item was previously encountered without a retrieval of contextual details. Importantly, recollection is assumed to be conscious, effortful, and heavily reliant on attention (Yonelinas, 2002). Hicks and Marsh hypothesized that retrieval driven by recollection, as opposed to familiarity, would be severely affected by dividing attention. To test this, Hicks and Marsh had participants encode items in one of two manners: reading intact words or generating words from anagrams. It has been previously shown that generating words during encoding produces more recollection during retrieval than does reading

(Gardiner, 1988). Hicks and Marsh found little effect of DA for memory in the read condition (a finding consistent with the results from Baddelely et al., 1984 and Craik et al., 1996). Importantly, they found retrieval of the generated items was greatly affected by a concurrent task. According to this analysis, prior studies found little or no DA effect because they used encoding conditions that failed to elicit recollective retrieval on the subsequent memory test.

In an extension of Hicks and Marsh's (2000) study, Lozito and Mulligan (2006) had participants encode a series of word either semantically or phonetically through the use of orienting questions. Semantic questions asked participants about the category membership or synonymity of a word; phonetic questions asked participants about the sound of the word. Half of the words word encoded semantically and half phonetically. Further, half of the semantic and phonetic questions required a positive response (yes-items) and half a negative response (no-items). It was found that DA affected retrieval of items in the semantic and phonetic conditions equally. Interestingly, DA affected yes-items but not no-items. Craik and Tulving (1975) noted differences between yes- and no-items that help explain the results: "…it does not seem intuitively reasonable that words associated with *yes* responses require deeper processing before the decision is made. However, if high levels of retention are associated with "rich" or "elaborate" encodings of the words (rather than deep encoding), the differences in retention between positive and negative words becomes understandable." [italics in original] (Craik & Tulving, 1975, p. 281). Under this view, the yes questions facilitate the integration of the studied word and its encoding (question) context into a coherent memory trace, which can assist recognition accuracy. During the test, a yes-item might lead to a retrieval of the question, which would be positive evidence of "oldness." No-items, however, are less likely to lead to question retrieval (Craik & Tulving, 1975; Morris, Bransford, & Franks, 1977). Such retrieval of contextual information is typically conceived of as recollection (e.g., Yonelinas, 2002). Consequently, the present results and analysis are an extension of Hicks and Marsh's (2000) general claim that conditions promoting recollection produce retrieval susceptible to dividing attention.

Rohrer & Pashler (2003) argued that many prior studies on DA and retrieval used insufficiently demanding secondary tasks, which failed to produce deleterious effects of the task on memory retrieval (see also, Hicks & Marsh, 2000, for a similar argument). Specifically, they argued that the CRT task used in many prior studies (e.g., Craik et al., 1996) suffered from two limitations. Firstly, it was self-paced, which would allow participants to "cheat" by alternating between the primary and secondary task (i.e., purposely responding to this task in between memory retrievals rather than during memory retrievals). Secondly, the CRT task has highly compatible response mapping (i.e., if the asterisk appeared in the right-most box, participants pressed the right-most button), rendering this task easier. In response to this, Rohrer and Pashler utilized a secondary task that was not self-paced and for which the response mappings were not compatible. Their secondary task consisted of a serial-choice-reaction task in which participants responded to stimuli that appeared at a fixed presentation rate. Each stimulus was either a red, blue, or green square that appeared on a computer screen for a fixed duration. Participants used the keyboard and pressed the appropriate key for each color square (B for red, N for green, and M for blue). They found that their secondary task greatly reduced free recall performance, supporting the idea that, given a sufficiently demanding secondary task, any type of memory test can be disrupted by a concurrent task.

A good deal of recent research has explored the role of attention during memory retrieval. One limitation is that nearly all of the extant research in this area has focused on conscious, explicit memory. Almost no research has focused on the role of attention during unconscious, implicit retrieval.

CHAPTER III

IMPLICIT MEMORY

Memories can be retrieved either explicitly or implicitly. In traditional explicit memory tests, participants are required to consciously think back and intentionally retrieve information about prior events (usually experimenter provided). Explicit memory is typically measured by tests that make specific reference to the prior events, such as recall or recognition. These may be contrasted with implicit memory tests, which assess unintentional, or incidental, influences of memory. Implicit memory is inferred by changes in performance such as increased speed or accuracy in responding to a recently-experienced stimulus relative to a baseline condition. Examples of implicit tests include word-stem and word-fragment completion tasks. In these tasks, participants are initially presented with a series of words (e.g., *table*). During a later test phase, participants are presented with a series of word stems (e.g., *tab___*) or word fragments (e.g., *t_b_e*) and are asked to complete each with the first appropriate word that comes to mind (e.g., '*table*'). Some of the stems or fragments can be completed with studied (old) words and others can be completed with counterbalanced new words. Implicit memory is measured by subtracting the probability of successfully completing the new fragments from the probability of successfully completing the old fragments. Thus, the resulting number represents the degree to which prior exposure to the words benefited participants on the old fragments. Importantly, implicit tests make no mention of the relationship of the test to the prior study episodes. Facilitation on these tests can occur without conscious recollection of the study episode (see Schacter, 1987, for a review).

Dissociations between Implicit and Explicit Tests

The distinction between implicit and explicit retrieval is supported by converging evidence from neuropsychological, neuroscientific, aging, clinical, and pharmacological research. Such research has demonstrated consistent dissociations between implicit and explicit retrieval, with certain populations or conditions experiencing deficits to one type of retrieval, with relative sparing of the other. I will next describe population and pharmacological dissociations that underscore fundamental differences between implicit and explicit types of retrieval.

Warrington and Weiskrantz (1968, 1970, 1974, 1978) provided the first examples of a dissociation between implicit and explicit memory. In one study, Warrington & Weiskrantz (1970) examined memory for words in patients with anterograde amnesia and normal controls using three types of retrieval tasks: free recall, recognition, and word-fragment completion. Compared to healthy controls, amnesic patients consistently showed deficits to explicit memory (recall and recognition), with near-normal levels of priming (word-fragment completion). A similar pattern of results has been shown using a variety of other implicit tasks (e.g., Cohen & Squire, 1980; Graf & Schacter, 1985; Graf, Squire, & Mandler, 1984; Moscovitch, 1982; Shimamura, 1986; for a review, see Schacter, 1987).

The effects of age reveal a similar dissociation between implicit and explicit memory. When healthy younger and older adults are compared, older adults are typically impaired on explicit tests (see Verhaeghen, Marcoen, & Goossens, 1993, for a review). On implicit tests, however, younger and older adults typically show equivalent levels of priming (e.g., Light & Singh, 1987; for reviews, see Fleischman & Gabrieli, 1998; Craik, Anderson, Kerr, & Li, 1995; Zacks, Hasher, & Li, 1999). Light and Singh, presented younger and older adults with a series of words and explored age differences in implicit memory (with tests of word-stem completion and perceptual identification) and explicit memory (free recall, cued recall, and recognition). They found that older adults had consistently lower levels of explicit memory on all tests, with no deficit in any of the implicit tests. People with schizophrenia (Danion, Meulmans, Kauffman-Muller, Vermaat, 2001; Gras-Vincendon et al., 1994) and with depression (Bazin, Perruchet, de Bonis, & Féline, 1994) show similar patterns of implicit and explicit memory performance compared to healthy controls.

Pharmacological studies also support the implicit—explicit distinction. Benzodiazepines (including triazolam, diazepam, and midazolam) are central nervous system depressants used in anesthesia and to treat anxiety. These drugs also produce a powerful but temporary form of anterograde amnesia, in which memory for information encountered after administration of the drug is poor. Research has shown that such adverse effects on memory are largely restricted to explicit memory with relatively unaffected levels of priming[1] (Danion, Zimmerman, Willard-Schroeder, Grangé, & Ghoneim, 1989; Hirshman, Passanante, & Arndt, 1999a; Hirshman, Passanante, & Arndt, 2001; Hirshman, Passanante, & Henzler, 1999b; Polster, McCarthy, O'Sullican, Gray, & Gilbert, 1993; Weingartner, Hommer, Lister, Thompson, & Wolkowitz, 1992; see Curran, 2000, for a review). Hirshman et al. (1999b) induced amnesia in participants using midazolam. Each participant participated in two sessions (one under the influence of midazolam and the other with a saline control). Participants initially studied a series of visually presented words. The test phase began 50 minutes after the study phase to ensure that participants were no longer under the influences of the midazolam. During the test phase, participants engaged in two implicit tests (perceptual identification and

[1] A (relative) sparing of implicit memory, compared with concomitant disruption to explicit memory, has been demonstrated across many studies using a variety of benzodiazepines. However, it has been found that one benzodiazepine, namely Lorazepam consistently reduces memory performance across explicit and implicit memory tests (e.g., Brown, Brown, & Bowes, 1989; Danion et al., 1999; Sellal et al., 1992; Vidaihet, Kazès, Danion, Kauffmann-Muller, & Grangé, 1996; Vidailhet, Danion, Chemin, Kazès, 1999).

word-fragment completion) and one explicit test (free recall). Relative sparing of implicit memory was found. That is, the midazolam-induced amnesia was disproportionately larger for explicit memory (see also Polster et al., 1993, for similar results). Thus, the benzodiazepine-induced amnesia produces a similar dissociation between implicit and explicit memory as that caused by organic amnesia.

All such studies demonstrate single dissociations. That is, a dissociation in which a population shows a deficit in explicit memory, with no effect on implicit memory. Even more compelling evidence for the implicit—explicit distinction would be a double dissociation. In other words, a dissociation in which two distinct populations (i.e., patients with damage to different parts of the brain) exhibit opposite patterns of implicit and explicit performance. One study demonstrated such a double dissociation between implicit and explicit retrieval (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995). Gabrieli et al. gave a series of explicit (recognition and cued-recall) and implicit (perceptual identification, word-stem completion, and category exemplar production) tests to a patient, M. S., who has a lesion to the right occipital lobe. Gabrieli et al. found that M. S. had intact explicit memory and impaired implicit memory across all administered tests. This contrasts to the dissociations described above, in which amnesic patients with medial temporal lobe damage showed the opposite dissociation. These dissociations provide striking evidence in favor of a distinction between implicit and explicit types of retrieval.

All of the above research has demonstrated population dissociations between implicit and explicit memory. A study by Jacoby (1983) further supports this distinction by demonstrating a functional dissociation between implicit and explicit memory. During the learning phase, participants studied words in one of three conditions. In the no-context condition, participants read words that were presented with a preceding neutral stimulus (e.g., *xxx—cold*). In the context condition, participants read words presented with a preceding antonym (e.g., *hot—cold*). In the generate condition, participants generated target words from antonym cues and the first letter of the target word (e.g., *hot—c*, for *cold*). During retrieval, participants engaged in either a perceptual identification or recognition test. The results for the recognition test replicated the traditional generation effect (Slamecka & Graf, 1978), with generated items producing the greatest recognition accuracy, followed by the context condition, with the no-context condition producing the lowest accuracy. Interestingly, performance on the perceptual identification task produced the exact opposite pattern. Thus a generation manipulation also dissociates performance on these implicit and explicit tests.

Dissociations between Perceptual and Conceptual Tests

Implicit (and explicit) retrieval is further dissociable into perceptual and conceptual forms, here referred to as the *perceptual—conceptual hypothesis*. *Perceptual priming* reflects implicit memory for stimulus form and is sensitive to changes in perceptual (e.g., visual or auditory) information. Because of this, perceptual implicit tests emphasize form attributes of the stimulus. One example of a perceptual implicit test would be a word-stem completion task in which participants are presented with a word stem (e.g., *sto*__) and are asked to complete the stem with the first word that comes to mind. Such a task places heavy reliance on visual information about the word. Because perceptual tests reflect visual or auditory information about a stimulus, such tests are sensitive to changes in study—test form (i.e., changes between study and test items in visual or auditory information). For example, priming in word-stem completion is lower when study words were presented aurally than when they were presented visually (e.g., Gabrieli, Fleicshman, Keane, Reminger, & Morrell, 1995; Graf, Shimamura, & Squire, 1985). Further, participants are faster to name pictures at test (i.e., a picture naming task) when they were presented with pictures at study than when they were presented with picture names (e.g., Brown, Neblett, Jones, & Mitchell, 1991; Park & Gabrieli, 1995).

Further, perceptual priming shows a reverse generation effect, with reading words producing more perceptual priming than generating words (e.g., Jacoby, 1983). Generally, perceptual priming is enhanced by emphasizing perceptual encoding of a stimulus and is decreased by a disruption to or change in perceptual information.

Conceptual priming reflects implicit memory for stimulus meaning. Thus, conceptual implicit tests emphasize semantic attributes of the stimulus. One example is category exemplar production in which participants are presented with category names (e.g., *furniture*) and are asked to quickly generate exemplars from each category. Priming is inferred when previously-studied examples are more likely to be produced than baseline examples. Priming in such a test is heavily reliant on conceptual (semantic) information about the word. Conceptual implicit tests are therefore sensitive to encoding manipulations than emphasize semantic features of stimuli. Having participants think about the meaning of the words during the study phase has been shown to enhance later conceptual priming more than having participants think about the form of words (i.e., conceptual tests show a levels-of-processing effect; e.g., Mulligan, Guyer, & Belland, 1999). This contrasts with perceptual priming, which show no levels-of-processing effects. Finally, changes in study—test form (e.g., modality manipulations) do no affect conceptual priming, again contrasting with perceptual tests.

Much research has supported the distinction between perceptual and conceptual types of processing (e.g., Blaxton, 1989; Jacoby, 1983; for reviews, see Roediger, 1990; Roediger & McDermott, 1993; Roediger, Weldon, & Challis, 1989). In revisiting the Jacoby (1983) study, it has been since argued that the recognition test relies more heavily on conceptual processing and the perceptual identification task relies more heavily on perceptual processing. Thus the two memory tests differ along implicit—explicit and perceptual—conceptual lines. This functional dissociation between implicit and explicit types of retrieval can therefore also be interpreted in terms of a distinction between perceptual and conceptual retrieval tasks.

Blaxton (1989) elaborated on the Jacoby (1983) study by further demonstrating a separation of implicit (and explicit) retrieval into perceptual and conceptual types. Blaxton included four types of memory tests: (1) word-fragment completion (an implicit—perceptual test); (2) general knowledge questions, some of whose answers were presented at study (an implicit—conceptual test); (3) graphemic cued recall in which participants were presented with words that were visually similar to studied words and were asked to use the visual cue to recall the study word (an explicit—perceptual test); and (4) free recall and semantic cued recall in which participants were presented with words that were semantically related to prior studied words and were asked to use the semantic cue to recall the study word (both are explicit—conceptual tests). Thus, Blaxton expanded upon the Jacoby study by including implicit-conceptual and explicit-perceptual types of tests. The study phase was identical to Jacoby's study. Blaxton replicated the results from Jacoby's study with explicit—conceptual tests exhibiting a generation effect and implicit—perceptual tests exhibiting a reverse generation effect. In addition, the no-context condition enhanced memory on the explicit—perceptual tests and the generate condition enhanced priming for the implicit—conceptual tests. As a result, such a finding shows a clear dissociation between perceptual and conceptual types of implicit (and explicit) retrieval with generation enhancing performance across all conceptual tests and reading (with no context) enhancing performance across all perceptual tests.

A further manipulation that dissociates these two types of tests is dividing attention during the study portion. This has been consistently shown to significantly reduce levels of conceptual priming across a multitude of conceptual implicit tests (e.g., Gabrieli et al., 1999; Mulligan, 1997, 1998; Mulligan & Hartman, 1996). Perceptual priming is less likely to be disrupted by the same DA manipulations (e.g., Mulligan, 2003, Experiment 2; Mulligan & Hornstein, 2000; Mulligan & Hartman, 1996; Parkin & Russo, 1990; Russo & Parkin, 1993 cf. Mulligan, 2003, Experiment 1; Light & Prull, 1995). Thus, dividing attention during study appears to affect perceptual and conceptual tests differently.

The functional dissociations between perceptual and conceptual priming may reflect corresponding anatomical dissociations in neural systems that underlie these two types of priming tasks (for a review, see Schacter, Wagner, & Buckner, 2000). Converging evidence from neuropsychological and neuroscientific research indicates that perceptual priming is supported by activity in modality-specific regions of the brain. For example, visual priming is linked to visual areas of the occipital lobes, with neural activity in extrastriate cortex heavily linked to visual priming (Blaxton et al., 1996; Buckner et al., 1995; Fleischman et al., 1995; Gabrieli et al., 1995; for a review, see Schacter et al., 2000). Conceptual priming, on the other hand, is supported by activation in left frontal and temporal-parietal brain regions (Blaxton et al., 1996; Gabrieli et al., 1996; Demb et al., 1995). Along similar lines, Schacter and his colleagues (e.g., Schacter et al., 2000) have proposed that perceptual priming is supported by the perceptual representation system (PRS), a memory system that processes information about the structure and form of objects, prior to analysis of their semantic content. Presumably, conceptual priming is primarily driven by activation of representations within the semantic memory system (Schacter et al., 2000). Because dissociations between these two proposed systems of memory have been observed using brain imaging techniques (e.g., Blaxton et al., 1996), it may provide further evidence of a neurological, as well as functional, dissociation between perceptual and conceptual types of priming.

Dissociations between Identification and Production Tests

A more recent distinction between types of implicit tests was motivated by research on patients with Alzheimer's disease (AD). Initial studies of AD seemed to support the implicit—explicit and the perceptual—conceptual distinction. Similar to amnesic patients, AD patients show impairment to explicit memory (recall and recognition), while exhibiting intact perceptual priming (e.g., a word identification task; Abbenhuis, Raajmakers, Raajmakers, & Van Woerden, 1990; Fleischman et al., 1995; Fleischman et al., 2001; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991; Russo & Spinler, 1994; for a review, see Fleischman & Gabrieli, 1998). Unlike amnesic patients, however, AD patients show reduced priming on conceptual tests (e.g., word-association and category-exemplar production; Brandt, Spencer, McSorely, & Flostein, 1988; Carlesimo, Fadda, Marfia, & Caltagirone, 1995; Monti et al., 1996; Vaidya, Gabrieli, Monti, Tinklenberg, & Yesavage, 1999; for a review, see Fleischman & Gabrieli, 1998). Thus AD patients show an additional dissociation that amnesic patients do now show: intact perceptual priming and impaired conceptual priming.

However, AD patients show an additional deficit that fails to map onto either the implicit—explicit distinction or the perceptual—conceptual distinction. Namely, AD patients display a significant impairment in word-stem completion priming (Fleischman et al., 2001; Gabrieli et al., 1994; Gabrieli et al., 1999; Keane et al., 1991; Salmon, Shimamura, Butters, & Smith, 1988; Shimamura, Salmon, Squire, & Butters, 1987). Such an impairment cannot be explained by a deficit to explicit memory, nor to a deficit in conceptual priming. This task therefore represents an implicit—perceptual task that is impaired among AD patients.

In response to this additional deficit, Gabrieli et al. (1999; Fleischman et al., 2001; Prull, 2004) introduced a further distinction between implicit tasks to account for the data from AD patients, here referred to as the *identification—production hypothesis*. According to this distinction, implicit tests are classified as tests that involve stimulus identification or that involve stimulus production. *Identification priming tasks* instruct participants to identify a test stimulus (e.g., What is this word? *table*) or verify an attribute of the stimulus (e.g., Is *table* a type of furniture: yes or no?; Is *table* living or nonliving?). Identification tests can involve the analysis of either the form or the meaning of a stimulus. Stimuli may be presented normally, or in degraded form. In all cases, participants are asked to identify the stimulus, or some feature of the stimulus. One example of this kind of task would be a category verification test in which participants are presented with a word (e.g., *table*) and are asked to verify whether or not it comes from a specific category (e.g., *furniture*). Other identification tasks include word or picture naming, lexical decision, semantic verification, semantic classification, and single-response word-fragment tests. Critically, identification tests have in common a search process for which there is only one correct answer, implying that retrieval cues map onto, or activates, only a single representation in memory. That is, search processes ultimately converge upon a single response or representation. As a result, Gabrieli et al. argued that these tasks rely on *convergent search processes* (see also, Prull, 2004).

Other kinds of implicit tasks cannot be achieved by identifying, verifying, or classifying a stimulus. Rather participants use a cue in an open-ended manner to generate many correct responses. These kinds of implicit tasks are called *production priming tasks*. An example of this kind of task would be a word-stem completion task in which participants are presented with a word stem (e.g., *sto*___) that matches many legitimate completions (e.g., *store*, *stone*, *stole*, *storm*, etc.), and are asked to complete the stem with the first word that comes to mind. Other production tasks include: category-exemplar production, multiple-response word-fragment completion, and word association. Critically, for production tests, there are many possible answers, implying that test cues map onto (or activates) many potential responses. Because many potential responses are activated by test cues, Gabrieli et al. argued that these kinds of tasks involve *divergent search processes*. Such search processes are purported to require the selection of one response from an array potential responses that are activated by the presented cue (see also, Prull, 2004).

The identification—production distinction is empirically supported by dissociations across several behavioral and neuropsychological studies. For example, production priming tasks have been shown to be more adversely affected by study phase division of attention (Gabrieli et al., 1999, Experiment 2). In this experiment, half of the participants studied either picture or words (the names of the pictures) in isolation; the other half of participants studied the same pictures or words while maintaining a concurrent memory load. The identification priming task was a picture naming task and the production priming task was a word stem completion task (all participants who studied pictures performed the identification task and all participants who studied words performed the production task). Gabrieli et al. indeed found that study phase division of attention affected word stem completion but not picture naming.

Neuropsychologically, it has been demonstrated that people with Alzheimer's disease (AD) show disrupted production priming and near-normal identification priming (e.g., Fleischman et al., 2001; Gabrieli et al., 1999; see Fleischman & Gabrieli, 1998, for a review). For example, relative to healthy controls, people with AD demonstrated reduced priming on word-stem completion but normal priming in word naming (Fleischmman et al.; Gabrieli et al.). Furthermore, people with AD were impaired on category exemplar production but had normal levels of priming in category-exemplar verification (Gabrieli et al., Experiment 3). Thus, the identification—production distinction fits the pattern of implicit performance among AD patients and highlights why they show impairment in word-stem completion: it is a production task, on which they are generally impaired.

It has been argued that one further distinction between identification and production tasks lies in attentional demand during retrieval (Fleischman et al., 2001).

Specifically, production tests require the selection of a response from an array of potential responses, producing response competition. Identification tests activate only a single representation, eliminating response competition. This increased response competition is purported to induce heavier attentional load for production tests relative to identification tasks during retrieval. Evidence in favor of this comes from brain imaging studies (e.g., Desmond, Gabrieli, & Glover, 1998; Thompson-Shill, D'Esposito, Aguirre, & Farah, 1997), which have shown that left frontal lobe activation increases systematically with increases in response competition in production tasks. Prior researchers have posited that tasks that heavily activate frontal areas will be most susceptible to dividing attention (e.g., Moscovitch, 1994). Because response competition is minimized for identification tasks (because the search processes converge upon a single response), these tasks may involve less left frontal brain activation and less allocation of attentional resources. Thus this analysis also indicates that production tests should be more affected by dividing attention than identification tests. As noted earlier, Gabrieli et al. (1999) demonstrated that dividing attention during study affected production tasks more than identification tasks. However, given that this distinction emphasizes differences in the processing requirements (including attentional requirements) of the test, this makes the clear prediction that dividing participants' attention during the test phase should more adversely affect production tasks than identification tasks. Because attentional manipulations have only been implemented during the study phase, the identification—production distinction has yet to be fully evaluated in this regard.

CHAPTER IV

ADDITIONAL THEORETICAL AND EMPIRICAL WORK

Automatic Implicit Retrieval

Dual-process models of memory retrieval distinguish between recollection and familiarity, arguing that both contribute to memory retrieval (Jacoby, 1991; Yonelinas, 2002). Recollection is assumed to be conscious and attention-demanding; whereas familiarity is assumed to be automatic. Furthermore, in this model, familiarity is assumed to rely on the same mechanisms that produce priming on implicit tests (e.g., Jacoby, 1991). Thus, the dual-process model argues that familiarity, and by extension implicit memory retrieval, is automatic. In fact, some researchers have made the specific claim that implicit memory retrieval processes, relative to explicit memory retrieval, are unconscious and therefore automatic (e.g., Gooding et al., 1999; Jacoby, 1991; Moscovitch, 1992), here termed the *automaticity hypothesis*. To date, most studies have focused on the role of automatic and controlled processing in explicit retrieval tasks such as recognition, with very few studies investigating such processing in implicit retrieval.

Further, Logan (1990) argues that both repetition priming and automaticity result from a common underlying mechanism – namely, the storage and retrieval of representations of individual exposures to specific items. In other words, in repetition priming tasks, old items are experienced for the second time, whereas new items are experienced for the first time (within the context of the experiment). Thus, Logan argues that this second exposure to the item decreases the attentional demands of processing the item and the improvements in performance found for old items relative to new items is the result of the increased automaticity of processing these items.

Neuroimaging research suggests that the priming component of implicit tests reflect decreases in brain activation (e.g., Blaxton et al., 1996; see Henson, 2005, for a review). Blaxton et al. (1996) contrasted a conceptual (semantic association) and perceptual (word-fragment completion) implicit test. They found that the semantic association task generally activated medial and lateral left hemisphere in frontal and temporal regions. Word-fragment completion, in contrast, produced greater activation in right frontal and temporal cortex as well as bilateral activation in more posterior regions. For semantic association, comparisons of the old trials with new trials (control) revealed memory-specific deactivations in left medial and superior temporal cortex as well as left frontal cortex. Memory-specific deactivations for word-fragment completion were localized in more posterior regions including occipital cortex. These patterns of deactivation imply diminished processing demands old items relative to new items.

The component process model proposed by Moscovitch (1992) is also relevant to the present study. According to this model, memory performance across a variety of types of tests is mediated by four components: (1) a nonfrontal neocortical component, (2) a modular medial temporal/hippocampal component, (3) a frontal-lobe central system, and (4) a basal ganglia component. Critically, it is proposed that the frontal-lobe central system is involved in strategic, effortful processing at encoding and retrieval; whereas the other components process information manditorily and automatically. Thus, relative to tasks that involve central systems, tasks that are mediated by modules require few attentional resources for their operation and should not be disrupted by a concurrent task (e.g., Moscovitch, 1994). Originally, Moscovitch (1992) proposed that implicit memory retrieval is mediated by the nonfrontal, neocortical component. Thus, the original version of this model predicted that implicit memory retrieval should generally be automatic and unaffected by a concurrent task during retrieval. Later research indicated that conceptual priming was driven by activation in frontal areas of the brain. Thus this analysis suggests that conceptual priming, driven by the frontal component, will be sensitive to dual-task demands; perceptual priming, on the other hand, will not be.

The Role of Environmental Support

One additional theoretical framework is relevant to my inquiry. This framework, developed by Craik (1986; Craik & Byrd, 1982), posits that retrieval tasks vary in the degree to which they require self-initiated cognitive operations. That is, certain retrieval tasks provide little environmental support (e.g., test cues), increasing the need for participants to reconstruct the original encoding event (e.g., retrieve the study context) to successfully retrieve information. Other tests, however, provide greater amounts of environmental test support, diminishing the need for self-initiated processing.

For example, Craik (1986) argues that free recall, for which participants are given no overt cues and thus little environmental support requires the heaviest use of self-initiated processing. Recognition, which re-presents the actual study stimuli, requires much less self-initiated processing. Cued recall, for which participants have to recall an item based on a test cue, falls between free recall and recognition in terms of need for self-initiated processes and amount of environmental support. This implies a continuum which distinguishes memory tests in terms of reliance upon self-initiated processing.

Craik has adduced support for this framework from research on age differences in memory. Craik posits that aging is accompanied by a concomitant reduction in attentional resources. He further argues that those tasks that require the heaviest use of self-initiated processes are most attention-demanding and therefore should show the largest age-related deficits in memory performance. In support of this, older adults typically show memory deficits largest for free recall, smallest for recognition, and intermediate for cued-recall (for reviews, see Craik, 1986; Craik & Byrd, 1982; see Verhaeghen, Marcoen, & Goossens, 1993 for a meta-analysis). For present purposes, this continuum is relevant in terms of the attention demand of different tests. That is, free recall would be most attention-demanding, recognition least attention-demanding, with cued-recall intermediate. Further support for this comes from studies that have shown that DA effects are largest for free recall, followed by cued-recall, with recognition performance least affected (e.g., Craik et al., 1996).

Because implicit retrieval is posited by some to be more automatic (the *automaticity hypothesis*), on the above continuum, implicit memory tests should generally be less reliant upon self-initiated processing (see Craik, 1986, for a similar argument). Thus, these tests should generally be less attention-demanding than explicit tests. Furthermore, identification priming should be less attention-demanding than production priming. For identification tests, participants are typically presented with original study stimulus and are asked to identify it or verify some aspect of it. For production tests, participants are typically presented with a test cue and are forced to generate a well-known response to it. This is accompanied by an active selection of a response from an array of potential responses. Thus, identification tasks provide more environmental support (i.e., re-presentation of the actual study item), whereas production tasks appear to require more use of self-initiated processing (i.e., active response selection). As a result, this framework implies that production tasks are more attention-demanding than identification tests, and should be more affected by dividing attention. In sum, the full continuum suggests (in terms of attentional engagement): free recall > cued recall > recognition > production priming > identification priming.

Prior Empirical Findings

One study provides evidence that implicit retrieval processes are largely automatic, supporting one of the predictions of the automaticity hypothesis (Gooding et al., 1999). In this study, participants were presented with sentences that contained cue and target words. Participants were told to read the sentences and rate the degree to which the sentence linked the cue and target words. The cue and target words were presented in all capital letters in red font (all other words were presented in lowercase letters in black font). Participants were not told to remember either the cue or target words or of the upcoming memory tests. During the test phase, participants took three memory tests: word-stem completion, cued-recall, and recognition. For the word-stem completion task, participants were presented with cue word—word stem pairs (e.g., *dove—sti*__), some of which corresponded to cue and target words that were presented in earlier sentences. The pairs presented during this test fell into one of three categories: same paired (where the cue word and word stem represented a pair that was presented together in an earlier sentence), re-paired (where the cue word and the word stem were each presented earlier, but in different sentences), or new (where a new word stem was paired with a previously presented cue word). Because both the same paired and re-paired conditions involved old word stems, priming was measured with regard to each of these conditions. For this task, priming was defined as the proportion of correct stem completions for each "old" condition minus the proportion correct for the "new" condition. The word-stem task was either done either alone or with a concurrent task. The secondary task consisted of presentation of a series of 3-4 digits, which the participants were asked to sum. The set of 3-4 digits was presented concurrently with each cue-stem pair. Consistent with the automaticity hypothesis, it was found that the concurrent task failed to disrupt the level of priming for either "old" condition (Gooding et al., 1999), despite a significant DA effect for cued-recall and recognition.

A further study provides additional insight. In this study, Helman and Berry (2003) created an artificial grammar (AG), which defined particular sequences of letters as either acceptable or unacceptable examples of the AG. During the study phase of this experiment, participants were presented with a series of strings of letters, each of which conformed to the AG. Participants were not told of the AG, only that they would be presented with a series of random letters. As a result, learning of the AG was incidental. During a later test phase, half of the participants were placed in an implicit group and the other half in an explicit group. Participants in both groups were told that they would be presented with more strings of letters and to rate how much they liked each string (using a 6-point scale). All strings during this portion of the experiment were new (i.e., they were not the same as any string presented earlier) and either did or did not conform to the AG. Participants in the implicit group were told to rate their liking of the new strings on a "gut feeling" or "first impression"; participants in the explicit group were told to rate their liking on how similar the new strings were to the ones presented earlier. Further, half of the participants in each group did only the liking ratings task, whereas the other half in each group performed the liking ratings task while concurrently engaging in a verbal random number generation task.

For the explicit group, it was found that in the FA condition, strings of letters that conformed to the AG were rated higher than those that did not (demonstrating explicit memory of the AG sequences). Under DA, however, liking ratings were no different for stings that conformed and those that did not (thus, DA reduced explicit memory). For the implicit group, it was found that in the FA condition, strings that conformed to the AG were rated higher than those that did not (demonstrating implicit memory of the AG sequences). Importantly, dividing attention had no effect on implicit liking ratings. That is, participants still rated those that conformed to the AG higher than those that did not, providing further evidence in favor of the automatic nature of implicit retrieval. The present study will extend such prior research and provide a more complete analysis of the role of attention during implicit retrieval, with respect to a variety of theoretical issues.

CHAPTER V

THE PRESENT STUDY

The present study has four goals. The first goal is to generally assess the effect of dividing attention during implicit memory retrieval. The second goal is to test whether conceptual or perceptual types of implicit tests will be affected by a concurrent task. The third goal is to determine whether identification or production types of implicit tests will be affected by DA. The final goal is to determine the role of the concurrent task is obtaining DA effects. Each of these goals is discussed in turn.

First, some prior research has indicated that implicit retrieval is automatic (the automaticity hypothesis; e.g., Gooding et al., 1999). According to this notion, implicit memory should generally be unaffected by dividing attention during retrieval. In support of this, one study has indeed shown that implicit retrieval is unaffected by dividing attention (Gooding et al.). Further research similarly implies that implicit memory is automatic. Jacoby (1991) has equated explicit retrieval to recollection and implicit retrieval to familiarity. Recollection is assumed to be slow, conscious, and attention-demanding; whereas familiarity is assumed to be fast, unconscious, and automatic. In support of this, Hicks and Marsh (2000) found that retrieval driven by recollection was more affected by dividing attention than retrieval driven by familiarity. This analysis implies that familiarity-driven and, critically, implicit retrieval should be relatively unaffected by a concurrent task (see Yonelinas, 2002, for a review). Other research suggests that any kind of retrieval can be affected by DA, given a sufficiently demanding secondary task (Rohrer & Pashler, 2003). Thus one goal of this research is to determine whether or not implicit memory retrieval is generally affected by a concurrent task. This study will extend that research by testing effects of dividing attention across a variety of implicit tests. Other theories predict that specific types of implicit tests that should be affected by dividing attention, which will be briefly summarized next.

Second, I will explore whether perceptual or conceptual tests are affected by DA than perceptual tests. Given the extensive differences between conceptual and perceptual priming, a thorough analysis of attention and implicit retrieval demands inclusion of this variable. Furthermore there are empirical and theoretical reasons why the perceptual—conceptual hypothesis predicts DA effects on conceptual, but not perceptual, priming. Specifically, conceptual implicit memory is more consistently affected by dividing attention during encoding, which indicates that conceptual implicit memory may be more reliant on controlled processing (for a review, see Mulligan & Brown, 2003). Further, conceptual implicit tests engage frontal areas of the brain (e.g., Blaxton et al., 1996), whereas perceptual implicit tests engage modality-specific areas of the brain (e.g., Gabrieli et al., 1995). Prior research has argued that tasks heavily-reliant on frontal-lobes are more susceptible to disruption from a concurrent task (Moscovitch, 1992, 1994). If this is correct and frontal lobe involvement is critical in obtaining DA effects, this yields the prediction that dividing attention should disrupt conceptual priming but not perceptual priming.

Third, I will explore whether identification or production tests are affected by DA. According to the identification—production hypothesis, one difference between production and identification implicit tests is response competition. Specifically, production tests produce more response competition than identification tests. Resolving this response competition (i.e., choosing a single response from the activated array) is assumed to be attention-demanding (Fleischman et al., 2001). Support from this comes from the fact that as response competition of a task increases, so does frontal lobe activation. As stated above, tasks that are heavily-reliant on frontal-lobes are more susceptible to disruption from a concurrent task (Moscovitch, 1992, 1994). Thus the identification—production hypothesis asserts that production tests are more reliant on attentional resources than identification tests (Fleischman et al., 2001) and DA should disrupt production priming but not identification priming.

These two considerations dictate a 2 (perceptual—conceptual) × 2 (identification—production) array of implicit tests. Thus, the present study will use of four types of implicit tests: perceptual identification, word-stem completion, category verification, and category exemplar production. Perceptual tests include perceptual identification and word-stem completion; conceptual tests include category verification and category exemplar production. Identification tests include perceptual identification and category verification; production tests include word-stem completion and category exemplar production.

Fourth, I will assess the role of the concurrent task used to divide attention. In the domain of explicit memory, an important issue is the specific characteristics of concurrent tasks that produce DA effects (e.g., Fernandes & Moscovitch, 2000; Hicks & Marsh, 2000; Rohrer & Pashler, 2003). Specifically, some researchers have argued that DA effects are most likely when the materials in the memory test and concurrent task match, producing competition for access to a material-specific representational system (e.g., Fernandes & Moscovitch, 2000). Others have argued that such effects arise because of competition for general, non-specific, resources (Hicks & Marsh, 2000; Rohrer & Pashler, 2003). Hicks and Marsh, for example, found that multiple types of secondary tasks (e.g., digit load, number generation, letter generation, and serial addition) produced large DA effects, none of which used materials that matched the word-based memory tests. Thus it remains unclear whether DA effects result from material-specific interference or for competition from general processing resources (material-general interference). To explore this, I will use secondary tasks that match those used in the implicit tests (material-specific tasks) and secondary tasks that do not match those in implicit tests (material-general tasks). All of the present implicit tests will use word stimuli. As a result, material-specific tasks will also use word stimuli and material-general tasks will use number stimuli. To assess this, I will use two versions of the three-odd task: one number-based and one word-based. The number-based three-odd task will present participants with a series of numbers; participants must respond whenever three odd digits appear in succession. The word-based three-odd task will present participants with a series of words; participants must respond whenever three two-syllable words are presented in a row. Number-based three-odd tasks have been commonly used as concurrent tasks in prior studies (e.g., Jacoby, 1991; Mulligan & Hirshman, 1997). The word-based three-odd task has also been used in prior analyses of the role of material specificity in obtaining DA effects (e.g., Fernandes & Moscovitch, 2000).

Prior research has indicated that frequency of responding to the concurrent task is also an important factor. The central bottleneck model (Pashler, 1994) proposes that certain processes (including response selection, memory encoding, and memory retrieval) require the use central bottleneck process. Importantly, only one critical process has access to the bottleneck process at any time. This analysis implies that the selection of a response to a concurrent task will be a source of disruption to memory retrieval. Critically, then, DA effects should be most apparent when participants must respond frequently to the concurrent task than when the task requires infrequent responding. That is, if the concurrent task requires frequent responding, it will frequently use the bottleneck process, which may disrupt retrieval processes from gaining access to the bottleneck process. This contrasts with the material-specificity hypothesis in that the bottleneck process is central and amodal, predicting that response selection from any task (be it material-specific or material-general) in any modality will require the use of the central bottleneck and can disrupt memory retrieval.

These two secondary task considerations dictate a 2 (material specificity) × 2 (response frequency) array in terms of type of secondary task used. Thus, the present study will use of four types of secondary tasks: (1) a choice reaction time (RT) tasks in which participants will be presented continuously with a series of words and must decide for each word whether it has one or two syllables, (2) a word-based three-odd task in which participants will be presented with a series of words and must respond whenever three two-syllable words are presented in a row, (3) a choice RT task in which participants will be presented with a series of numbers and must decide for each number whether it is odd or even, and (4) a number-based three-odd task in which participants will be presented with a series of numbers and must respond whenever three odd digits appear in succession. Material-specific secondary tasks will include the word-based three-odd and choice RT tasks; material-general secondary tasks will include the number-based three-odd and choice RT tasks. High-response secondary tasks will include the word-based and the number-based choice RT tasks; low-response secondary tasks will include the word-based and number-based three-odd tasks.

Thus, I will examine the magnitude of the DA effect produced by each type of secondary task to help delineate the specific conditions under which DA effects occur. I will also examine the secondary tasks costs produced by each of the types of implicit tests for several reasons. First, much prior research in the explicit domain has focused not only on the DA effect produced by the secondary task on the memory test, but also on the secondary task costs produced by the memory test. Second, such an analysis might provide a more sensitive manner in which to assess the role of attention during implicit retrieval. Specifically, exploration of secondary task costs uncovered the importance of attention to explicit retrieval, even when it was not revealed in analysis of DA effects on memory performance (e.g., Craik et al., 1996). Third, assessment of both memory effects and secondary task costs provides a manner in which to fully explore the role of attention during implicit memory retrieval. The various theoretical positions described above make the same predictions for the size of the secondary task costs as they do for the effects on priming.

Secondary task costs will presently be measured in two manners. First, global secondary tasks costs produced by the implicit task. This will be measured by comparing a baseline condition (when the secondary task was performed alone under FA) to a DA condition (when the secondary task was performed with the memory test). This measures general secondary task costs produces by this task in which implicit retrieval is embedded, and not just costs associated with implicit reteival (i.e., priming). I am specifically interested in how implicit memory retrieval affects secondary task performance. As a result, I will also obtain a second measure of secondary task costs: the costs produced by old items relative to new items. This will be measured by comparing secondary task performance for old trials vs. new trials. Comparing secondary task costs across these two conditions will be informative to the actual cost produced by implicit retrieval.

Although this is not the first study to explore the role of attention during implicit retrieval (Gooding et al., 1999; Helman & Berry, 2003), it is the most complete. For example, Gooding et al. found no effect of dividing attention on a word stem completion task using a numerical secondary task. The implicit test was a perceptual, production test, and the secondary task was material-general and required infrequent responding. Further, secondary task costs were not measured. Thus, this study (and Helman & Berry) provides an incomplete analysis of attention and implicit retrieval.

CHAPTER VI

EXPERIMENT 1

This first experiment used a perceptual identification test. Attention was divided during the test phase only (all learning occurred under FA). Because the test is perceptual and requires stimulus identification, the two hypotheses predict that levels of priming for this test should be unaffected by dividing attention. First, according to the perceptual—conceptual hypothesis, perceptual implicit tests should be unaffected by a concurrent task. Second, according to the identification—production hypothesis, implicit tests that require stimulus identification should be unaffected by a secondary task.

Attention was divided with each of the four secondary tasks described above. DA effects were measured with respect to a baseline condition, in which participants performed the perceptual identification test in isolation. Although the perceptual—conceptual hypothesis and the identification—production hypothesis prediction minimal effects of dividing attention, the nature of the secondary tasks may induce an effect. First, prior research with explicit memory has shown that material-specific interference causes a deleterious effect of DA. As a result, it would be expected that those secondary tasks using words (e.g., the word-based three-odd and choice RT tasks) will generally produce larger DA effects than secondary tasks that use numbers (the number-based three-odd and choice RT tasks). Second, according to central bottleneck models, response selection for the secondary task will interfere with memory retrieval and produce DA effects. Thus, this account would predict that those tasks that require frequent response selection (the word-based and number-based choice RT tasks) will generally produce larger deficits than tasks that require infrequent response selection (the word-based and number-based three-odd tasks).

I also measured secondary task costs produced by the implicit test. As stated above, secondary task costs were measured in two manners: (1) Global secondary tasks costs produced by the perceptual identification task. This was measured by comparing a FA baseline condition to a DA condition. For this and all other experiments, the baseline is defined as the average of a pre-test baseline (when the secondary task was performed alone prior to it being performed in conjunction with the memory test) and a post-test baseline condition (when the secondary task was performed along after being performed in conjunction with the memory test). (2) Specific costs associated with implicit retrieval. In other words, the costs produced by old items relative to new items. Finally, baseline levels of secondary task performance (i.e., RT and accuracy) across each of the tasks were different. As a result, magnitudes of secondary task costs were not directly comparable across secondary tasks.

Method

Participants. 80 undergraduate students at the University of North Carolina at Chapel Hill participated for course credit in an introductory psychology course.

Design & Materials. The DA conditions constituted a 2 (materials) × 2 (frequency) design, with one additional FA control condition. Materials and frequency of the secondary task were both manipulated between-subjects. Participants took the perceptual identification test in isolation (FA) or in conjunction with one of four secondary tasks (DA), described in previous sections.

The same materials were used in all experiments, which consist of different implicit tests. The materials consisted of 60 critical examples from 60 different categories, from the norms of Battig and Montague (1969), Hunt and Hodge (1971), and Van Overschelde, Rawson, and Dunlosky (2004). The examples chosen from the categories were moderate- to high-frequency associates of the category name. No two examples came from the same category. Critical examples were chosen to satisfy two additional constraints: (1) no two examples had the same word stems (the first three letters) and (2) each example's word stem could be completed with at least five unique solutions. I also selected 30 examples from 30 additional categories which were used as filler items on each implicit test. Filler items were selected with same constrains described above. The critical examples were divided into two master study lists (A and B) of 30 words each. Half of the participants received study list A and the other half received study list B such that items are counterbalanced over old—new status as well as across each attention condition.

The perceptual identification test consisted of all 60 critical items (30 old items presented during the study phase and 30 new items not presented study list), randomly intermixed with 30 filler items. For half the participants in each attention condition, words from study list A were old and words from study list B were new, with the opposite being true for the other half of participants. Filler items were never presented to participants during the study phase.

Word-based secondary tasks consisted of a list of 45 moderate- to low-frequency one- and two-syllable words. Half of the words had one-syllable and the other half had two-syllables. None of the words in these tasks overlapped with critical items. Number-based secondary tasks consisted of a list of 45 even and odd numbers between 0 and 9. Half were even and half were odd. For the word- and number-based three-odd tasks, there were 8 target sequences (three two-syllable words or three odd numbers in succession) in the list of 45 words or numbers. This list were repeated throughout the duration of its performance. The word- and number-based choice RT tasks used the same 45 words or numbers, again cycled throughout its duration.

Procedure. Participants were tested individually. The experiment consisted of four parts: a calibration phase, a study phase, a distracter phase, and a test phase. Participants were initially told that experiment was a study of attention and perception. During the calibration phase, participants performed a perceptual identification task identical to the one performed during the test phase. For this task, participants were given a perceptual identification test. Each trial began with a prompt consisting of the words "get ready" above a plus sign (+). The prompt was centered on the computer screen for 500 ms. Following the prompt, each word was displayed in the same position as the plus sign for 16, 32, or 50 ms, followed by a backwards mask (a row of Xs). The word remained on the screen for an additional amount of time such that the total trial (excluding the prompt) lasted 5000 ms. The first block of trials presented the words for 16 ms, the second block for 32 ms, and the final block for 50 ms. Participants were instructed to fixate on the cross to maximize their chances of identifying the words. They were instructed to name the word by saying it out loud. All responses were recorded by the experimenter and checked for correctness. The presentation speed that yielded closest to 30-40% correct during this phase determined later presentation speed during the test phase.

During the study phase, participants were presented with words from either study list A or study list B. Each word was presented in the center of the computer screen in white font on black background. Participants were instructed to read each word, and then rate the word's pleasantness on a scale of 1 to 7, where 1 indicated very unpleasant and 7 indicated very pleasant. The word appeared on the screen for 3 s, within which the participants are to make a response. No mention was made of the subsequent memory test.

During the distracter phase, participants engaged in two separate cognitively-engaging tasks. The first distracter task was an *N*-back working memory task. For this task, participants judged whether or not the number currently on the computer screen matched the number presented on the preceding trial. This task lasted for three minutes. Next, the participants carried out one of the four secondary tasks. In the DA conditions, this served as the pretest baseline measure of the secondary task as well as the second distracter task. In the FA condition, this task merely served as the second distracter task. In the DA conditions, the task used was the same task later used to divide attention. In the FA condition, participants received one of the four tasks, with each secondary task being given to one quarter of the full-attention participants. Participants performed this task during the distracter phase for an additional three minutes. Participants were given feedback for this task after every 30 trials.[2] Feedback consisted of a screen indicating their percent correct on the task for the preceding 30 trials. Participants were instructed to read over the feedback and to try to maintain a high level of accuracy throughout the task.

During the test phase, participants performed the same perceptual identification test as during the calibration phase. Each trial will begin with the "get ready" prompt for 500 ms. Following the prompt, each word was displayed in the same position as the plus sign for 16 or 32 ms, depending upon the results from the calibration task (no participant ended up in the 50 ms condition). The word was followed by an immediate backwards mask (a row of Xs). Participants were instructed to name the word by saying it out loud. All responses will be recorded by the experimenter and checked for correctness. Each trial (excluding the prompt) lasted for a total of 5000 ms. The first few items in the test

[2] Pilot testing revealed that participants struggled with the secondary task while doing the implicit test simultaneously. In other words, many participants were at (or even below) chance levels of performance. As a result, feedback (percent correct) was provided for each participant after every 30 trials with the aim of generally improving performance. The same feedback was provided during each FA baseline measure (pre-test and post-test) and the divided attention measure (during the test phase) for each of the four experiments.

were filler items to allow participants to get used to the test. No mention of the connection between this task and the studied words was made.

One-fifth of the participants performed the perceptual identification task in isolation (FA). The remaining participants performed the task with one of the four secondary tasks (DA). Those participants who received the word-based three-odd task were presented aurally with a series of words at a rate of one word every 2500 ms. Participants were told to listen to each word and make a response (by pressing the "Space Bar") whenever three two-syllable words (a target sequence) appeared in succession. Those who received the number-based three-odd task were presented aurally over headphones with a series of numbers at a rate of one number every 2500 ms. They were told to listen to each number and make a response (by pressing the "Space Bar") whenever three odd numbers (a target sequence) appear in succession. Participants who received the word-based choice RT task were presented aurally with a series of words at a rate of one word every 2500 ms. On each trial participants were told to listen to the word and indicate whether it has one- or two-syllables (by pressing the "1" key for one-syllable, and the "2" key for two-syllables). Participants who received the number based choice RT task will be presented aurally with a series of numbers at a rate of one number every 2500 ms. On each trial, participants were told to listen to the number and indicate whether it is even or odd (by pressing the "1" key for odd, and the "2" key for even). Participants in the DA conditions performed the secondary tasks throughout the entire perceptual identification test. Participants in the DA condition were told to stress each task equally and were again given feedback after every 30 trials of the secondary task.

After the test phase, those participants in the DA conditions again performed their secondary task alone for an additional three minutes, with feedback after every 30 trials. Finally, after completion of the experiment, all participants were given a post-test awareness questionnaire. This questionnaire consisted of a series of increasingly specific questions assessing the participants' knowledge of the connection between the study and test phases. This questionnaire was used determine whether or not participants engaged in explicit retrieval of prior study episodes. (see Appendix A for the specific questions).

Results

Implicit Test. Each verbal response was recorded as correct or incorrect (the latter category included non-responses). With 30 old items, and 30 new items, proportion correct was determined by the number correct for old items out of 30, and the number correct for new items out of 30. Implicit results (Proportion Old, Proportion New, Proportion Priming) are presented in Table 1. As can be seen in that table (see also Figure 1), overall priming appears to be found for the FA condition. Further, dividing attention during retrieval appeared to have no overall effect on levels of priming. In fact, none of the five attention conditions appear to produce different levels of priming.

Priming rates from the perceptual identification test were submitted to a series of analyses. Unless otherwise specified, all alpha-levels were set at 0.05. Proportion correct for the new condition (baseline) did not differ across attention condition, $F(4, 75) = 1.61$, $MS_e = 0.05$. Priming in the FA condition was submitted to a *t*-test to establish that this condition produced significant priming. Priming was significantly greater than zero, $t(15) = 5.68$, $p < 0.05$. Priming for each DA condition was also significant, $t(15)\text{s} > 4$. Priming across all conditions was further analyzed using two separate analysis of variance (ANOVA) tests. The first analysis was a one-factor ANOVA, with 5 levels of that factor (attention condition). The five levels of this factor were the FA condition, and each of the four DA conditions. Attention condition was a between-subjects factor. This ANOVA revealed no effect of attention condition, $F < 1$, indicating that priming did not vary over attention conditions. Priming was further analyzed with a 2 (materials: material-general vs. material-specific) × 2 (frequency: high frequency vs. low frequency) ANOVA, with both materials and frequency as between-subjects factors. There was no main effect of materials, $F < 1$, indicating that material-specific and material-general tasks produced equivalent levels of priming. There was no main effect of frequency, $F < 1$, indicating that high and low frequency tasks produced equivalent levels of priming, and no materials × frequency interaction, $F < 1$. Finally, it should be noted that whether participants reported intentionally thinking back to the prior list during the test had no effect on any of the results.

Secondary Task. There were four secondary task conditions: material-general high frequency (MGHF); material-specific high frequency (MSHF); material-general low frequency (MGLF); and material-specific low frequency (MSLF). Secondary task performance was measured using proportion correct (accuracy) and reaction time (RT). All analyses will be reported with respect to each dependent variable. Secondary task costs were obtained for each dependent variable by subtracting secondary task performance under DA from secondary task performance under FA. FA secondary task performance was obtained by taking the mean performance (proportion correct and RT) for the pre-test and post-test phases. Secondary task costs were analyzed in two ways: (1) Performance in the FA condition was compared to performance in the DA condition to assess overall costs produced by the perceptual identification task. This was analyzed using a set of *t*-tests for each of the four secondary task conditions. The magnitude of secondary task costs were not compared across conditions due to issues of scaling as the result of different baseline levels. (2) Performance for secondary task trials that were associated with 'old' trials on the implicit test were compared performance for secondary task trials that were associated with 'new' trials on the implicit test. This assessed the costs specifically associated with the priming component of the perceptual identification task. This analysis was performed only for high frequency trials. Low frequency tasks could not be analyzed in this manner because responding (or failing to respond) on a particular trial was dependent upon that trial, plus the two previous trials. Thus if a participants failed to make a response to a critical sequence, it could have been the result of interference of any of the previous three trials. Because there were two items for the secondary task associated with a single trial for the implicit test, I also measured costs associated with the first item compared to the second item (again, this was possible only for the high frequency tasks).

Accuracy and reaction times are presented in Table 2. For the high frequency tasks, all items associated with filler trials were excluded. As can be seen from that table, there appear to be overall secondary task costs produced by the perceptual identification task. Specifically, the implicit test appeared to decrease accuracy across each of the four conditions. Data were first analyzed using a series of *t*-tests. An overall DA cost to secondary task performance was found, $t(63) = 9.45$. Specific costs were also found for the MGHF condition, $t(15) = 5.68$; for the MSHF condition, $t(15) = 5.96$; for the MGLF condition, $t(15) = 3.07$; and for the MSLF condition, $t(15) = 7.70$.

Accuracy results were then submitted to a 2 (order: first vs. second) × 2 (status: old vs. new) ANOVA, with order and status as within-subjects factors. As stated above, this analysis was restricted to the two high frequency tasks. This analysis revealed a main effect of order, $F(1, 31) = 4.05$, MS_e = 0.l0, indicating that accuracy for the first items was lower than accuracy for the second items. There was a non-significant trend towards a main effect of status, $F(1, 31) = 4.05$, $MS_e = 0.02$, $p < 0.06$, indicating that accuracy was marginally higher for items on old trials than for items on new trials. The interaction between order and status was significant, $F(1, 31) = 12.81$, $MS_e = 0.00$, indicating that the benefit for secondary task performance for old items was larger for the items presented synchronously with the test item (see Figure 2). Given this interaction, simple effects were tested which compared old and new trials for each order separately. These analyses revealed a difference between old and new if they were presented first, $t(31) = -3.45$, indicating that proportion correct was higher for old trials than new trials. The difference between old and new if they were presented second was not significant, $t(31) = .31$. It must be noted that this difference between old and new trials is driven by the MSHF condition; the MGHF condition shows no difference between old and new trials (see Table 2).

RT results (Table 2) reflect median reaction times for correct trials. Incorrect trials were excluded from these analyses. For the high frequency tasks, filler trials were again excluded, as were trials with a RT under 500 ms. RTs are measured from the beginning of the onset of the word or number. These auditory files take over 500 ms to play through. All responses under 500 ms were coded as a non-response because participants were responding before fully hearing the number or word. These exclusions as well as other non-responses amounted to less than 1% of all trials for the MGHF and MSHF conditions. As with the accuracy results, there appear to be overall secondary task costs produced by the perceptual identification test. Unlike the accuracy results, however, these secondary task costs appear to be restricted to the high frequency tasks. RT data were first analyzed first using a set of *t*-tests. Results confirmed what was observed in the table. Overall, there were secondary task costs, $t(63) = -5.28$. For each specific condition, costs were found for the MGHF condition, $t(15) = -8.59$, and for the MSHF condition, $t(15) = -10.90$. However, no costs were found for the MGLF condition, $t(15) = -0.94$, or for the MSLF condition, $t(15) = 0.41$.

RT results were similarly submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. As with the accuracy results, this analysis was restricted to the two high frequency tasks. This analysis revealed a main effect of order, $F(1, 31) = 126.69$, $MS_e = 22511.11$, indicating that RTs for first items were higher than for second items. Neither the main effect of status nor the interaction were significant, $F\text{s} < 1$.

Discussion

As a preliminary point, I found that the perceptual identification task produced robust priming in the FA condition. This is the typical testing condition, and fits well with other studies that also found high levels of priming for this test (e.g., Hirshman et al., 2001; Keane, Wong, Verfaellie, 2004; Mulligan, 2002; Mulligan, 2003; Mulligan & Hornstein, 2000). This is critical in the present case because it implies that there is a substantial ability to measure reductions in primary should any be produced by the DA conditions.

Despite the high levels of priming in the control (FA) condition, none of the DA conditions produced any reductions in priming. This result is consistent with the predictions from research concerning the perceptual-conceptual and identification-production dissociations. These each predict that the perceptual identification test (which is perceptual, and involves identification) should not rely heavily upon attentional resources, and thus be unaffected by a secondary task. Further, it was found that the material-general and material-specific groups produced equivalent levels of priming. That is, both the material-general and the material-specific secondary task failed to affect levels of priming. These results are inconsistent with research showing that material-specific tasks produce robust DA effects on memory retrieval. Further, the high-frequency and low frequency groups produced equivalent levels of priming. That is, the high frequency and low frequency secondary tasks failed to affect levels of priming. These results are inconsistent with the predictions from the central bottleneck model that tasks involving frequent response selection should affect memory retrieval. All of the above results, however, are consistent with the automaticity hypothesis.

Despite the fact that the secondary task failed to produce deficits to implicit memory, it was found that implicit retrieval produced robust global secondary task costs for accuracy and RT. It was found that generally, the perceptual identification task reduced accuracy and increased RT, relative to a FA condition (where the secondary task was performed alone). Specifically, the implicit test decreased accuracy for each of the four secondary task conditions RTs, however, increased significantly in only the two high frequency secondary tasks. For the high frequency tasks, it was further found that performance was lower (lower accuracy, higher RTs) for the first item in the trial compared to the second item. Because the first item was presented synchronously with the implicit test item, and the second item was presented 2.5 s after, this provides further indication of the effect that the test items had on the secondary task. These results demonstrate only the costs produced by the task in which implicit retrieval is couched, and do not speak directly to the costs associated specifically with implicit retrieval. These costs were specifically measured by comparing items for the secondary task associated with old items for the implicit test to items for the secondary task associated with new items for the implicit test. Critically, I found that for accuracy, there was a near significant trend for secondary task items associated with old trials to show an improvement in performance compared to new items. This indicates that the secondary task became easier for old trials (when implicit retrieval can play a role in task performance) compared to new trials. Further analysis of old trials compared to new trials (specifically for the first items presented) yielded a significant difference, with performance for old trials being easier. This difference was not present for the second items present. This further demonstrates that the secondary task did in fact get easier during an old trial of the implicit test.

Taken together, these results highlight several critical points: (1) implicit retrieval (on the perceptual identification task) is immune to DA effects, as indicated by the lack of a DA effect on priming; (2) the perceptual identification task generally produces costs to a secondary task, as indicated by the general and specific secondary task costs produced by the implicit test; and (3) for accuracy, implicit retrieval specifically seems to have no negative effect (and appears to make performance on the secondary task easier, for proportion correct). I will address the implications of these findings later in the general discussion.

CHAPTER VII

EXPERIMENT 2

The second experiment used a word-stem completion test, a test classified as a perceptual task and a production task. Consequently, the hypotheses make conflicting predictions about the effects of dividing attention. The perceptual—conceptual hypothesis predicts that perceptual priming should be unaffected by dividing attention. The identification—production hypothesis, however, indicates that dividing attention should disrupt production priming. Again, attention was divided during the test phase only, using the same four secondary tasks described in Experiment 1.

Method

Participants. 80 undergraduate students at the University of North Carolina at Chapel Hill participated for course credit in an introductory psychology course.

Design & Materials. The design and materials were identical to the first experiment with the following exception: participants took a word-stem completion test during the test phase. During this test participants were presented with a series of 90 word stems, each consisting of the first three letters of the word followed by a blank. Of the 90 stems, 30 were completable with old words (presented during the study phase), 30 were completable with critical new words (from the non-presented list), and 30 were filler.

Procedure. The study phase and distracter phase were identical to Experiment 1. During the test phase, participants took a word-stem completion test. One-fifth took the test alone (FA) and the remaining took the test with one of the four secondary tasks described above (DA). Word stems were presented at a fixed rate (one stem every 5000 ms). Participants were told to read each word stem and complete it with the first word that comes to mind by saying the completed word out loud. All responses will be recorded by the experimenter and were checked for correctness. Again, after the test phase, participants in the DA conditions performed their secondary task alone for an additional three minutes. Finally, all participants were given the same post-test questionnaire as in the first two experiments.

Results

Implicit Test. Each verbal response made by the participant was recorded as either correct (they produced the critical item) or incorrect (they failed to produce the critical item). Implicit results are presented in Table 3. As can be seen in that table (see also Figure 3), overall priming appears to be found for the FA condition. Further, levels of priming appear equivalent across conditions.

Proportion correct for the new condition (baseline) did not differ across attention condition, $F(4, 75) = 1.61$, $MS_e = 0.05$. Priming rates from the FA condition were first submitted to a *t*-test to establish that this task produced significant overall priming in this version of the category production test. Priming was significantly greater than zero, $t(15) = 7.50$, $p < 0.05$. Priming for each DA condition was also significant, *t*s > 5. Priming was unaffected by attention condition, $F < 1$. As can be seen in Figure 3, there does appear to be a slight visual trend towards a reduction in priming across DA condition. Given this, a specific test of the FA condition and the lowest DA condition (the MSLF condition) was conducted. This also yielded a non-significant effect ($p = 0.11$). From this, it is clear that none of the conditions yielded any significant decrement to levels of priming.

Priming in the DA conditions was further analyzed with a 2 (materials) × 2 (frequency) ANOVA, with both materials and frequency as between-subjects factors.

There was no main effect of materials, $F(1, 60) = 1.38$, $MS_E = 0.01$, indicating that material-specific and material-general tasks produced equivalent levels of priming. There was no main effect of frequency, $F < 1$, indicating that high frequency and low frequency tasks produced equivalent levels of priming. Finally, there was no materials × frequency interaction, $F < 1$. As in Experiment 1, whether participants reported intentionally thinking back to the prior study list had no effect on the results.

Secondary Task. Secondary task accuracy and RT results are presented in Table 4. The same exclusion criteria from Experiments 1 and 2 were used. As can be seen from that table, there appear to be overall secondary task costs produced by the word-stem completion task. Specifically, the implicit test reduced performance greatly across each of the four conditions. Data were first analyzed using a series of *t*-tests. There was an overall secondary task cost, $t(63) = 9.76$. Specific costs were also found for the MGHF condition, $t(15) = 6.58$; for the MSHF condition, $t(15) = 5.66$; for the MGLF condition, $t(15) = 3.84$; and for the MSLF condition, $t(15) = 3.93$.

Accuracy results from the high frequency tasks were then submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. This analysis revealed a main effect of order, $F(1, 31) = 16.24$, $MS_e = 0.01$, indicating that accuracy for the first item was lower than accuracy for the second item. The interaction was marginally significant, $F(1, 31) = 4.08$, $MS_e = 0.00$, $p < 0.06$, indicating that the difference between old and new trials was larger for items presented first. There was no main effect of status, $F(1, 31) = 2.70$, $MS_e = 0.01$. Given this near-significant interaction (see Figure 4), simple effects were tested which compared old and new trials for each order separately. These analyses revealed a difference between old and new if they were presented first, t(31) = -2.37, indicating that proportion correct was higher for old trials than new trials. The difference between old and new if they were presented second was not significant, t(31) = -0.34.

RT results are also presented in Table 4. The same exclusion from Experiment 1 was used (less than 2% of all trials for the MGHF condition, and less than 1% of all trials for the MSHF conditions were excluded). As with the accuracy results, there is an overall secondary task costs produced by the perceptual identification test, $t(63) = -5.86$. For each specific condition, costs were found for the MGHF condition, $t(15) = -6.61$, for the MSHF condition, $t(15) = -8.49$, and for the MGLF condition, $t(15) = -2.47$. No costs were found, however, for the MSLF condition, $t(15) = 0.94$.

RT results from the high frequency tasks were then submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. This analysis revealed a main effect of order, $F(1, 31) = 27.31$, $MS_e = 36882.18$, indicating that RTs for the first item were higher than RTs for the second item. There was no main effect of status, nor an interaction, Fs < 1.

Discussion

As in many prior studies, I found that the word-stem completion task produced significant levels of priming in a FA retrieval condition. (e.g., Gabrieli et al., 1999; Gabrieli et al., 1994; Horton & Nash, 1999; Keane et al., 1991; Schwartz, 1989).

The results concerning the effect of the secondary task on levels of priming was consistent with the results from Experiment 1, which showed that priming was immune to a concurrent task. Importantly, it was found that none of the four DA conditions significantly diminished priming relative to the FA condition. This result is consistent with the prediction from the perceptual-conceptual distinction, which indicates that a perceptual test should not be attention-demanding and consequently should be unaffected by a secondary task. It is, however, inconsistent with the prediction from the identification-production distinction, which indicates that a production task should be attention-demanding, and thus affected by a secondary task. Further, it was found that the material-general and material-specific groups, and the high and low frequency groups produced equivalent levels of priming. These results are inconsistent with research demonstrating material-specific interference, and the predictions from the central bottleneck model. All of these results are, however, consistent with the automaticity hypothesis.

One further point about the implicit memory results requires mentioning. Numerically, there appeared to be DA effects on priming. Although each individual condition, material-specific vs. material general conditions, and high- vs. low-frequency conditions, failed to affect priming, there was a visual trend towards a decline (see Figure 3). Thus, it appeared that dividing attention might have produced at least some reduction in priming. However, given that none of the DA conditions (including the DA condition that produced lowest priming) significantly differed from the FA condition, there is no compelling evidence that DA has an effect on implicit retrieval. I will return to this issue in a power analysis reported following Experiment 4.

Despite the fact that the secondary task failed to produce significant deficits to implicit memory, it was again found that implicit retrieval produced robust global secondary task costs for accuracy and RT. The pattern again mirrors that found in the first experiment. The word-stem completion task reduced accuracy and increased RT, relative to a FA condition. Specifically, the implicit test decreased accuracy for each of the four secondary task conditions. RTs increased in both of the high frequency conditions, and for the number-based low frequency condition. It was further found that performance was worse (lower accuracy, higher RTs) for the first item compared to the second item. This pattern of results generally fits with those found in the previous experiment and demonstrates that the word-stem completion task produced secondary task costs. However, the specific interest is in whether implicit retrieval produces secondary task costs. These costs were specifically measured by comparing old trials to new trials. Critically, I found that secondary-task items associated with old trials were not significantly different (in terms of both accuracy and RTs) than secondary-task items associated with new trials, although there was a non-significant numerical trend for accuracy to be higher for old relative to new trials. Analysis of old trials compared to new trials (specifically for the first items presented) yielded a significant difference, with higher performance for old trials. This difference was not present for the second items present. This further demonstrates that the secondary task did in fact get easier during an old trial of the implicit test.

Taken together, these results demonstrate the several things: (1) implicit retrieval (on the word-stem completion task) appears to be immune to DA effects, as indicated by the lack of a DA effect on priming; (2) the word-stem completion task generally produces costs to secondary tasks; but (3) implicit retrieval specifically had no effect on secondary task performance as indicated by the lack of a difference in secondary-task costs for old and new trials. Further, simple effects analyses indicated that the secondary task improved (for proportion correct) during old trials. These results fit well with the results of the first experiment.

CHAPTER VIII

EXPERIMENT 3

This third experiment used a category exemplar production test. Again, attention was divided during the test phase only. Because this is conceptual and requires stimulus production, both hypotheses predict that levels of priming for this test should be disrupted by dividing attention. Attention was divided at test only, using the same four secondary tasks described in Experiment 1.

Method

Participants. 80 undergraduate students at the University of North Carolina at Chapel Hill participated for course credit in an introductory psychology course.

Design & Materials. The design and materials were identical to the first two experiments with the following exception: participants took a category exemplar production test during the test phase. During this test participants were presented visually with a series of 90 category names. Of the 90 categories, 30 corresponded to old items (presented during the study phase), 30 corresponded to critical new items (from the non-presented list), and 30 were filler.

Procedure. The study phase and distracter phase were identical to the first two experiments. During the test phase, participants took a category exemplar test. One-fifth took the test alone (FA) and the remaining took the test with one of the four secondary tasks described above (DA). For this test, participants were presented with a series of 90 category names in a random order. Participants were told to read each category and name the first exemplar from that category that comes to mind, saying the word out loud. Category names were presented at a fixed rate (one category every 5000 ms). All responses were recorded by the experimenter and checked for correctness. Again, after the test phase, participants in the DA conditions performed their secondary task alone for an additional three minutes. Finally, all participants were given the same post-test questionnaire as in the first two experiments.

Results

Implicit Test. Each verbal response made by a participant was recorded as either correct (they produced the critical item), or incorrect (they failed to produce the critical item). If participants failed to respond, the item was scored as incorrect. Proportion correct was determined by the number of correct old items out of 30, and the number of correct new items out of 30. Implicit results are presented in Table 5. As can be seen in that table (see also Figure 5), overall priming appears to be found for the FA condition. Further, as found in the previous experiments, dividing attention during retrieval appeared to have no effect on priming.

Proportion correct for the new condition (baseline) did not differ across attention condition, $F(4, 75) = 1.30$, $MS_e = 0.01$. Priming rates from the FA condition were first submitted to a *t*-test to establish that this task produced significant overall priming in this version of the category exemplar production test. Priming was significantly greater than zero, $t(15) = 4.30$, $p < 0.05$. Priming for each DA condition was also significant, *t*s > 3. Priming across all conditions was further analyzed using two separate ANOVAs. The first was a one-factor ANOVA, with 5 levels of that factor (attention condition). The five levels were the same as in previous experiments. This ANOVA revealed no effect of attention condition, $F < 1$, indicating that priming in each of DA conditions was equivalent to the FA condition. Priming was further analyzed with a 2 (materials) × 2 (frequency) ANOVA, with both materials and frequency as between-subjects factors. There were no significant effects, *F*s < 1, indicating that neither the materials or frequency of responding of the secondary task affected priming. As in previous experiments, whether participants reported intentionally thinking back to the prior list had no effect on the results.

Secondary Task. Secondary task performance was again measured using proportion correct and RT.

Accuracy results are presented in Table 6. The same exclusion criteria from earlier experiments were used. As can be seen from that table, there appear to be overall secondary task costs produced by the category-exemplar production task. Specifically, the implicit test appeared to lower performance greatly across each of the four conditions. Data were first analyzed using a series of *t*-tests. There was an overall cost to the secondary task while performing it with the implicit test, $t(63) = 11.47$. Specific costs were also found for the MGHF condition, $t(15) = 4.92$; for the MSHF condition, $t(15) = 9.67$; for the MGLF condition, $t(15) = 8.90$; and for the MSLF condition, $t(15) = 4.41$.

Accuracy results for the high frequency tasks were then submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. This analysis revealed a main effect of order, $F(1, 31) = 45.78$, $MS_e = 0.01$, indicating that accuracy for the first item was lower than accuracy for the second item. There was no main effect of status, nor an interaction *F*s < 1.

RT results are also presented in Table 6. The same exclusion criteria from earlier experiments were used (less than 4% of all trials for the MGHF condition, and less than 3% of all trials for the MSHF conditions were excluded). As with the accuracy results, there appear to be overall secondary task costs produced by the category exemplar production test. Unlike the accuracy results, however, these secondary task costs appear to be restricted to the high frequency tasks. RT data were analyzed first using a set of t-tests. Results confirmed what was observed in the table. There was an overall secondary task cost, $t(63) = -5.63$. For each specific condition, costs were found for the MGHF condition, $t(15) = -15.63$, and for the MSHF condition, $t(15) = -10.35$. However, no costs were found for the MGLF condition, $t(15) = -0.49$, or for the MSLF condition, $t(15) = 0.54$.

RT results from the high frequency tasks were then submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. This analysis revealed a main effect of order, $F(1, 31) = 213.94$, $MS_e = 21405.43$, indicating that accuracy for the first item was lower than accuracy for the second item. There was no main effect of status, $F(1, 31) = 1.68$, $MS_e = 5217.84$. The interaction approached significance, $F(1, 31) = 3.17$, $MS_e = 7152.04$, $p < 0.10$, indicating a slight trend towards differences between RTs for old trials and new trials to be larger for first items (see Figure 6). Given this near-significant interaction, simple effects were tested which compared old and new trials for each order separately. These analyses revealed a nearly significant difference between old and new trials if they were presented first, $t(31) = 1.97$, $p < 0.06$, indicating faster RTs for old items relative to new items. The difference between old and new if they were presented second was not significant, $t(31) = -0.59$.

Discussion

I found that this task produced significant levels of priming for the category exemplar production test. This fits with numerous other studies, which show high levels of priming (e.g., Gabrieli et al., 1999; Kinoshita, 1989, Light, Prull, & Kennison, 2000; Mulligan, 1997; Mulligan et al., 1999; Mulligan & Stone, 1999; Vaidya et al., 1999).

The results concerning the effect of the secondary task on levels of priming was consistent with the results from the earlier experiments, each of which showed that priming was immune to a concurrent task. This result is inconsistent with several of the predictions discussed earlier. Firstly, both the perceptual-conceptual and identification-production dissociations predict that the category exemplar production test (which is conceptual, and involves production) should be attention-demanding, and thus be affected by a secondary task. Further, it was found that the material-general and material-specific groups, and the high and low frequency groups produced equivalent levels of priming. These results are inconsistent with research demonstrating material-specific interference, and with the predictions from the central bottleneck model. Again, all of these results are consistent with the automaticity hypothesis.

Despite the fact that the secondary task failed to produce deficits to implicit memory, it was found that implicit retrieval produced robust global secondary task costs for accuracy and RT. Once again, this pattern mirrors one found in the previous experiments of this study. The category exemplar production task lowered accuracy and increased RT, relative to a FA condition. Specifically, for each of the four secondary task conditions, accuracy was significantly lower in the DA condition. RTs, however, significantly increased in only the two high frequency secondary tasks. It was further found that performance was lower (lower accuracy, higher RTs) for the first item compared to the second item. As a whole, these results indicate that the category exemplar production task produced secondary task costs. For specific costs associated with implicit retrieval, I generally found that secondary items associated with old trials were no different (in terms of both accuracy and RTs) than secondary items associated with new trials. There was, however, a near-significant difference in RTs between old and new items, when they were presented first. This pattern of an improvement to secondary task performance during old trials fits with similar patterns found in Experiments 1 and 2 (which showed improvement for proportion correct).

Taken together, the pattern of results fit very well with the findings from the previous experiments that the secondary task produced no effect on implicit retrieval, and implicit retrieval had no negative effect (and a slight positive effect) on secondary task performance. Again, the implications will be returned to in the general discussion.

CHAPTER IX

EXPERIMENT 4

The fourth experiment will use a category verification test, a test classified as a conceptual task and an identification task. Consequently, the hypotheses make conflicting predictions about the effects of dividing attention. The perceptual—conceptual hypothesis predicts that conceptual priming should be disrupted by dividing attention. The identification—production hypothesis, however, indicates that this identification task should be unaffected by dividing attention. Again, attention will be divided during the test phase only, using the same four secondary tasks described in Experiment 1.

Method

Participants. 63 undergraduate students at the University of North Carolina at Chapel Hill participated for course credit in an introductory psychology course.

Design & Materials. The design and materials were identical to those in the earlier experiments with the exception that during the test phase, participants took a category verification test. This test consisted of presentation of a series of pairs of category names and category examples. For some of the pairs, the example came from the category with which it was paired (yes-items); for others, the example, did not come from the category with which it was paired (no-items). Typically, for category verification tests, priming effects are often larger for yes- than no-items (e.g., Gabrieli et al., 1999). As a result, I wanted a majority of critical yes-items. To create the materials for this test, each master study list (A and B) of 30 examples was divided into three further sub-sets

(1, 2, and 3) of 10 items each. Using these sets, three separate lists (1, 2, and 3) were created for lists A and B. List 1 paired words on sets 1 and 2 with the category from which it comes (yes-items) and words on set 3 items with a category from which it does not come (no-items). List 2 paired words on sets 1 and 3 with the category from which it comes (yes-items) and words on set 2 items with a category from which it does not come (no-items). List 3 paired words on sets 2 and 3 with the category from which it comes (yes-items) and words on set 1 items with a category from which it does not come (no-items). Thus each test list had 20 critical yes-items and 10 critical no-items in both the old and new conditions. Because this was done for both list A and B, this created six different lists, counterbalanced across participants.

The test consisted of presentation of 90 pairs, of which 30 examples were old, 30 examples were new, and 30 examples were filler. Of the 30 old items, 20 were yes-items and 10 were no-items; of the 30 new items, 20 were yes-items and 10 were no items. To create equal numbers of yes- and no-items across the test, 5 filler items were yes-items and 25 were no-items, creating 45 yes-items and 45 no-items across the entire test.

Procedure. Prior to the study phase, participants engaged in a practice task to get accustomed to activating a microphone attached to a voice key that would be used during the test phase. Participants were presented with a blue screen with the word 'yes' or 'no' on it. They were to read the word out loud. If the voice key was activated, the screen changed color. Participants were told to try to activate the voice key on their first attempt on every trial. This task lasted for 40 trials. After this practice phase, participants began the study phase. The study phase and distracter phase were identical to those in Experiment 1. During the test phase, participants took a category verification test. One-fifth took the test alone (FA) and the remaining took the test with one of the four secondary tasks described above (DA). Each trial consisted of a presentation of a category alone for 1000 ms. Next, a word appeared on the screen below the category name. The word was presented for 4000 ms. Participants were instructed to read the category when they first saw it, then read the word after it is presented and quickly indicate whether or not the example comes from the category with which it is presented by saying "yes" or "no" out loud. Responses were recorded by a microphone attached to a voice key, which recorded the interval between visual presentation of the word pair and the onset of the verbal response. The experimenter also recorded answers for their correctness and monitored the participant's performance for non-response vocalizations (e.g., coughs, false starts) that might trip the voice key. Again, after the test phase, participants in the DA conditions performed their secondary task alone for an additional three minutes. Finally, all participants were given the same post-test questionnaire as in Experiment 1.

Results

Implicit Test. Three participants yielded extremely high levels of priming (i.e., between 500 – 800 ms). Outlier analysis confirmed that these participants were aberrant, relative to the rest of the participants. Outlier analysis consisted of calculating the interquartile range (IQR) for each condition. The IQR was multiplied by 1.5 and was added to the third quartile and subtracted from the first quartile. This yielded a range of values for each condition; any participant who scored outside that range was considered an outlier and replaced (see Moore & McCabe, 1998). As a result, these three participants were excluded, which yielded an effective sample size of $N = 60$.

In addition to recording RTs, each verbal response was also scored as either correct or incorrect. All implicit test analyses were performed with filler trials, incorrect trials, and trials with false starts omitted (less than 1% of all trials were excluded). Critically, unlike other experiments, DA altered baseline (new) performance. In other words, for new items, RTs were slower under DA than under FA, $F(4, 55) = 8.13$, $MS_E =$ 61681.42. Post-hoc testing (using Tukey's HSD test) revealed that each performance for new items was higher for each DA condition, relative to the FA condition. As a result, comparing raw priming scores across conditions raises the potential of scaling artifacts. To address this, each priming score was transformed into a proportion change from baseline measure [(New RT - Old RT) /New RT]. The proportion change measure and raw priming scores yielded the exact same pattern of results. As a result, the scaling artifact is not a major concern and all priming results are presented with respect to RTs. Level of priming (RT) for each attention condition is plotted in Figure 7. Implicit results (New RT, Old RT, and Priming RT) are presented in Table 7. As can be seen from that table (see also Figure 7), overall priming appears to be found for the FA condition. Further, there appears to be a numerical decrease in mean priming across DA conditions. DA, however, also appeared to increase variability, relative to the FA condition. I will return to these points later in the discussion.

Priming rates from the FA condition were first submitted to a *t*-test to establish that this task produced significant overall priming in this version of the category production test. Priming was significantly greater than zero, $t(11) = 4.43$. Unlike other experiments, however, priming failed to reach significance for any of the DA conditions, *t*s < 1 presumably because of the high variability in these conditions. Priming across all conditions was further analyzed using two separate ANOVAs. The first was a one-factor ANOVA, with 5 levels of that factor (attention condition). The five levels of this factor were the same as in the first experiment. This ANOVA revealed no effect of attention condition, $F < 1$, indicating that priming was equivalent across each condition. Priming was further analyzed with a 2 (materials) × 2 (frequency) ANOVA, with both materials and frequency as between-subjects factors. There was no main effect of materials nor an main effect of frequency, *F*s < 1, indicating that material-specific and material-general, and high and low frequency tasks produced equivalent levels of priming. Finally, there was no materials × frequency interaction, $F < 1$. As in Experiment 1, whether participants reported intentionally thinking back to the prior study list had no effect on the results.

Secondary Task. Secondary task performance was again measured using proportion correct and RT.

Accuracy results are presented in Table 8. The same exclusion criteria from Experiment 1 were used. As can be seen from that table, there appear to be overall secondary task costs produced by the category verification task. Specifically, the implicit test appeared to reduce performance across each of the four conditions. Data were first analyzed using a series of *t*-tests. There was an overall secondary task cost, $t(47) = 7.08$. Specific costs were also found for the MGHF condition, $t(11) = 3.80$; for the MSHF condition, $t(11) = 4.59$; for the MSLF condition, $t(11) = 4.34$; but not for the MGLF condition, $t(11) = 1.50$.

Accuracy results from the high frequency tasks were then submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. This analysis revealed a main effect of order, $F(1, 23) = 11.50$, $MS_e = 0.01$, indicating that accuracy for the first item was lower than accuracy for the second item. There was no main effect of status nor an interaction, *F*s < 1.

RT results are also presented in Table 8. The same exclusion criteria from the previous experiments were used (less than 1% of all trials for the MGHF and MSHF conditions were excluded). As with the accuracy results, there appear to be overall secondary task costs produced by the perceptual identification test. RT data were first analyzed using a set of *t*-tests. Results confirmed what was observed in the table. There was an overall secondary task cost, $t(47) = -5.07$. For each specific condition, costs were found for the MGHF condition, $t(11) = -6.18$, for the MSHF condition, $t(11) = -8.77$, and for the MGLF condition, $t(11) = -2.24$. No costs were found, however, for the MSLF condition, $t(11) = 0.54$.

RT results from the high frequency tasks were submitted to a 2 (order) × 2 (status) ANOVA, with order and status as within-subjects factors. This analysis revealed a main effect of order, $F(1, 23) = 8.02$, $MS_e = 20312.55$, indicating that RTs for the first item were higher than RTs for the second item. There was no main effect of status, $F < 1$, nor an interaction, $F(1, 23) = 2.11$, $MS_e = 6314.31$.

Discussion

The category verification task produced significant levels of priming in the FA condition, which fits with other studies using this task (CITES). Unfortunately, all of the results concerning the effect of DA on priming from this experiment need to be approached with caution. Unlike other experiments, in this experiment DA had a rather large effect on amount of variability (as can be seen in Figure 3, error bars vary widely across condition). A test for equality of variances revealed that variance did differ as a function of group, $F(4, 55) = 3.95$, $p < 0.05$. The variance in the FA condition was substantially lower than variance in any of the DA conditions (i.e., relative to the FA condition, standard error increased by as many as four times in some DA conditions). As a result, this reduced the power of this experiment and suppressed the ability to detect effects that might otherwise have been revealed. This is especially relevant because in this experiment levels of priming were numerically lower in each of the DA conditions, relative to the FA condition. I will address this point in more detail in the general discussion.

The results concerning the effect of the secondary task on levels of priming were consistent with the results from the earlier experiments, which showed that priming was immune to a concurrent task. Importantly, it was found that none of the four DA conditions diminished priming relative to the FA condition. Further, it was found that the material-general and material-specific groups, and the high and low frequency groups produced levels of priming not different from zero (due to the high variability).

There was a numerical trend towards material-general secondary tasks to reduce priming more than material-specific tasks, although this trend failed to reach significance. Although these points are inconsistent with several theoretical considerations (specifically, the perceptual—conceptual hypothesis, material-specific interference, and the central bottleneck model), the limitations of this study prevent us from drawing any firm conclusions.

Despite the fact that the secondary task failed to produce deficits to implicit memory, it was again found that implicit retrieval produced robust global secondary task costs for accuracy and RT. The pattern generally mirrors one found in the first experiments of this study. The category verification task generally decreased accuracy and increased RT on the secondary task. Specifically, the implicit test significantly decreased accuracy for three of the four secondary task conditions; the MGLF condition was not disrupted, although the trend was in the predicted direction. RTs increased in both of the high frequency conditions, and for the MGLF. It was further found that performance was worse (lower accuracy, higher RTs) for the first item compared to the second item. This pattern of results generally fits with those found in the first experiments and demonstrates that the category verification task produced secondary task costs. However, the specific interest is in whether implicit retrieval produces secondary task costs. These costs were specifically measured by comparing old trials to new trials. Critically, I found that secondary items associated with old trials were no different (in terms of both accuracy and RTs) than secondary items associated with new trials. However, I must again treat this result with great caution because the DA conditions failed to demonstrate significant priming. Consequently, I can not draw unequivocal conclusions regarding the attentional costs of implicit retrieval in this case of category verification.

CHAPTER X

POWER ANALYSES ACROSS EXPERIMENTS

The primary results focus on the effects of DA on priming. Because many of the conclusions about priming are based on null effects, power to detect DA effects in the present study must be considered. In order to increase power, I conducted two further analyses, using data combined across experiments. Given the limitations of Experiment 4, and the highly similar results in Experiments 1-3, these analyses combined data from first three experiments only. The first analysis was a one-factor ANOVA, with 5 levels (FA and the four DA conditions). This ANOVA revealed no effect of any of the DA conditions, $F < 1$. The second analysis was a t-test comparing the FA condition to all DA conditions combined. This analysis similarly revealed no effect of DA, $t(238) = 0.84$. This last analysis was also subjected to a formal power analysis (Cohen, 1988). To determine power, I first obtained effect sizes from a recent study on DA and explicit memory (Lozito & Mulligan, 2006). In this study, DA significantly reduced memory performance on a standard recognition test and a perceptually-driven recognition test. The effect size of divided-attention on accuracy in the standard and perceptual recognition was d = 0.78 and d = 0.67, respectively, yielding an average effect size of d = 0.73. The power of the combined analysis to detect an effect of attention on priming of that size exceeded 0.99. In case effect sizes are generally smaller for implicit retrieval than for explicit retrieval, I conducted a second power analysis for an effect size two-thirds as large (d = 0.48). Power analysis revealed that the power to detect an effect of this magnitude was 0.83. Thus, the present study had substantial power to detect an effect of attention on priming even if the effect was substantially smaller than that found with explicit recognition.

CHAPTER XI

GENERAL DISCUSSION

Numerous lines of theoretical and empirical work make specific predictions concerning the role of attention during implicit memory retrieval. No study, to date, has provided a systematic exploration of these issues, a gap that the present study was designed to fill. Specifically, I investigated whether perceptual or conceptual tests, or identification or production tests would be affected by a secondary task. I also examined whether the type of secondary task played a role in obtaining DA effects. Finally, I measured the secondary task costs produced by each of the implicit tasks, and by implicit retrieval. Before addressing the theoretical implications of the above set of experiments, I briefly revisit and summarize the several lines of research that motivated the present study.

Some prior theoretical and empirical work implies the automaticity hypothesis, which states that implicit retrieval is automatic. Other research proposes a distinction between perceptual and conceptual types of implicit tests and that posits that conceptual, but not perceptual, tests should be affected by dividing attention (the perceptual—conceptual hypothesis). Other research supports a distinction between identification and production types of implicit tests and further predicts that production, but not identification, tests should be disrupted by dividing attention (the identification—production hypothesis)..

Other theoretical frameworks argue that all memory retrieval can be disrupted by dividing attention, depending on the nature of the secondary task. These views suggest that the characteristics of the secondary task are critical. One view posits that if the secondary task and memory test use the same types of materials (e.g., words), material-specific interference will occur, and memory retrieval will be greatly affected by dividing attention (e.g., Fernandes & Moscovitch, 2000). Another view (the central bottleneck model) holds that if the secondary task requires frequent responding (and consequently, frequent response selection), it should compete for the same central processes as memory retrieval, and produce DA effects (e.g., Pashler, 1994; Rohrer & Pashler, 2003).

Next, I consider the results of the experiments in light of these theoretical considerations. The general pattern of results was similar across all experiments. First, priming was found in the FA condition for each experiment. Second, dividing attention during retrieval produced no measureable effect on levels of priming in any of the experiments. This equality of priming held across all four individual DA conditions, implying that the exact nature of the distracter task, material-specific vs. material-general tasks or high frequency vs. low response frequency, was unimportant: Implicit retrieval (as assessed by the amount of priming) was unaffected by any of the secondary tasks.

The present set of results provides clear support for the automaticity hypothesis, a point that I will return to in more detail later in this section. These findings, however, are inconsistent with many of the above theoretical considerations. The finding that perceptual tests and identification tests were unaffected by a secondary task is in line with prediction from both the perceptual—conceptual hypothesis and the identification—production hypothesis, respectively. Taken as a whole, however, it is clear that neither of these two hypotheses were supported because each hypothesis also predicts significant reductions for other types of tests. Specifically, neither conceptual nor production types of test were affected, refuting the central ideas of these respective hypotheses. The appearance of a trend towards a DA effect in word-stem completion (Figure 2) might be taken as limited support for the identification—production hypothesis. However, overall there was no measurable effect of attention condition in this experiment, nor did the FA condition significantly differ from any individual DA condition. In addition, the results of the other production test (category exemplar production, Figure 3) demonstrated not the least effect of DA. Consequently, the entire pattern of results provides little support for the identification—production hypothesis. It must be noted that these results do not invalidate the general distinction between perceptual and conceptual tests, or between identification and production tests. Rather, they provide evidence that certain assumptions (and assertions) concerning these types of tests – namely, that conceptual and production tests place heavier demands on attention – appear to be incorrect.

These findings also fail to support the notion of material-specific interference. Specifically, it was found that participants in material-specific (word-based) groups had equivalent levels of priming to those in the material-general (number-based) groups, and further, that each of these groups showed equivalent levels of priming to the FA group. Although this account was developed in the explicit, episodic memory domain, the prediction that retrieval of words should be disrupted by a word-based secondary task still hold for implicit retrieval. Further, these results also fail to support the predictions of the central bottleneck model. Participants in the high frequency groups had equivalent priming to those in the low frequency group, and that both groups had equivalent priming to the FA group. The high frequency tasks (which require frequent response selection) should impair performance on the implicit tests (which similarly require selection of some response on every trial). Again, this model was not developed within the implicit domain, but the predictions generalize to the present circumstances.

As described in the introduction, the attention demands of memory tasks are also assessed by examining the effects of memory retrieval on the secondary task (that is, the secondary task costs). Across experiments, it was found that each implicit task produced such costs. Specifically, each implicit test disrupted performance of each of the secondary tasks (as measured by decreased proportion correct, increased RTs, or both), relative to when the secondary task was performed alone. As a secondary point, I found that proportion correct was consistently affected across all experiments; RTs, however, were more consistently affected for the high frequency tasks. That is, most experiments found that one or both low frequency task showed no costs to RTs. This may indicate that the high frequency tasks are more consistently affected by the implicit task, or are more sensitive measures of secondary task costs (at least with respect to RTs). Because high-frequency tasks, by definition, require more responding, this yields more measures of RT across the entire task. The relatively small number of responses in the low-frequency conditions might limit the utility of RTs as a dependent measure for the present low-frequency tasks (proportion correct is the typically the sole dependent measure).

Critically, the general secondary-task costs described above are the costs associated with the tasks in which priming is couched, but not the costs specifically associated with the implicit retrieval component of the tasks. That is, the general costs imply that generating category exemplars, solving word stems, identifying degraded stimuli, and verifying semantic facts might all require some amount of attention. However, that would not tell us that the implicit (priming) component of these tasks is attention-demanding. These costs are measured by comparing secondary task performance for trials associated with old test items and secondary task performance for trials associated with new test items. This is done because priming is measured by exploring the difference between performance for old trials and performance for new trials. Old trials are typically associated with a benefit in performance relative to new trials. Thus, it is reasonable to assume that only old trials reflect implicit retrieval, whereas new trials reflect a baseline of the task. Importantly, secondary task performance was equivalent for old and new test trials, implying that implicit retrieval produced no specific costs to secondary task performance. . Further, Experiments 1, 2, and 3 demonstrated a (sometimes significant) trend such that old test trial *improved* secondary-task performance relative to new trials (for proportion correct in Experiment 1 & 2, and RTs in Experiment 3). To a degree, secondary task performed seemed to get *easier* during old test trials. Further analysis revealed that the benefit for old trials relative to new trials was significant for the items presented synchronously with the implicit test item (i.e., first). This lack of specific costs (and, notably, improvements) is highly inconsistent with research from the explicit domain, which found large and robust secondary task costs produced by explicit retrieval (e.g., Craik et al., 1996; Craik et al. 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000a; Naveh-Benjamin et al., 2000b; Naveh-Benjamin & Guez, 2000).

The entire package of results is highly consistent and presents a very clear picture. As a group, these results provide support for the automaticity hypothesis. In other words, these results fit very well with the notion that that implicit retrieval is automatic, at least as implicit memory is reflected by repetition priming tasks. This claim of automatic implicit retrieval is based on criteria delineated in work on explicit memory retrieval (e.g., Craik et al., 1996; see also Hasher & Zacks, 1979, for a related view). To summarize, Baddeley et al. (1984) initially found that a secondary task failed to affect memory retrieval. They concluded that explicit retrieval was automatic. Craik et al. (1996) argued that a full assessment of the attentional demands of requires measuring both the effect of the secondary task on the memory test and secondary task costs produced by the memory test. Craik et al. found that although retrieval was unaffected, it produced robust secondary task costs. From this, they concluded that explicit retrieval was not automatic, but rather attention-demanding and obligatory. Unlike prior studies that have divided attention during implicit retrieval (e.g., Gooding et al., 1999; Helman &

Berry, 2003), this study includes both measures. It was argued that if costs are found for either the memory test or the secondary task (or both), then retrieval cannot be automatic. That (across all experiments) none of the secondary tasks significantly reduced levels of priming, and that implicit retrieval produced no decrement (and even yielded improvements) to secondary task performance suggests a heavy reliance on automatic processing during implicit retrieval.

Aside from the numerous lines of work that this supports, the finding of improvement of secondary task performance (for Experiments 1, 2, & 3) during old trials bears at lease some mention. Although this result was not predicted by most of the prior theorizing regarding attention and memory retrieval, there are two lines of research which anticipate this type of finding, one based on behavioral research the other based on neuroimaging results. First, Logan (1990) argued that one hallmark of automaticity is improvement in performance through repeated exposure. Repetition priming is observed by increases in proportion correct or decreases in RTs (i.e., better performance) for recently-experienced old items relative to newly-experienced items. Thus, this draws a distinct parallel between the mechanisms underlying repetition priming, and those underlying automaticity. According to this analysis, then, repetition priming arises as the result of increased automaticity for old items. In other words, for old trials, participants are experiencing the item for the second time, which should result in easier, more automatic processing of the item. Critically, this does not happen for new items because it is the first exposure to that item (within the context of the experiment). This predicts easier processing of secondary task items during old trials, relative to new trials and supports the pattern of results found in Experiments 1 and 2 (for proportion correct) and marginally in Experiment 3 (for RTs).

The second line of research consonant with decreased secondary-task costs for old items is research on neuroimaging of repetition priming. The typical finding is a pattern of reduced activation for old trials, relative to new trials (e.g., Blaxton et al., 1996; for a review, see Henson, 2005). In other words, priming appears to reduce activation in areas associated with the task in general. In one study, Blaxton et al., contrasted perceptual and conceptual types of tests. They found, generally, that conceptual and perceptual tasks led to differential brain activation (described briefly in the introduction) for new trials. Further, they found patterns of deactivations for old trials in some of those same regions. Specifically, old trials for perceptual tests led to deactivations in posterior regions, including occipital cortex; old trials for conceptual tests were associated with deactivations in left medial and superior temporal cortex, and left frontal cortex. This too is consistent with the notion that re-processing old items requires less effort, less expenditure of processing resources, and thus less interference to other ongoing processes (such as secondary tasks).

Despite producing a generally similar pattern of results as the other three experiments, Experiment 4 contained several limitations that limit my ability to draw conclusions. Firstly, baseline (i.e., new items) levels of performance were affected by DA in that RTs were significantly increased relative to FA. Secondly, the variability of the priming measure was much higher under DA than FA, so high in fact, that significant priming could not be detected in any of the DA conditions, even in the condition (MSLF) producing priming score comparable to the (significant) amount of priming found in the FA condition. Neither of these problems was present in any of the other three experiments.

Why was this pattern of high baseline performance and high variability under DA found in the present experiment, but not others? One possibility lies with the fact that the category exemplar production test yields a different dependent measure. All other experiments used proportion correct to measure priming; in this experiment, RT was used. It is known that dividing attention has a rather large effect on RTs, even under conditions when it has no effect on accuracy rates (e.g., Baddeley et al., 1984). Further, Prull (2004) noted that differences in dependent measures can be critical in driving observed differences between types of implicit tests. Specifically, he argued that the majority of production tests use as their dependent measure proportion correct; many identification tests use reaction times. Prull argued that observed differences between identification and production tests might be partly explained by a difference in dependent measure, and not because of a fundamental difference in processing requirements. He specifically argued that observed age differences in priming (typically found for production test and not identification tests) might be more likely when priming is measured by proportion correct. Thus, observed age differences found for production, but not identification, tests might reflect the dependent measure and not the test. Prull equated the dependent measures (i.e., both the production and identification tests used RTs) and eliminated the typical age differences found for production tests. From this, one should be cautious about making claims concerning differences between identification and production types of tests when the dependent measures are not equated. I will return to this point shortly.

Because the category verification test uses RTs, and dividing attention is shown to have large effects on RTs, this indicates that RT might not be optimal for exploring attention effects on priming. The first problem was addressed by changing the dependant measure to percent change from baseline. Because this yielded the same pattern of results as the raw priming scores, the scaling artifact was not a major concern. The second problem was more severe because it necessarily decreased any ability to find effects. This problem was especially relevant because in this experiment priming was numerically diminished across most of the DA conditions (and was even negative in some conditions).

Complete analysis of the role of attention during implicit retrieval requires the inclusion of a test that is conceptual in nature and requires stimulus identification. Category verification is the prototypical test that fits into this category, and should be included, but its current dependent measure poses a problem. How, then, to use this test and correct for this problem in future studies? One possibility would be to impose strict time limits in which participants must respond. For example, in the FA condition, average response times were approximately 900 ms. As a result, participants could be forced to try to respond within 900 ms. If the participants responds within the time (and answers the question correctly), the trial is scored as correct. If the participant fails to respond (or answers the question incorrectly), the trial is scored as incorrect. This transforms the dependent measure to proportion correct and presumably would eliminate the issue of changes in variability under DA. Further, it would still allow for inclusion of the most typical conceptual, identification type of test. Because average response time is 900 ms, this should yield approximately 50% of trials correct, and 50% incorrect. Further, because old trials are responded to more quickly, this should yield a higher proportion correct for old items compared to new items, thus demonstrating priming. Critically, this version of this test is still classified as conceptual and identification. Because RTs slow under DA, it is expected that baseline levels of performance should change under DA (i.e., proportion correct should be lower under DA). However, this problem could again be addressed through the use of a proportion change measure in addition to raw proportion correct (as was done in Experiment 4).

One final issue related to Experiment 4 is the amount of priming observed. Raw priming was measured to be only 35 ms, which translates to a 3.57% change in performance relative to baseline. This implies that for this task, priming was a very small percentage of total performance. Observing differences from such a small improvement in performance might be challenging. This provides further impetus for altering the dependent measure to proportion correct, which (typically, and in the present experiments) yielded more robust levels of priming.

As stated, the simplest (and most complete in explaining results across all experiments) explanation of these results is that implicit memory is automatic. It must be noted that I specifically assessed implicit memory with repetition priming of single items. This represents the most common manner in which to study implicit memory, but certainly not the only method. For example, implicit memory can be further explored using procedural learning tasks, for which participants learn a new task or sequence. Along these lines, some researchers have argued that procedural retrieval occurs implicitly (e.g., Shanks & Channon, 2002). That is, participants do not consciously retrieve the cognitive or motor skills necessary to perform the task. The study by Helman and Berry (2003) is relevant here. In this study (described in detail earlier), participants studied letter sequences that fit with an artificial grammar. Later, participants were tested for their memory of this grammar either explicitly (a recognition test of previously presented sequences) or implicitly (liking ratings of sequences that fit or did not fit the grammar). Participants took the test under FA or DA. It was critically found that DA did not reduce implicit memory for the grammar sequences, but did reduce explicit memory. This furthers the assertion that implicit retrieval in general is automatic.

In the present study, I chose the four most prototypical types of implicit tests to fit each of the classifications discussed. Further, I studied priming of single items (words). Even within the realm of repetition priming tasks, there are other issues to consider. First, one could use other types of repetition priming tests to ensure that these results generalize. Second, one could use auditory analogs of the present tests (i.e., change test modalities). Third, one could study repetition priming of other non-word stimuli (e.g., pictures). Fourth, one could examine implicit memory for relationships between items (relational priming). In the explicit domain, relational memory (memory for source, context, order, or other associative information) is often viewed as being more demanding than item memory, because of its heavier reliance on recollective processing (e.g., Hicks & Marsh, 2000; Troyer, Winocur, Craik, & Moscovitch, 1999; see Yonelinas, 2000, for a review; cf. Troyer & Craik, 2001, Experiment 2). Thus, implicit tests that stress relationships between items might be more attention-demanding during retrieval. A final area would be to study repetition priming of novel stimuli (e.g., non-word, abstract pictures). Relative to verbal materials, priming of novel stimuli are more likely to show effects of DA at encoding (e.g., Smith & Oscar-Berman, 1990), suggesting greater demands in processing. Thus it is possible that novel stimuli might represent a circumstance that would increase attentional demands of the implicit test and produce DA effects to either priming or the secondary task. On the other hand, Logan's (1990) analysis yields a different prediction. According to this position, old items are processed more automatically than new items. The potential gains in automaticity due to a single presentation should be greater for novel materials than well-known materials. This would imply that, for novel stimuli, the increased automaticity and reduced secondary task costs should be even greater, relative to the baseline condition at test. As a result, the improvements to secondary task performance for old trials relative to new trials found in several experiments here might be larger and found more consistently with novel stimuli.

The present study is aimed at being the most (to-date) comprehensive exploration into the role of attention during the retrieval component of implicit memory. The overwhelming majority of research into attention and implicit memory has focused on the study phase of implicit memory. This study used several types of implicit tests, several types of secondary tasks (all based on prior theoretical considerations), and divided attention during the retrieval phase only. The lack of DA effects on implicit retrieval and the lack of secondary task costs produced by implicit retrieval have significant bearing on these considerations. Finally, this study represents the first step towards an understanding of whether retrieval processes in implicit memory act on principles of automatic or controlled processing. Although the implications are clear, this study plus future research will help fully address this central issue.

Table 1:

Experiment 1 implicit memory performance (Proportion Old, Proportion New, Proportion Priming) as a function of attention condition

	Old	New	Priming
FA	.61	.36	.25
MGHF	.79	.53	.26
MGLF	.72	.46	.26
MSHF	.78	.54	.24
MSLF	.74	.52	.21
Total	.73	.48	.25

Table 2:

Experiment 1 secondary Task Performance (Proportion Correct & RTs) as a function of attention condition and the status of the trial

		Attention		Trial Status	
	Condition	FA	DA	Old	New
Proportion Correct	MGHF	.99	.94	.93	.94
	MGLF	.98	.91	--	--
	MSHF	.95	.80	.84	.78
	MSLF	.95	.81	--	--
	Total	.97	.87	.89	.86
RT	MGHF	1233	1395	1453	1421
	MGLF	1455	1494	--	--
	MSHF	1511	1730	1723	1736
	MSLF	1660	1645	--	--
	Total	1465	1566	1588	1579

Table 3:

Experiment 2 implicit memory performance (Proportion Old, Proportion New, Proportion Priming) as a function of attention condition

	Old	New	Priming
FA	.54	.29	.25
MGHF	.51	.29	.22
MGLF	.50	.28	.22
MSHF	.46	.27	.19
MSLF	.47	.30	.18
Total	.50	.28	.21

Table 4:

Experiment 2 secondary Task Performance (Proportion Correct & RTs) as a function of attention condition and the status of the trial

		Attention		Trial Status	
	Condition	FA	DA	Old	New
Proportion Correct	MGHF	.99	.86	.88	.85
	MGLF	.95	.85	--	--
	MSHF	.99	.84	.86	.83
	MSLF	.91	.80	--	--
	Total	.96	.84	.87	.84
RT	MGHF	1294	1598	1598	1597
	MGLF	1366	1464	--	--
	MSHF	1497	1709	1709	1709
	MSLF	1617	1581	--	--
	Total	1443	1588	1653	1653

Table 5:

Experiment 3 implicit memory performance (Proportion Old, Proportion New, Proportion Priming) as a function of attention condition

	Old	New	Priming
FA	.48	.33	.15
MGHF	.44	.29	.15
MGLF	.45	.29	.16
MSHF	.47	.32	.15
MSLF	.51	.35	.16
Total	.47	.32	.15

Table 6:

Experiment 3 secondary Task Performance (Proportion Correct & RTs) as a function of attention condition and the status of the trial

		Attention		Trial Status	
	Condition	FA	DA	Old	New
Proportion Correct	MGHF	.99	.83	.82	.83
	MGLF	.98	.79	--	--
	MSHF	.96	.62	.63	.61
	MSLF	.88	.76	--	--
	Total	.95	.75	.73	.72
RT	MGHF	1211	1589	1576	1599
	MGLF	1396	1422	--	--
	MSHF	1537	1838	1838	1843
	MSLF	1567	1538	--	--
	Total	1428	1597	1701	1721

Table 7:

Experiment 4 implicit memory performance (New RT, Old RT, Priming RT) as a function of attention condition

	New RT	Old RT	Priming RT
FA	939	903	36
MGHF	1135	1164	-31
MGLF	1182	1180	2
MSHF	1348	1353	-5
MSLF	1284	1248	36
Total	117	1170	8

Table 8:

Experiment 4 secondary Task Performance (Proportion Correct & RTs) as a function of attention condition and the status of the trial

		Attention		Trial Status	
	Condition	FA	DA	Old	New
Proportion Correct	MGHF	1.00	.93	.93	.93
	MGLF	.96	.94	--	--
	MSHF	.94	.83	.82	.82
	MSLF	.95	.82	--	--
	Total	.96	.88	.88	.88
RT	MGHF	1300	1468	1467	1468
	MGLF	1288	1368	--	--
	MSHF	1543	1733	1736	1731
	MSLF	1627	1603	--	--
	Total	1440	1543	1602	1599

Figure 1:

Priming (Proportion Old – Proportion New) on the perceptual identification test as a function of attention condition

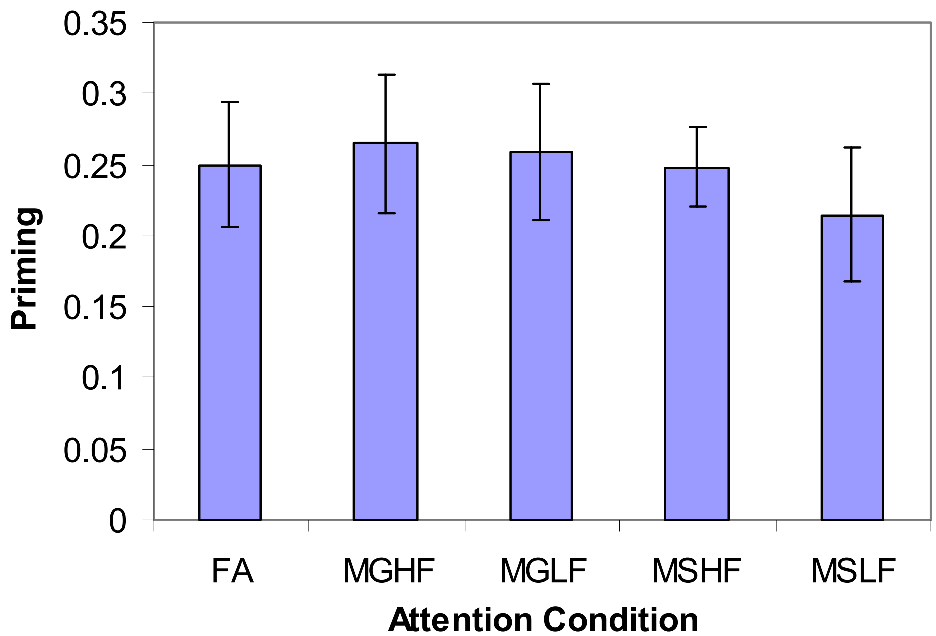


Figure 2:

Proportion correct for secondary task performance (MGHF and MSHF) in Experiment 1 as a function of old/new status of the trial and whether the item was presented first or second

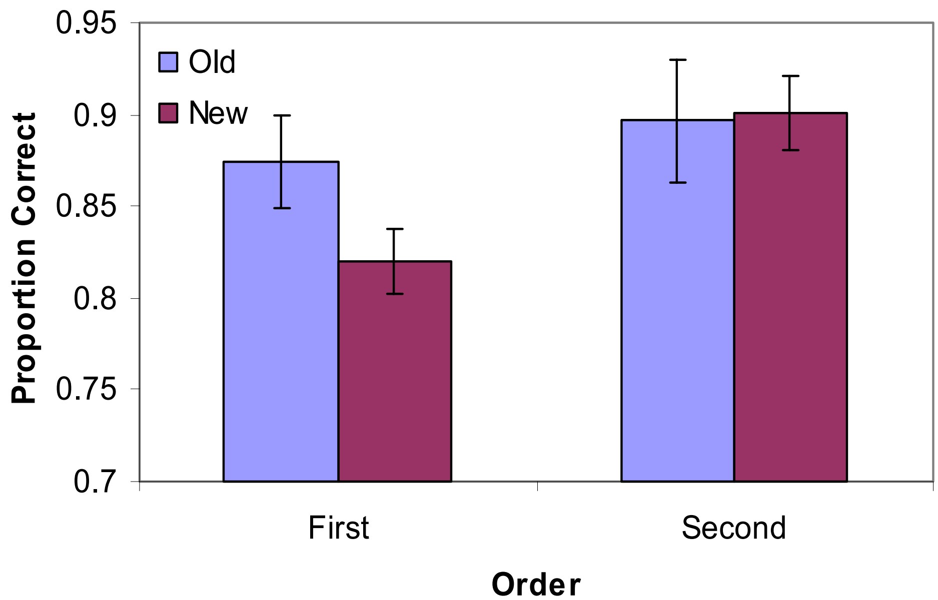


Figure 3:

Priming (Proportion Old – Proportion New) on the word-stem completion test as a function of attention condition

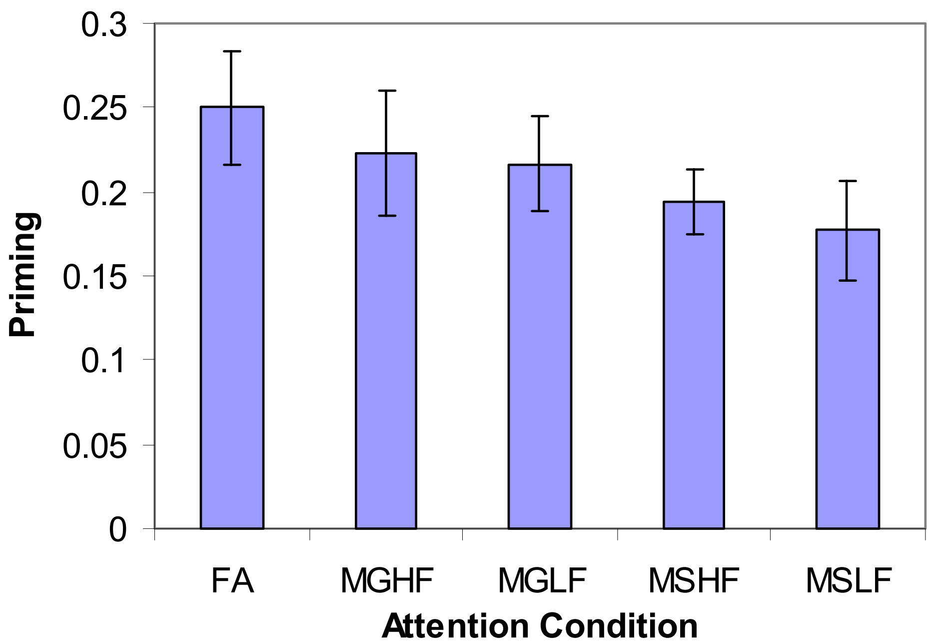


Figure 4:

Proportion correct for secondary task performance (MGHF and MSHF) in Experiment 2 as a function of old/new status of the trial and whether the item was presented first or second

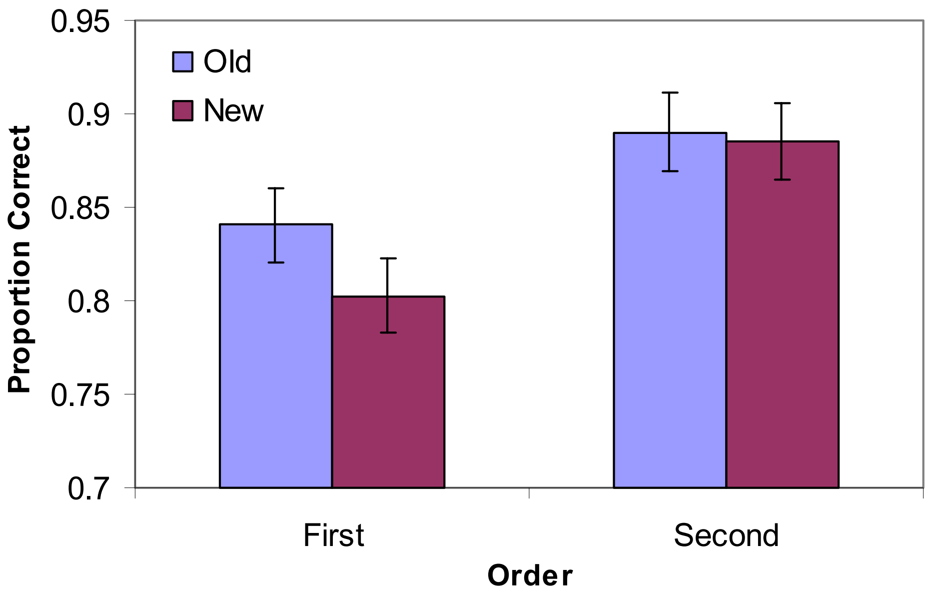


Figure 5:

Priming (Proportion Old – Proportion New) on the category exemplar production test as a function of attention condition

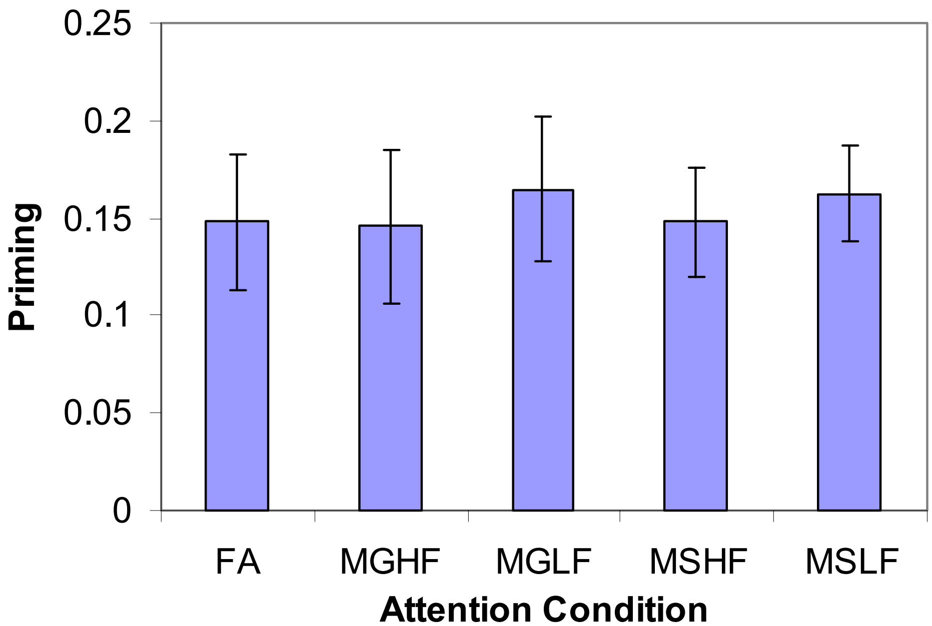


Figure 6:

RT (in ms) for secondary task performance (MGHF and MSHF) in Experiment 3 as a function of old/new status of the trial and whether the item was presented first or second

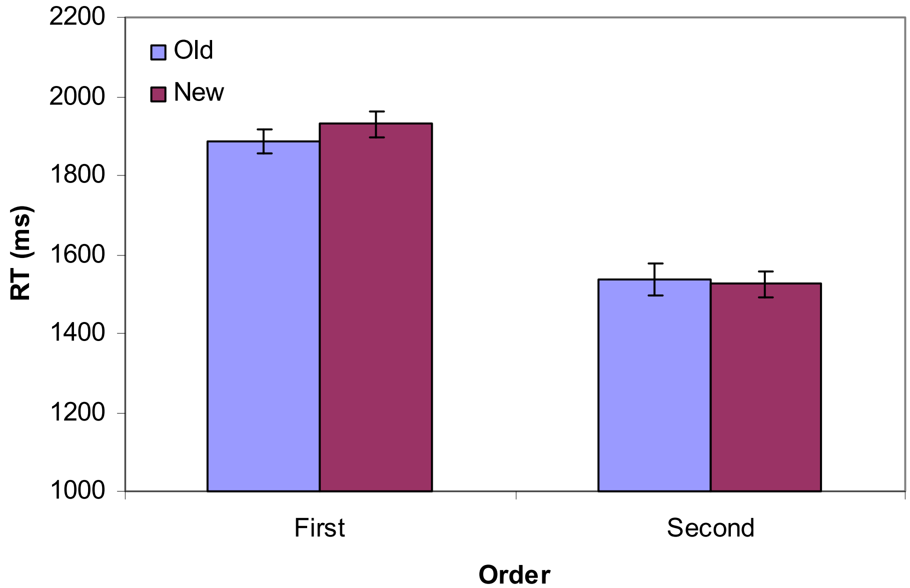
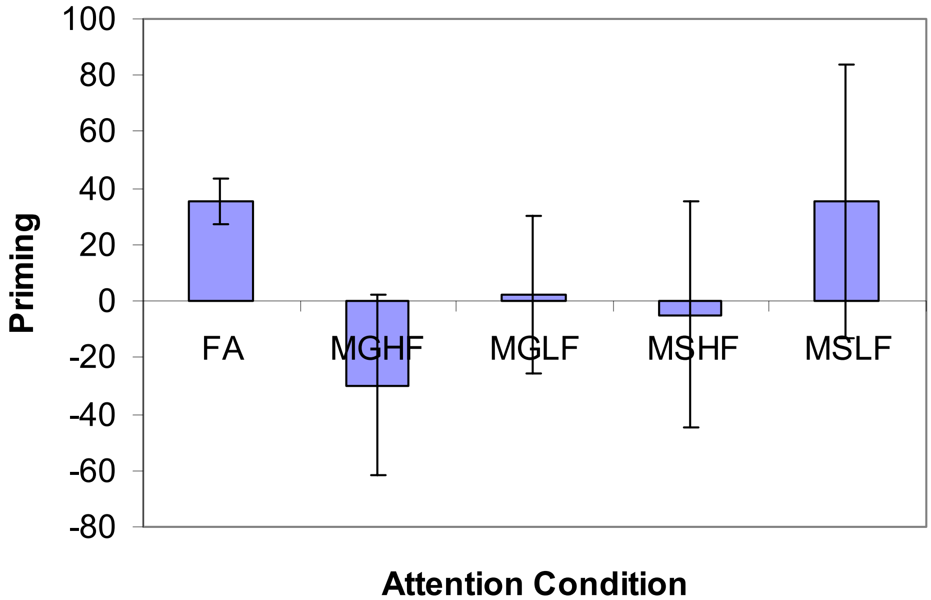


Figure 7:

Priming (New RT – Old RT) on the category verification test as a function of attention condition



Appendix A:

Awareness Questionnaire

Awareness Questionnaire (Perceptual Identification)

1. What do you think was the purpose of the task you just completed?
2. Did you think there was anything unusual about the words that were presented?
3. Did you notice any connection between the words you heard earlier and the task you just performed?
4. If the subject says 'yes.', then ask: '*What* did you notice?'
5. Were you aware of this connection at the time you were identifying the words, or did you only become aware of it after I began to ask these questions?
6. If the subject noticed that some of the responses corresponded to the words presented earlier, ask: 'Did you consciously try to use words from the earlier part of the experiment to help you identify words presented in the last part of the experiment?'

NOTE: YOU ARE NOT FINISHED WITH THE QUESTIONNAIRE UNTIL YOU, THE EXPERIMENTER, CAN ANSWER THE FOLLOWING QUESTIONS:

1. Was the subject aware, at the time, of the connection between the two parts?

   Yes / No (circle one)

2. Did the subject consciously try to use the words from the earlier part as responses in the last part?

   Yes / No (circle one)

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