DISSOCIATION BETWEEN DECLARATIVE AND PROCEDURAL MECHANISMS IN LONG-TERM MEMORY

A dissertation submitted to the
Kent State University College
of Education, Health, and Human Services
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

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August, 2017
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The purpose of this study was to investigate the potential dissociation between declarative and procedural elements in long-term memory for a facilitation of procedural memory (FPM) paradigm. FPM coupled with a directed forgetting (DF) manipulation was utilized to highlight the dissociation. Three experiments were conducted to that end. All three experiments resulted in facilitation for categorization operations. Experiments one and two additionally found relatively poor recognition for items that participants were told to forget despite the fact that relevant categorization operations were facilitated. Experiment three resulted in similarly poor recognition for category names that participants were told to forget. Taken together, the three experiments in this investigation demonstrate a clear dissociation between the procedural and declarative elements of the FPM task. Namely, the continued maintenance of declarative elements is not necessary for the subsequent facilitation of categorization operations.
ACKNOWLEDGMENTS

Vampire or zombie? And then I woke up.
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CHAPTER I
INTRODUCTION

Goals and Questions of the Current Investigation

The facilitation of procedural memory (FPM) is conceptualized as a strengthening of cognitive operations (Woltz & Was, 2006, 2007). Put differently, the use of specific operations is hypothesized to increase the efficiency of those operations upon subsequent use. For example, if one were to categorize the word oak, a likely response would be that oak is a tree. Let us now categorize the word elm. Similarly, the response is likely to be elm is a tree. FPM predicts that the second response will be more efficient than the first. The pertinent question is why? Previous studies of FPM have concluded that the increased efficiency of specific cognitive operations (i.e., categorizing trees in the example) is due to the relevant procedural elements. However, the procedural elements are implicit (i.e., occurring outside of awareness) and are therefore difficult to isolate. Because of this difficulty, there is a possibility that what has been described as procedural is in fact a product of continued activation or maintenance of relevant declarative elements (i.e., oak, elm, and tree in the example). Therefore, the current investigation attempts to validate the procedural elements of the FPM effect by dissociating them from the declarative elements.

The following sections will provide a more detailed discussion distinguishing procedural and declarative memory, the hypothesized method for teasing out this
distinction in regards to the FPM effect, as well as the rational for each of the three experiments in this investigation.

**Declarative versus Procedural Memory**

One important characteristic of long-term memory (LTM) is the distinction between the procedural and the declarative (Anderson, 1976). Declarative memory is that which is accessible to awareness. That is, information that an individual is aware of or can be aware of is declarative. Procedural memory, complementarily, is system knowledge used for access to and processing of declarative memory and is not available to conscious awareness (Anderson & Lebiere, 1996).

The Adaptive Control of Thought – Rational (ACT-R) is a computational model of human cognition (Anderson, 2007). ACT-R utilizes three basic components. The first component is the goal. At any moment in time the goal is a change from the current position. The current position includes awareness of the goal as well as any declarative elements activated to the level of awareness. At this point the second basic component in ACT-R, procedural memory, recognizes patterns in the current declarative awareness and goal state in order to retrieve a suitable response or solution to the present problem. The response of procedural memory is often the activation of the third component, declarative memory. An interdependence exists between procedural and declarative memory. Active declarative memory triggers relevant procedural memory that in turn activates additional declarative memory and so on and so forth. The new declarative activation changes the current activation pattern, which may then elicit the use of a different procedure in order to produce an appropriate response. Anderson hypothesized the
existence of this interdependence between declarative and procedural components where changes in declarative activation result in changes in procedural activation and vice versa.

Similar to ACT-R, Oberauer’s procedural working memory model is predicated on the interdependence of declarative and procedural memory. Oberauer (2009) suggests that working memory (WM), like LTM, has both a declarative as well as a procedural component. The model is based on a hierarchical structure of memory element activation. On the broadest level is all of LTM, including both declarative and procedural elements. Within LTM is the portion of activated LTM (ALTM). A subset of declarative ALTM is described as the region of direct access. The analogous subset of procedural ALTM is called the bridge. In a generic stimulus-response experiment, for example, the set of relevant stimuli is the declarative region of direct access whereas the relevant responses to those stimuli are in the procedural bridge. Only a single declarative item is selected from the region of direct access to be the focus of attention. The declarative item in the focus of attention then elicits the selection of a single procedural response from the bridge. The use of a procedural response may then substitute one or more items in the region of direct access, which may in turn require a different procedural set in the bridge.

The distinction between procedural and declarative memory is well substantiated. Indeed, procedural memory has long been discussed in psychology literature. Ebbinghaus (1885) describes procedural memory as the “occurrence of any condition or process” that “consists in facilitating the occurrence and progress of similar
processes.” (p. 2). Additional evidence for the distinction between declarative and procedural memory comes from neuropsychological studies of amnesiac patients who demonstrate procedural learning but fail to retain new declarative information (Squire, 1980). The same evidence suggests that long-term declarative memory is reliant upon the hippocampus, while long-term procedural memory is thought to rely more on the basal ganglia (Ullman, 2004). Anderson (2007) suggests the basal ganglia as the neural correlate of procedural module in ACT-R.

Procedural and declarative memories are distinct but interdependent and both play a role in cognitive activity. FPM presumably utilizes the described interplay between the procedural and declarative. An examination of which should provide insight into specific procedural memory mechanisms that may account for the ability of complex cognition to operate given the capacity limitations of working memory (WM). A close review of the FPM literature provides more detail regarding theoretical processes involved in the strengthening of specific cognitive operations.

**Procedural and Declarative Elements in FPM**

In order to understand the hypothesized interaction of procedural and declarative elements in FPM, it is useful to view the FPM task from an ACT-R perspective. Recall that an ACT-R model has three basic components; procedural memory, declarative memory, and the goal (Anderson and Lebiere, 1998). When completing the FPM task (e.g., Woltz & Was, 2006 2007) the participants’ main goal is to categorize a given word. Therefore, the declarative element is the given word and the procedural element is identifying the category to which the given word is a member. It is the procedural
element that recognizes the pattern between the goal of categorization and the declarative element of *given word*. Returning to our previous example, if one were to categorize the word *elm*, the goal remains the same (i.e., categorize *[given word]*)]. The relevant declarative element becomes *elm*. The procedural element then recognizes the pattern of categorize *[elm]* and returns the most likely answer, *tree*. *Tree* is now an active declarative element that satisfies the goal. Notice that the declarative elements include both the *given word* and the *category* while the procedural elements are the processing of the *given word* in the context of the goal and then retrieval of the most likely *category*.

**Dissociating the Procedural from the Declarative**

In order to determine the relative contribution of the procedural and declarative elements they need to be dissociated. That is, given the same stimuli, at least two measures, one for the procedural mechanism and one for the declarative mechanism, are needed. As FPM is purported to measure change in procedures, it was chosen to detect the procedural mechanism. To detect the declarative mechanism, a directed-forgetting (DF) paradigm was used.

DF is a phenomenon that shows a decreased memory for items that participants were explicitly instructed to forget as compared to items that participants were instructed to remember. In one particular form of DF, the item method, participants are cued to remember or forget specific items. Upon test, memory is worse in the forget condition then in the remember condition. The difference in accuracy between the remember (R) and forget (F) items is a measure of explicit memory.
The directed forgetting effect appears to be limited to explicit memory tests such as recall and recognition, where remembering is done consciously. On implicit memory tests such as completing partial words that were or were not studied, or reading aloud as quickly as possible words that were or were not studied the evidence is quite consistent that there is no difference between F items and R items. As well, the effect disappears if the F items are meaningfully linked to the R items. Such results implicate conscious encoding and retrieval processes as the locus of the directed forgetting effect. (MacLeod, 2012, pp. 994-995)

**FPM and DF setup.** In the current investigation, a standard FPM task was used with two alterations. One, following the memory list, the participants were instructed to remember words from one of the semantic categories and forget the words from the other semantic category. Second, following 18 trials of memory list and category comparisons, a yes/no recognition task was completed. The recognition task contained declarative elements from the previous memory lists. These alterations were meant to incorporate the DF paradigm into the FPM task.

It was hypothesized that the integration of DF into the FPM task would result in one of two outcomes. If the FPM effect is due to strengthening of procedural elements, the results should show the general FPM effect along with a DF effect. That is, participants should continue to demonstrate a facilitation of the specific categorization procedure of the items they were instructed to forget. However, participants should fail to recognize items in the memory load that they were instructed to forget compared to
recognition of items they were instructed to remember. Alternatively, if the FPM effect is
due to the strengthening and/or spreading of activation from declarative elements in the
memory load and/or their superordinate categories, the DF effect should not occur,
although the facilitation effect does occur.

**Experimental Rational**

The rational for each of three experiments is described below.

**Experiment 1.** Does the FPM effect rely upon the maintenance of declarative elements from the memory load? If FPM is procedural, it should be dissociable from declarative memory. Experiment 1 was designed to dissociate declarative maintenance from procedural facilitation. The FPM task used was a modified version of Woltz and Was (2007). The dependent measures of interest were 1) the speed of category comparisons (a measure of procedural facilitation) and 2) recognition accuracy of previously presented memory load items (a measure of declarative maintenance). A procedural account of FPM would be supported if memory load items were successful in stimulating the FPM effect but were unrecognizable. Such a result would suggest that the declarative elements (i.e., the memory load items) needed to instantiate the relevant procedure do not need to be maintained for the procedure to be facilitated. Stated differently, the facilitation of the procedure would not dependent upon maintenance of the declarative elements that were used to call the procedure.

**Experiment 2.** Are the effects from Experiment 1 replicable? The results of Experiment 1 suggest that the continued maintenance of declarative memory load items is not necessary for the FPM effect to occur. It is therefore implied that the FPM effect
observed during category comparisons cannot be accounted for by spreading activation from memory load items to category comparison items. It is possible, however, that the recognition results of Experiment 1 are actually due to a response bias built into the experimental design. The correct responses during the recognition portion of Experiment 1 were disproportionately ‘no’ responses. The purpose of Experiment 2 is to determine if the results of Experiment 1 can be replicated after controlling for the potential response bias. Utilizing a modified version of Experiment 1, Experiment 2 will seek to replicate the two major results from Experiment 1. One, is the FPM effect present during the category comparison phase of the study? Two, if participants receive recognition items that are equally balanced between yes and no correct responses will the results differ from Experiment 1?

**Experiment 3.** If Experiment 2 successfully replicates the result of Experiment 1, there will be strong evidence against a need for memory load items to remain activated during FPM. However, there remains the possibility that the FPM effect is relying on the declarative maintenance of the category itself. If the category is activated during the memory load, which presumably happens, continued maintenance of the category could account for the FPM effect during category comparisons as well as differences in the recognition of the various memory load items. The individual memory load items do not need to remain active, which is the suggestion of Experiment 1, if the FPM effect is supported by the category. To examine the role of the declarative category representation in the FPM effect, Experiment 3 proposed to test participant recognition for the memory load categories. It was hypothesized that categorical activation would not account for the
FPM effect. The FPM results should look similar to those obtained from experiments one and two. Additionally, the category recognition results should show an advantage to the remember categories due to extended rehearsal of category members in WM. Such a result would suggest that the FPM effect is not relying on the continued maintenance of the category but instead procedural mechanisms relevant to the category.
CHAPTER II

REVIEW OF FPM LITERATURE

Introduction

In reviewing FPM, it is important to consider the motivation that led to the initial findings. Woltz and Was (2006) designed the FPM task, originally labeled the ALTM task, to investigate the concept of available long-term memory (ALTM). ALTM is similar to the embedded processes model suggested by Cowan (1988, 1995, 1999). Cowan (1988) argued that WM is actually an activated portion of LTM. The embedded processes model suggests that some of LTM is active and therefore highly accessible to conscious awareness. Additionally, within the highly accessible portion of LTM is a subset of currently attended memory. Currently attended memory is referred to as the focus of attention. Cowan suggests that the focus of attention is limited to four items or channels (Cowan, 1999). Information recently in the focus of attention comprises the portion of active LTM. This active portion of LTM, according to Cowan, is more likely to become the focus of attention than is inactive LTM. Therefore, the limited capacity of the attentional system is augmented by additional activation in LTM. ALTM, as described by Woltz and Was (2006) refers to information in long-term memory that is readily available for processing in WM. ALTM is a portion of LTM that is in a state of heightened availability due to its relation to items in the focus of attention. The FPM task was therefore designed to measure access to the unattended yet active information in LTM. The key difference between ALTM and Cowen’s embedded processes model is
that ALTM includes associated but never attended information, while Cowan’s model does not.

In the following review, several studies directly examining FPM and its effects will be discussed. Of particular interest are the conditions in which FPM is most and least robustly demonstrated. These conditions are predominately related to various time-courses and stimulus types. Clearly defining the conditions under which FPM operates should lead to a better understanding of the mechanism behind the FPM effect.

**Woltz and Was (2006)**

Woltz and Was (2006) was a series of four experiments investigating ALTM. Each of the four experiments is described in detail below.

**Experiment 1.** The original ALMT task from Woltz and Was (2006) Experiment 1, required participants to memorize a series of four words, with each word representing one of two distinct semantic categories (e.g., elm, chair, oak, table). Following presentation of the words, participants were informed that they would later be required to recall one category of words (e.g., remember the trees). The *remember* category was stated explicitly during each experimental trial and the participants were then required to report the exemplars that belonged to that category. After exemplar recall, the participants completed a series of category comparison trials. Each trial required participants to indicate whether two presented exemplars (e.g., maple-pine) were from the same (e.g., maple-pine) or different (e.g., lamp-car) categories. The words used in the comparisons came from the remember category, the *ignore* category (i.e., the other
semantic category from the memory load), or a novel category (i.e., words belonging to neither the remember nor the ignore categories). Importantly, the words in the comparisons were associated with the memory load items (i.e., belonging to the same semantic category) but they were not repeated items (i.e., items from the memory load).

The results indicated that participants gave the most correct responses-per-minute to category comparisons containing words from the remember category. That was followed by comparisons from the ignored category. The fewest correct responses-per-minute came from comparisons between words belonging to a novel category.

Woltz and Was (2006) interpreted these findings as evidence that previous processing of remember and ignore category exemplars during and after the memory load led to improved processing efficiency for the subsequent processing of semantically related exemplars (i.e., remember and ignore category comparisons). This interpretation makes sense from the perspective of Ericsson and Kintsch (1995) who proposed a mechanism of long-term WM (LTWM). LTWM is purported to operate through the use of skilled memory storage and retrieval processes. Evidence for this idea comes from experts’ ability to rapidly memorize and store complex information beyond the classic scope of WM capacity. An interesting nuance, however, is that LTWM is only effective within an individual’s domain of expertise. It is suggested, therefore, that LTWM structures for storage and retrieval are developed overtime with practice through exposure to specific circumstances. In the context of ALTM, the expertise described by Ericsson and Kintsch (1995) is that of categorization. Presumably the participants already know how to categorize the items from the memory load. Therefore the practice
of the established categorization procedure during the memory load phase allows for facilitation in the category comparison phase.

Another important result of Woltz and Was (2006, Ex 1) was the higher proportion of correct responses per minute for the remember category compared to the ignore category was taken as evidence for a degree of processing effect. It is assumed that upon hearing which category to remember, the participants continue to rehearse the exemplars from the remember category and cease rehearsal of exemplars from the ignore category. Hence, the remember category receives more processing than the ignore category which in turn increases the correct responses per minute to semantically related category comparisons. However, this processing explanation was possibly confounded by the explicit presentation of the remember category name following the memory load. The ignored and novel categories were never explicitly named during any trial. Naming only the remember category may have privileged subsequent processing of the remember category relative to the ignored and novel categories. Therefore, the relative contributions of rehearsal and category naming were unclear. The effect of explicit category naming versus item maintenance was explored in Experiment 2.

**Experiment 2.** Experiment 2 from Woltz and Was (2006) was designed to answer the question resulting from Experiment 1. That is, do explicit category labels affect access to relevant LTM? The procedure of Experiment 2 followed that of Experiment 1 with the exception that half of the trials labeled the remember category and the other half of the trials labeled the ignore category (e.g., “remember the trees” versus “ignore the furniture”). Only one of the categories from the memory load was explicitly
labeled in each trial. The intention of the manipulation was to determine whether the advantage of the remember category during comparisons was due to the category being labeled or to the extra processing, in the form of rehearsal that the remember exemplars were likely to receive. The results showed that the largest advantage during the comparison phase went to the category that was explicitly labeled. That is, on trials that gave instructions to ignore a specific category subsequent comparisons between exemplars of the ignore category had the most correct responses per minute. The same was true of remember-category-comparisons following explicit instruction to remember the exemplars from a specific category. These results suggest that the attention-driven processing (i.e., drawing the participants’ attention to the category membership of specific exemplars) had a larger effect upon subsequent processing than did the extra rehearsal received by the remember category exemplars. One critique of Experiment 2 is that it failed to replicate the facilitation of the ignored category following a remember instruction that was demonstrated in Experiment 1. The same pattern of facilitation was present but there was no significant difference found between the ignore-category-comparisons and the novel-category-comparisons. However, results from the explicit-ignore trial type did indicate a significant difference between the remember-category-comparisons and the novel-category-comparisons. This result is analogous to Experiment 1 in that the non-labeled category was significantly facilitated over the novel category. However, it is still reasonable to suspect the added rehearsal of the remember-category-exemplars to be is playing a role in the facilitation. Experiment 3 tried to further examine the role of rehearsal processes during the FPM task.
**Experiment 3.** Experiment 3 from Woltz and Was (2006) used the same procedure from Experiment 1 but altered the order of the within-trial tasks. Experiment 1 proceeded as a memory load list, recall of the to-be-remembered words, followed by category comparisons. Experiment 3 followed the same procedure on half of the trials and used a new task order on the other half of the trials (i.e., prior recall condition). The new order was created by moving the recall task to after the comparison task (i.e., concurrent maintenance condition). This manipulation required participants to maintain the to-be-remembered words until after the comparison task on half of the trials. Recall that memory load items were not used as comparison items. The question addressed by this manipulation was how concurrent versus prior memory load maintenance affects category comparison performance. Stated differently, does the added cognitive load of maintaining memory load items during the category comparisons alter the FPM effect? If the FPM effect relied on the same limited resources that WM maintenance of information relies, than it would be suspected that a concurrent WM task (i.e., memory load maintenance) would diminish the FPM effect. Alternatively, if the FPM effect does not rely on WM resources then a concurrent memory task should not affect the FPM results. The results showed firstly an FPM effect in both the prior and concurrent conditions. However, participants produced significantly less correct responses per minute for all comparison types in the concurrent maintenance condition when compared to the prior recall condition. The overall decrease in correct responses per minute across comparison types suggests that the presence of the concurrent memory load affected each comparison type in a similar way. That is, there was no interaction between comparison type (i.e.,
remember, ignore, novel) and trial type (i.e., prior versus concurrent memory load maintenance). Since only the remember and ignore categories are affected by processing of the memory load (i.e., the FPM effect), the similar reduction in correct responses per minute for the novel comparisons suggests that the concurrent rehearsal is not interfering with the FPM effect but instead the comparison process as a whole. Stated differently, the concurrent rehearsal seems to affect the comparisons in a way distinct from the FPM effect because each comparison type, including the novel comparisons was affected to the same degree. This supports the idea that the FPM effect is, to some degree, operating independently of the working memory load and short-term rehearsal. However, it may be that since the memory load maintenance was only for two items the processing resources that FPM depends on were not strained enough to affect the pattern of FPM results in the concurrent condition. Therefore, experiment 4 increased the number of to-be-remembered exemplars to examine the effect of additional WM processing.

**Experiment 4.** Experiment 4 used the same design as Experiment 3 but with the added variable of memory load distribution. The memory load still contained four exemplars from two distinct semantic categories but the number of exemplars from each category was either one or three. Therefore, if the remember category had three exemplars the ignore category had only a single exemplar and vice versa. As in Experiment 3, the recall of the to-be-remembered exemplars occurred either before or after the category comparisons. The goal of Experiment 4 was to determine if varying the number of the to-be-remembered exemplars affect the pattern of FPM results. The results indicated that the FPM effect was present regardless of the number of to-be-
remembered exemplars. However, the pattern of results varied with the number of to-be-remembered exemplars. When the remember category only contained a single exemplar, the FPM effect was strongest for the ignored-category-comparisons regardless of when the remember-category-exemplar was recalled. This result is likely due to the fact that when the remember category had one exemplar the ignore category had three and examining the memory load in this condition required more processing, initially, of the ignore category than of the remember category. It follows then that FPM would be stronger for the category that received the most semantic processing. It should be noted that the remember-category-comparisons were also facilitated compared to the novel-category-comparisons even when only a single remember-category-exemplar was presented. This supports the findings of Experiment 2 in that explicitly drawing attention to the category membership of an exemplar strengthens FPM. What is unique about Experiment 4 is that the effect of category naming was apparent with only a single exemplar. When the memory load contained three to-be-remembered exemplars, the remember-category-comparisons had the largest FPM effect compared to the novel-category-comparisons. This pattern of FPM was present whether recall of the to-be-remembered-exemplars occurred before or after the category comparisons. The results of the three, to-be-remembered, exemplars condition in Experiment 4 replicated Experiment 3. That is, the number of correct responses per minute for each comparison type (i.e., remember, ignore, and novel category comparisons) was lower when recall of the to-be-remembered exemplars occurred after the comparison phase as opposed to before the comparison phase. Again, fewer correct responses per minute across each comparison
type suggests that concurrent memory rehearsal affects the comparison types similarly. Since FPM is measured by the difference between the memory-load-category-comparisons (i.e., the remember and ignore categories) and the novel-category-comparisons, the lack of interaction between the FPM effect and the duration of memory load rehearsal (i.e., prior to category comparisons versus concurrent with category comparisons) is evidence that the processing resources of FPM and rehearsal are distinct. This is an important point because it suggests a dissociation between the FPM process(es) and the WM process of rehearsal. However, there remains the argument that perhaps the concurrent rehearsal of only three items is not sufficient to impede the FPM process.

An important claim of Woltz and Was (2006) is that the results cannot be accounted for by the spreading activation explanation of many semantic priming effects. Spreading activation is a classic mechanism of network models in cognitive psychology (Quillian, 1967; Collins & Loftus, 1975; Anderson, 1976). Spreading activation claims that the activation of a specific concept will spread to associates of that concept. Semantic priming is therefore possible because activation of a prime word spreads to the related target word. The spreading activation results in an increase in processing efficiency of the target word. The problem with using spreading activation as an explanation for the FPM effect is that spreading activation decays rapidly (i.e., in as little as 500 ms) (Ratcliff & McKoon, 1988). The time between the memory load and category comparison phases of the experiment far exceed the 500 ms suggested by Ratcliff and McKoon (1988). However, this delay was not explicitly manipulated until Woltz and Was (2007).
Woltz and Was (2007) contained two experiments designed to replicate and extend Woltz and Was (2006). Each of the two experiments is described below.

**Experiment 1.** Utilizing a very similar experimental procedure to that of Woltz and Was (2006), Woltz and Was (2007) Experiment 1 sought to examine the difference between indirect FPM and direct FPM as well as the effect of lag between the memory load and comparison phases of each trial. Unlike indirect FPM (i.e., the FPM procedure used in Woltz and Was, 2006), direct FPM re-uses words from the memory load in the comparison phase. The results showed greater speed (i.e., correct responses per minute) for direct FPM comparisons than for indirect FPM comparisons. It should be noted that the presentation of the memory load occurred aurally over headphones and the subsequent category comparisons were conducted on visual word pairs. The multimodal presentation of the experimental stimuli was meant to control for the potential of perceptual priming (i.e., speeded responses due to perceptual similarities between stimuli) between the memory load and category comparison phases. Therefore, the FPM effects demonstrated in Experiment 1 are, presumably, conceptual in nature as opposed to perceptual. This is especially important for direct FPM comparisons because of the use of repeated items. Also of note is the manipulation of lag between the memory load and comparison phases of Experiment 1. Lag was varied from zero to 32 intervening stroop-like trials. The FPM effect (i.e., increased correct responses per minute) showed little to no decline across the levels of lag for either direct or indirect category comparisons. These results suggest that the FPM effect is operating largely independent from the...
processing demands of the stroop-like task. Additionally, the persistence of the FPM effect after lag 32, which lasted up to two minutes, suggests that the FPM effect is relatively long lasting. Priming effects are not generally detectable beyond a lag of one (i.e., a single interleaved stimulus between the prime and the target)(McNamara, 2012).

The results of Woltz and Was (2007, Exp. 1) left the authors wondering what the underlying mechanism of the FPM effect was. One possible explanation was that perhaps FPM is affecting the declarative representation(s) and associations of the words presented in the memory load. Another explanation was that perhaps FPM was affecting the cognitive operations relevant to the FPM task (e.g., identification of category membership).

**Experiment 2.** Experiment 2 was designed to investigate the two potential explanations of the FPM effect. The major distinction between these potential explanations is the role of declarative versus procedural memories. To investigate these ideas Woltz and Was introduced a new stimulus type to the FPM task, the feature. A feature is a component or attribute of a broader semantic category. The category BIRD, for example, has features that include wing, feather, beak and so forth. Experiment 2 from Woltz and Was (2007) used the same experimental procedure as Woltz and Was (2006) Experiment 1 with the addition of category features. The memory load contained either all exemplars or all features from two semantic categories. Similarly, the comparison phase contained either all exemplars or all features. This created a 2x2 design (i.e., memory load type (Exemp. or Feat.) x comparison type (Exemp. or Feat.)). The results showed an FPM effect for congruent trials (i.e., trials having exemplars or
features in both the memory load and comparison phases). The FPM effect was not found in trials that crossed stimulus type (i.e., exemplars and features) between the memory load and comparison phases. That is, when the memory load contained exemplars and subsequent comparisons were between new exemplars belonging to the memory load categories, the results replicated the effects in semantically similar experiments (Hughes & Whittlesea, 2003). The same FPM pattern was replicated when a memory load of features was followed by a comparison phase using features. The FPM effect was not present in trials that did not match stimulus types across trial phases. When exemplars were used in the memory load, category comparisons between features did not show the FPM effect. The same was true of exemplar comparisons following a memory load of features. Together these results suggest that FPM may be affecting the cognitive operation of category identification differently for exemplars than features. Because the exemplar-memory-load facilitated exemplar comparisons but failed to facilitate feature comparisons from within the same category, there appears to be a unique link between the exemplars of a category and the category itself that is not shared to any significant degree with the features of that same category. Similarly, the features of a category seem to utilize a link that is unique from the exemplars of the category. These results seem inconsistent with the idea that FPM is dependent upon on the strengthening of the representations themselves. If the representations were strengthened, one would expect facilitation across related exemplars and features due to the high association among the items. Alternatively the FPM effect appears to be operationally specific. That
is, the semantic relationship between specific items and their broader category is relevant to the FPM effect.

**Was (2010)**

Woltz and Was (2006, 2007) administered their FPM tasks during a single sitting. It is possible that during that time participants were able to gain a sense of the experimental manipulation (i.e., words from the memory load or words similar to those in the memory load will be seen again). Demand characteristics are long standing problem in experiments on human subjects (Orne, 1962). In such a case, participants may have been able to flag memory load items and/or categories for later processing. The expectancy effect, where participants activate a pool of potential targets following a prime, has been demonstrated in semantic priming tasks (Neely, 1977, 1991). If the facilitation of repeated and related items in the ALTM task was due to some form of flagging then the argument for the strengthening of unique cognitive operations suffers due to a potential confound from demand characteristics in the experimental design. Was (2010) attempted to control for potential flagging by inserting a 24-hour delay into the FPM task. Following 24 memory load presentations and recall phases of the FPM procedure participants received a 24-hour break. The next day, participants returned to complete 24 sets of comparison trials. The results showed significantly more correct-responses-per-minute for comparisons between memory load items (i.e., repeated items) and items related to memory load items (i.e., new items belonging to memory load category) relative to novel comparisons. Said differently, the FPM effect was still present after a 24-hour delay.
Was (2010) concluded that the results were very unlikely due to short-term semantic priming mechanisms such as spreading activation as activation is thought to decay rapidly (Ratcliff & McKoon, 1988). Expectancy, as described by Neely (1977, 1991), was also unlikely due to the lack task repetition present in Woltz and Was (2006, 2007), as well as the 24-hour delay between memory load and category comparison phases. Instead, Was (2010) argued that the results were more in line with long-term semantic priming and transfer effects (Becker, Moscovitch, Behrmann, & Joordens, 1997; Joordens & Becker, 1997; Woltz, 1990, 1996; Hughes & Whittlesea, 2003).

Indeed, the FPM task is in accordance with McNamara’s (2012) description of these effects as needing relatively elaborate semantic processing as well as being specific to the elaboration. That is, FPM requires a specific categorization procedure to occur in the memory load in order for facilitation of the same procedure to occur in the category comparison phase.

To summarize, the basic FPM effect is a relatively long lasting improvement in the speed of determining category membership following associated processing. The FPM effect also seems to be item general so long as those items have the same semantic relationship to the same category. That is, both oak and maple share the same relationship with the tree category. However, it is unclear to what degree the declarative memory load items (e.g., oak) and categories (e.g., tree) play in the subsequent facilitation of associated item categorizations (e.g., maple is a tree). This investigation attempts to clarify this issue.
Individual differences in FPM

Was and Woltz (2007) examined the relative contributions of WM and FPM in explaining individual differences in listening comprehension. WM is limited. Current estimation of WM capacity is around four bits of information (Cowan, 2001). It has been suggested that the limits of WM capacity struggle to account for the large amounts of information often required for listening comprehension (Baddeley, 2012; Cowan, 1988; Erikson & Kintsch, 1995). FPM is thought to demonstrate efficient access to LTM via ALTM. It was therefore suspected that FPM might mediate the relationship between WM and listening comprehension. To do so the authors built two structural equation models (SEM). The first model had three latent variables (i.e., FPM, WM, and listening comprehension). The latent FPM variable represented the common variance among three observed measures of FPM (i.e., FPM for exemplars, features, and synonyms). Similarly, the latent variables for WM and comprehension represented the common variance among three measures of each of those constructs. The SEM was set up to see if the FPM factor mediated the relationship between WM and comprehension. As stated earlier, the capacity limitations of WM do not account for the breadth of knowledge needed for complex cognitions such as listening comprehension. As such, FPM, which is thought to demonstrate efficient access to long-term memory, was expected to mediate the relationship between WM and comprehension. The results indicated that FPM did show the hypothesized mediation. A second SEM was constructed by adding an additional background-knowledge factor to the first SEM. The concern being that perhaps the mediation seen by the FPM factor in the first SEM is actually an effect for background-
knowledge. The results of the second SEM maintained that FPM mediates the relationship between WM and comprehension even after accounting for background-knowledge. If WM requires efficient access to LTM to complete complex cognitions and FPM is a mediating factor in that relationship, it is suggested that FPM is a measure of said efficiency.

Was, Dunlosky, Bailey, and Rawson (2012) also examined individual differences in FPM. The authors used similar latent variables (i.e., FPM, WM, and comprehension) as those used by Was and Woltz (2007) as well as the additional latent variable of fluid intelligence. Fluid intelligence is one’s ability to derive solutions to novel problems (Engle, Tuholski, Laughlin, & Conway, 1999; Engle, Kane, & Tuholski, 1999; Kane & Engle, 2002). A significant relationship was expected to exist between the FPM, WM, and comprehension variables just as they had in Was and Woltz (2007). An additional hypothesis expected FPM and WM to account for unique variance in fluid intelligence as well. From an ACT-R perspective, it is clear that performing a fluid intelligence task requires the use of known procedures such as those for reasoning and comparison (Sternberg & Gardner, 1983). Therefore it is reasonable to suspect FPM to have a relationship with fluid intelligence. All of the hypotheses were supported by the results. Both FPM and WM accounted for a significant amount of unique variance in both comprehension and fluid intelligence. The results indicate that the processing used by FPM is associated significantly with the processing requirements of higher-order cognitions (e.g., fluid intelligence and comprehension). A similar association has also been demonstrated between FPM and skill acquisition (Smith & Was, 2014).
Smith and Was (2014) used regression analysis to assess the predictive value of individual differences in FPM upon individual improvement on color and number Stroop-tasks. Individual differences in FPM were found to be a significant predictor of improvement on both Stroop-tasks. The results indicate that individuals demonstrating a larger FPM effect tend to show greater improvement on the color and number Stroop tasks. This lends support to the idea that FPM is related to a strengthening of implicit cognitive procedures. However, as this study used correlational data, it is not useful in describing what the learning mechanism underlying FPM is.

Overall, the results of studies examining individual differences in FPM have indicated that the processes underlying FPM are highly associated with complex cognitions. Individuals that demonstrate stronger FPM effects also tend to demonstrate better comprehension, higher fluid intelligence, and stronger implicit learning ability. The mechanism underlying the FPM effect has obvious implications for FPM itself and possibly other higher order cognitive abilities. Therefore, FPM warrants further investigation.

**Current Investigation**

While the argument presented here is for the procedural nature of the FPM effect, there is yet to be an empirical dissociation between the relevant declarative and procedural aspects of the FPM task. Therefore, the primary objective of this investigation is to demonstrate a dissociation between the declarative and procedural elements of the FPM task. It is assumed that the declarative elements are the exemplars and categories from the memory load while the procedural elements are the
categorizations. Experiments 1 and 2 looked for differences between the proposed
procedural facilitation and declarative recognition of the memory load items. Experiment
3 looked for a similar difference between the procedural facilitation and recognition of
the categories themselves. If differential results are obtained between the comparison and
recognition phases of each experiment, it will serve as evidence for a dissociation
between the procedural and declarative elements of FPM.
CHAPTER III

METHODS, RESULTS, AND DISCUSSIONS

Experiment 1

The method, procedure, results, and discussion sections of experiment 1 are below.

Method

The participants, apparatus, and experimental task used in experiment 1 are described below.

Participants. Thirty-six undergraduate education majors participated in the study for course credit. There were 6 male and 30 female participants. Their median age was 20 years old (R = 4).

Apparatus. Participants completed the experimental task on IBM-compatible computers with SVGA monitors and standard keyboards, and circumaural sealed headphones. The experiment was programmed with E-Prime software (Psychology Software Tools, Inc., 2002).

Experimental Task. Category stimuli for this experiment were adapted from earlier studies (Woltz & Was, 2006, 2007). Though similar to the Woltz and Was (2006) experimental task, the details of the task components differ from the previous studies and include an item recognition task. Figure 1 presents an example of the order of the FPM task components. All components of the FPM tasks, with the exception of the memory
load were presented visually on the computer display. The four words in the memory load were presented aurally as they would later be presented visually in the recognition task. The cross modality was applied as it was assumed this would eliminate the facilitation of recognition from repeated perceptual processes and not contaminate the recognition task. Category stimuli were organized into 18 sets of three categories (i.e., remember, ignore, and neutral categories). These category triplets were organized to limit conceptual overlap among the three categories. For each participant, one category from each set was assigned to the remember category, one to the forget category, and one was assigned to be a category not presented in the memory load (a neutral category). Six versions of the experiment were created to allow for complete counterbalancing of categories assigned to each of the facilitation conditions (i.e., remember, forget, and neutral).
Aurally Presented Memory Load (Random Order)

Remember/Forget Instruction

Category Comparisons (Random Order after Warm-ups)

Recognition Task (Random Order, following 18 FPM trials)

Figure 1. Experimental procedure

Facilitation of Procedural Memory Task. Participants completed 18 trials of the FPM task portion of the experiment before completing the word recognition task. The components of FPM portion of the task (Figure 1) are described first, then the recognition portion of the experiment.
Memory Load. The memory load contained four words from two distinct categories. For example, one category might have been birds (e.g., sparrow and robin) and the other two words furniture (e.g., desk and chair). Each memory load was preceded by the message “Get ready to MEMORIZE words” displayed on the monitor for 2 s. A blank screen appeared for 1.5 s, then a tone sounded for 1 s to focus the participants’ attention, followed by an asterisk in the center of the screen for 500 ms. The first word of the memory load was then presented. Each word was presented aurally over headphones. The words were presented one at time at a rate of 2 s per word. A 500 ms asterisk in the center of the screen preceded each word. The fourth and final word in the memory load was followed by a 3 s pause.

Remember/Forget Direction. Following the 3 s pause after the presentation of the final memory load word, participants were instructed to both remember words from one category as well as forget the words from the other category. For example, the instruction might have read Remember the words that were a BIRD. Forget the words that were FURNITURE. The instruction screen was self-paced and participants used the spacebar to proceed to the next screen. A 2 s pause followed the remember/forget instruction.

Category Comparisons. After the remember/forget instruction, participants completed 10 category comparisons. The category comparison phase began with a 3 s screen that read Get ready to COMPARE words. Then a 2 s blank screen allowed participants to prepare for the comparisons. Each category comparison frame began with a 2 s blank screen followed by a pair of asterisks appearing one above the other in the center of the screen for 500 ms. 750 ms later the first category comparison appeared.
Each category comparison presented two words at a time. The words were presented one above the other in the center of the screen where the asterisks had been. The participants were tasked with determining whether the two words belonged to the same semantic category. Participants were instructed to rest their index fingers on the “D” and “L” keys. The ‘L’ key was used to represent like comparisons and the ‘D’ key was used to represent different comparisons. The first four category comparisons were warm-ups and not used in data analysis. The final six comparisons were the actual trial comparisons. Of the six actual comparisons three were like comparisons (i.e., the two words belonged to the same category) and three were different comparisons (i.e., the two words belonged to different categories). One of the like comparisons presented associates of the words belonging to the remember category from the memory load, one of the like comparisons presented associates of the words belonging to the forget category, and one of the like comparisons presented words from the neutral category. Each of the three different comparisons contained one word from either the remember, forget, or neutral category paired with an unrelated word. Participant responses (i.e., ‘L’ or ‘D’) initiated the presentation of the next pair of asterisks.

**Recognition Task.** Following the 18 trials of the FPM task (i.e., 18 memory loads each followed by a category comparison phase), participants completed the recognition task. During the recognition task, participants were presented one word at a time in the center of the screen. The participants were instructed to respond yes (by pressing the ‘Y’ key) if the word had been presented aurally during any of the memory loads earlier in the experiment and to respond no (by pressing the ‘N’ key) if the word had not been heard
during the memory loads. Participants were told explicitly to respond yes to any word that they had heard during the experiment regardless of the direction to remember or forget that particular item.

The recognition task contained 216 words. Every word from the memory load, both remember (36 words) and forget items (36 words), was included in the recognition task. The task also included distracter items that belonged to the remember (18 words) and forget (18 words) categories but were never used during any component of the FPM task. There were also new items belonging to the neutral categories (54 words) from the FPM task as well as truly novel items (54 words) belonging to categories never used during the FPM task. Accuracy was collected for each response. Each response initiated the presentation of the next word.

Procedure

Upon arrival to the lab, participants read and signed a consent form. They were then seated at one of four sound-dampening computer carrels. Participants were assigned to one of six counter-balanced versions of the experiment. The experiment started with a series of instructional slides describing the procedure. Namely, they were told that there will be a memory load followed by a remember/forget statement and category comparisons. The participants were also informed that their memory of the to-be-remembered items would be tested. The participants were instructed to put on the headphones and their hearing was tested. The hearing test required the participants to type a three-digit number that was presented aurally via the headphones. The participants first completed four practice FPM task trials. Following the FPM practice, the
participants completed a practice recognition task. The practice recognition task did not include any forget items from the practice FPM trials. Items used for the practice FPM task and recognition task were not used in any other portion of the experiment. The practice FPM and recognition trials were identical to the actual trials with the exception of stimuli used. Following the practice phase, participants were informed they were then to complete the actual trials. Each participant then completed 18 actual FPM task trials. The final phase of the experiment was the actual recognition task. The actual recognition task was preceded by an instructional slide that stated explicitly that participants were to respond yes to any items that were heard during any portion of the experiment including items they were told to forget.

Results

The results of experiment 1 are below.

Facilitation of Procedural Memory. Presented first are the results of the category comparison trials from the FPM task. For the sake of brevity, only results from the category comparisons that were like (i.e., positive match) trials are presented. This was done as both theory and evidence (e.g., Woltz, 1990; Woltz & Was, 2006, 2007) indicate that response facilitation is minimal or nonexistent in negative matched comparison trials. In addition, stimuli were not counterbalanced or randomly assigned to positive and negative matched comparisons and this could lead to a confounding of match type and content.

Table 1 presents the means and standard deviations of reaction and accuracy for the positive matched comparisons, by category condition (remember, forget, and neutral).
Inspection of the table indicates possible facilitation in both accuracy and latency. To test for significant facilitation a dependent measure was calculated by combining response time and accuracy.

Table 1.

*Means and Standard Deviations of Category Comparison Accuracy and Reaction Time by Category Type from Exp. 1*

<table>
<thead>
<tr>
<th>Comparison Type</th>
<th>Accuracy</th>
<th>Reaction Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>M</em></td>
<td><em>SD</em></td>
</tr>
<tr>
<td>Remember</td>
<td>.89</td>
<td>.11</td>
</tr>
<tr>
<td>Forget</td>
<td>.91</td>
<td>.07</td>
</tr>
<tr>
<td>Neutral</td>
<td>.84</td>
<td>.10</td>
</tr>
<tr>
<td>Overall</td>
<td>.88</td>
<td>.06</td>
</tr>
</tbody>
</table>

Because facilitation effects were apparent in both measures a speed measure was calculated by dividing the participants’ accuracy for each category comparison condition by the sum of the response times for each trial in that condition (both correct and incorrect). This measure is an index of response speed adjusted for errors and has been demonstrated to be appropriate for incorporating and combining meaningful variance from both latency and accuracy (e.g., Was, 2010; Woltz & Was, 2006, 2007). Figure 2 presents the average response speed by each trial condition. To test for facilitation a repeated-measures ANOVA was conducted with two orthogonal contrasts. The first contrast compared the average for remember and forget category comparison conditions with that of the neutral (non-facilitated) comparison condition to test for an overall effect
of memory load processing. Participants were faster in responding to the remember and forget category comparison than to non-facilitated category comparisons, $F(1,35) = 13.31$, $MSe = 79.04$, $p = .001$, $\eta^2 = 0.27$. This finding demonstrates significant response facilitation for categories represented in the memory load component. The second contrast found no difference in response speed between the remember and forget comparisons conditions, $F < 1$ (see Figure 2A).

**Recognition.** Table 2 displays the means and standard deviations for recognition accuracy for each condition. Recall that of the 216 words presented in the recognition task 72 words (33%) were from the memory load, 36 (16%) were words associated with remember and forget categories but not seen in the FPM task, 54 (25%) were associates of the neutral categories and 54 (25%) were truly novel words. It was thought necessary to balance the category representation in the recognition task. Put differently, the memory load categories (remember and forget combined) were each represented by six words (four memory load items and two associates). As there were 18 FPM task trials, this created 108 recognition trials related to the memory loads. Therefore, 54 neutral category associates and 54 completely novel items were chosen as stimuli in the recognition task. This not only allowed for an even number of items related and unrelated to the memory loads, it also allowed us to test for false alarms on associates of the memory load and neutral categories, which may be related to residual semantic priming effects. It is recognized that this may have created a confound as participants might have recognized the majority of words were not heard during the memory load and defaulted to an “answer no” strategy. Put differently, there are twice as many No response items than Yes
response items. This could promote a response bias inflating accuracy for No response items. However, the dependent measure for the test of our hypothesis, that facilitation of cognitive operations is not dependent on active maintenance of declarative memory, is the difference in recognition accuracy between forget and remember items from the memory load. Items from these conditions both require a Yes response and therefore would be equally affected by a No response bias.

Table 2

*Means and Standard Deviations of Recognition Accuracy for Exp. 1*

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Accuracy M</th>
<th>Accuracy SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>.76</td>
<td>.16</td>
</tr>
<tr>
<td>Remember Distractor</td>
<td>.88</td>
<td>.18</td>
</tr>
<tr>
<td>Forget</td>
<td>.58</td>
<td>.16</td>
</tr>
<tr>
<td>Forget Distractor</td>
<td>.88</td>
<td>.14</td>
</tr>
<tr>
<td>Neutral</td>
<td>.93</td>
<td>.12</td>
</tr>
<tr>
<td>Novel</td>
<td>.96</td>
<td>.12</td>
</tr>
<tr>
<td>Overall</td>
<td>.83</td>
<td>.09</td>
</tr>
</tbody>
</table>

Due to the possible response bias, three analyses were conducted to determine if participants were performing better than chance. Typically, such an analysis would use a value of .50 as for dichotomous responses with equally distributed correct responses. As the responses in our experiment were not evenly distributed (.67 No and .33 Yes) two one-sample t-tests using .67 and .33 as our cut values for overall recognition accuracy
were conducted. Both tests were significant, $t(35) = 21.72, p < .001, d = 7.34, 95\% \text{ CI} [.19, .23]$ and $t(35) = 56.86, p < .001, d = 19.22, 95\% \text{ CI} [.53, .57]$ respectively, indicating that participants were not performing at chance. Additionally, d-prime was calculated to detect a potential response bias. The values for d-prime are listed in Table 3 do not indicate a response bias.

Table 3

*d-prime by Stimulus Type for Exp. 1*

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>$d'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>1.88</td>
</tr>
<tr>
<td>Forget</td>
<td>1.38</td>
</tr>
</tbody>
</table>

Participant recognition accuracy was significantly better for remember items ($M = .76, SD = .16$) than for forget items ($M = .58, SD = .16$), $t(35) = 9.86, p < .001, d = 1.13, 95\% \text{ CI} [.14, .21]$. Put differently, participants were less accurate at recognizing memory load items that they were instructed to forget compared to items they were instructed to remember (see Figure 2B).

Although not a main focus of the experiment, there was interest in examining whether processing of the memory load exemplars and categories would lead to false alarms on the remember and forget associate exemplars. Due to the pertinent interest in memory load items, false alarms on category associates may indicate residual activation related to the memory load categories. To test for false alarms, recognition accuracy was aggregated for the forget and remember distractors and the same was done for the neutral
and novel items. A dependent samples t-test found that participants tend to false alarm on
the distractor items more often than the novel and neutral items, $t(35) = 5.73, p < .001, d = .46$, 95% CI [.04 .08].
Figure 2. A) Mean speed (i.e., correct responses per minute) by category comparison type from Experiment 1. B) Mean accuracy by recognition type from Experiment 1. Error bars are equal to ±1SE.
**Discussion**

The results of Experiment 1 indicate that the active maintenance of declarative memory items is not necessary for the facilitation of specific cognitive operations. This is an important finding as it may provide insight into models of complex cognitive processing. The results of Experiment 1 comprise two important results: 1) the data indicate that memory was worse for items from the forget category compared to the remember category and 2) they indicate a replication of the FPM effect. The FPM effects are discussed first.

Responses to category comparisons containing items belonging to remember or forget categories were faster and more accurate than those for neutral categories. The presence of an FPM effect was both hypothesized and confirmed. One interesting result from the FPM data was the lack of a difference in response speed between the remember and forget category comparisons. Statistically, there was no difference between the facilitation of the remember comparisons and the facilitation of forget comparisons. Recall that Woltz and Was (2006) found that whichever category was explicitly named following the memory load showed increased facilitation during category comparisons compared to the unnamed category in the memory load. That is, the naming of a category during the remember/forget instruction produced the strongest category facilitation. In the current study, both categories were explicitly named following the memory load (e.g., “Remember the Birds and Forget the Trees.”). As might be expected from the results of Woltz and Was (2006) but was not explicitly hypothesized here, the explicit identification of both remember and forget categories led to equivalent
facilitation over the neutral category. Although this is a finding of interest, of more interest to the current study was participant memory for items that received a forget instruction.

Recall that in their second experiment, Woltz and Was (2006) found that when participants were told to ignore a category, comparisons containing exemplars of that category were facilitated to a significantly greater magnitude than the category they were required to remember. However, participants were not required to recall the ignore category items. Germaine to this investigation was participant memory for forget items. Participant memory for forget items has important ramifications for the FPM effect; namely, the procedural and/or declarative nature of the FPM effect. The participants in the current study showed significantly less ability to recognize forget items compared to remember items.

Taken together, there was significant facilitation of the category comparisons containing associates of the forget memory load exemplars but decreased recognition of the memory load items from those same categories. There was also significant facilitation of the remember category but relatively little decreased recognition for remember items. Therefore, instructing participants to forget the memory load items belonging to a category led to improvements on within category comparisons but impairments for item specific recognition. Put differently, a forget instruction led to category-specific facilitation during category comparisons but item-specific impairment during the recognition task. Whereas a remember instruction also led to category-
specific improvement on category comparisons but significantly better item-specific recognition.

**Experiment 2**

Experiment 2 was conducted to serve two purposes: One, to test whether the results of the Experiment 1 would replicate and two, control for the possible response bias in the Experiment 1 recognition task.

**Method**

The methods of Experiment 2 were identical to those of Experiment 1 with one exception; the recognition task had an equal number of yes and no correct responses. Having an equal number of yes and no responses during the recognition task was meant to control for any potential response bias. The recognition task in Experiment 2 used a total of 108 items (i.e., 27 remember, 27 forget, and 54 novel items).

**Participants.** The participants in Experiment 2 were 45 undergraduate education majors. Participation in Experiment 2 was compensated with course credit. Eight of the participants were males and 36 were females. Their median age was 19 years old (R = 15).

**Results**

To assess the effects of Experiment 2, two repeated-measures ANOVAs were used. The first repeated-measures ANOVA was used to measure the FPM effect during the category-comparison phase of the experiment. The second repeated-measures ANOVA was used to measure the recognition accuracy between stimulus types.
Descriptive statistics for the category comparisons can be seen in Table 4. To test the FPM effect during category comparisons, two orthogonal contrast were conducted. The first contrast compared the average speed between remember and forget category comparisons to the novel category comparisons. The purpose of this contrast was to determine if there was a difference between memory load categories and neutral categories. Indeed, there was an effect for memory load categories versus non-memory load categories, $F(1,45) = 7.24, MSe = 64.45, p = .01, \eta^2 = 0.14$. The second contrast was meant to measure the difference in speed between the memory load categories (i.e., remember v. ignore). No significant difference was found between the speed of memory load category comparisons, $F(1,45) = 2.80, MSe = 111.72, p = .10, \eta^2 = 0.06$. A graphical depiction of the comparison results can be seen in Figure 3A.

Table 4.

<table>
<thead>
<tr>
<th>Comparison Type</th>
<th>Accuracy</th>
<th>Reaction Time (msecs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Remember</td>
<td>.92</td>
<td>.07</td>
</tr>
<tr>
<td>Forget</td>
<td>.88</td>
<td>.09</td>
</tr>
<tr>
<td>Neutral</td>
<td>.88</td>
<td>.09</td>
</tr>
<tr>
<td>Overall</td>
<td>.89</td>
<td>.08</td>
</tr>
</tbody>
</table>
To test for effects in the recognition data, a second repeated-measures ANOVA was conducted. The recognition accuracy means and standard deviations for the Remember, Forget, and Novel items are displayed Table 5. A significant main-effect for recognition type was found, $F(2,90) = 79.42, MSe = .02, p < .001, \eta^2 = 0.64$. Pairwise comparisons revealed significant differences between each level of the recognition factor, $p < .001$. To test for response bias in the recognition task, d-primes were calculated for the remember and forget recognition types. Values of d-prime are listed in Table 6.

Table 5

*Means and Standard Deviations of Recognition Accuracy for Exp. 2*

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Accuracy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>Remember</td>
<td>.84</td>
<td>.15</td>
</tr>
<tr>
<td>Forget</td>
<td>.66</td>
<td>.19</td>
</tr>
<tr>
<td>Novel</td>
<td>.96</td>
<td>.08</td>
</tr>
<tr>
<td>Overall</td>
<td>.82</td>
<td>.14</td>
</tr>
</tbody>
</table>

Table 6

*d-prime by Stimulus Type for Exp. 2*

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>$d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>2.88</td>
</tr>
<tr>
<td>Forget</td>
<td>2.29</td>
</tr>
</tbody>
</table>
Figure 3. A) Mean speed (i.e., correct responses per minute) by category comparison type from Experiment 2. B) Mean accuracy by recognition type from Experiment 2. Error bars are equal to ±1SE.
Discussion

Experiment 2 was designed to improve the methodology of Experiment 1. Specifically, there was a possibility that the unbalance of yes and no correct responses from Experiment 1 may have caused a bias in participant recognition performance. Also of interest was the replication of the FPM effect during category comparisons from Experiment 1. Namely, the equivalent facilitation of remember and forget categories over neutral categories. A more thorough discussion of the FPM and recognition results from Experiment 2 follows.

The FPM results from Experiments 2 replicated the pattern of results from Experiment 1. That is, the categories used in the memory load showed facilitation over the neutral categories. Furthermore, no significant difference existed for the speed of category processing between the remember and forget categories. However, unlike Experiment 1 the category comparisons in Experiment 2 also showed no significant difference between the forget categories and the neutral categories. The pattern of results between Experiment 1 and Experiment 2 are very similar however they are not identical.

The recognition task in Experiment 2 used balanced yes and no correct responses. That is, of the 108 items in the recognition task 54 were previously presented and 54 were not. The recognition results of Experiment 2 were very similar to those of Experiment 1. There was a significant difference between each of the three levels of the recognition condition. The highest to lowest recognition accuracy belonged to the novel, remember and forget categories, respectively. One interesting difference between the
recognition results of Experiment 1 and Experiment 2 was the eight point increase in recognition accuracy for both the remember and forget items. Recognition accuracy for the remember items was 76% and 84% for Experiments 1 and 2 respectively. Similarly, the recognition accuracy for the forget items was 58% and 66% for Experiments 1 and 2 respectively. This increase in accuracy is likely due to the fact that the remember and forget foils from Experiment 1 were removed from the task a part of the response balancing for Experiment 2. Without foils, any item belonging to a memory load category has a correct response of yes. Even so the d-prime values show a lack of response bias that replicates the findings of Experiment 1.

The results of Experiment 2 appear to replicate those of Experiment 1 with the exception of the lack of significant difference between the forget and neutral comparisons. Taken together, it seems as though the FPM effect is somewhat independent of the DF effect. However, this apparent dissociation between the FPM effect and the DF is only applicable to the memory load items themselves and not to the broader category. Experiment 3 will measure recognition for categories.

**Experiment 3**

While the FPM effect has been replicated several times, there remains a question as to how reliant the FPM effect is upon relevant declarative elements. The results of Experiment 1 and 2 suggest that the FPM effect does not rely wholly upon a continued activation of memory load items. Recall that differential recognition was found for remember and forget items following equivalent FPM effects. Despite the suggested dissociation between declarative and procedural elements in Experiments 1 and 2, there
remains the possibility that the memory load categories themselves are continually active throughout the FPM task. If equivalent recognition for remember and forget categories is found, then the dissociation suggested by Experiments 1 and 2 will be minimized. However, it is hypothesized that a clear advantage will exist in recognition of the remember categories over the forget categories. Additionally, the FPM effects should replicate those of previous experiments. In such a case, a dissociation will have been demonstrated between the declarative (i.e., individual memory load items as well as the broader categories themselves) and procedural (i.e., the relevant cognitive operations) elements of the FPM task.

**Method**

The methods of Experiment 3 were very similar to those of Experiment 2 with the exception that the recognition task contained memory load category names instead of memory load items (e.g., *Bird* instead of *Robin*). Both remember and forget categories will be used as well as novel categories to serve as a baseline reference. Each stimulus type in the recognition task was represented by 18 category names for a total of 54 yes/no recognition decisions. For the comparison phase, the remember, forget and neutral categories were counterbalanced resulting in six versions of the experimental task. The counterbalancing served to control for any stimulus effects. 18 memory loads and corresponding comparison phases were completed by each participant before moving on to the recognition phase.

If a clear a difference between the FPM effect and categorical recognition is found then it will provide strong support against conceptual activation as an explanation
for the FPM effect. In such a case further investigation of FPM is still needed to find its underlying mechanism.

**Participants.** The participants in Experiment 3 were 51 undergraduate education majors. Participation in Experiment 3 was compensated with course credit. Six of the participants were males and 45 were females. Their median age was 20 years old (R = 5).

**Results**

Similar to Experiments 1 and 2, two repeated-measures ANOVAs were used to analyze the data from Experiment 3. The first repeated-measures ANOVA was used to measure the FPM effect during the category-comparison phase of the experiment. The second repeated-measures ANOVA was used to measure the recognition accuracy for categories between stimulus types. See Figure 4 for a graphical depiction of the comparison and recognition data.

Table 7 lists accuracy and latency for each comparison type. To examine the effects of stimulus type during the category comparison phase of the experiment a repeated measures ANOVA was conducted with two orthogonal contrasts. The first contrast compared the average speed between the memory load category comparisons to the neutral category comparisons $F(1,50) = 27.96, MSe = 71.90, p < .001, \eta^2 = 0.36$. The second contrast compared the remember category comparisons to the forget category comparisons $F(1,50) = 4.13, MSe = 119.42, p = .047, \eta^2 = 0.076$. 


Table 7.

Means and Standard Deviations of Category Comparison Accuracy and Reaction Time by Category Type Exp. 3

<table>
<thead>
<tr>
<th>Comparison Type</th>
<th>Accuracy</th>
<th>Reaction Time (msecs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Remember</td>
<td>.91</td>
<td>.08</td>
</tr>
<tr>
<td>Forget</td>
<td>.89</td>
<td>.08</td>
</tr>
<tr>
<td>Neutral</td>
<td>.84</td>
<td>.08</td>
</tr>
<tr>
<td>Overall</td>
<td>.88</td>
<td>.06</td>
</tr>
</tbody>
</table>

Descriptive statistics for the recognition phase is listed in Table 8. A second repeated-measures ANOVA was conducted to analyze the recognition data. A significant main effect was detected between stimuli types remember, $M = .83$ ($SD = .02$), forget, $M = .62$ ($SD = .03$), and neutral, $M = .83$ ($SD = .02$), $F(2,100) = 22.75$, $MSe = .03$, $p < .001$, $\eta^2 = 0.31$. Pair-wise comparisons showed that recognition accuracy was significantly worse for the forget categories compared to the remember categories, ($t (50) = -7.31$, $p < .001$), and novel categories ($t (50) = -4.56$, $p < .001$). There was no significant difference between the remember and neutral categories, ($t (50) = .052$, $p = .96$). A calculation of d-prime was also included to check for response bias during the recognition task (see Table 9).
Figure 4. A) Mean speed (i.e., correct responses per minute) by category comparison type from Experiment 3. B) Mean accuracy by recognition type from Experiment 3. Error bars are equal to ±1SE.
Table 8

**Means and Standard Deviations of Recognition Accuracy for Exp. 3**

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
</tr>
<tr>
<td>Remember</td>
<td>.83</td>
</tr>
<tr>
<td>Forget</td>
<td>.62</td>
</tr>
<tr>
<td>Novel</td>
<td>.83</td>
</tr>
<tr>
<td>Overall</td>
<td>.76</td>
</tr>
</tbody>
</table>

Table 9

**d-prime by Stimulus Type for Exp. 3**

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>$d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>1.91</td>
</tr>
<tr>
<td>Forget</td>
<td>1.26</td>
</tr>
</tbody>
</table>

**Discussion**

Following Experiments 1 and 2 there was a question as to whether perhaps the FPM affect seen during the comparison phases was in fact due to residual activation in the categories themselves as opposed to just the memory load items. Experiment 3 was designed to test the hypothesis that using category names in the recognition task instead
of memory load items would yield similar recognition results from Experiments 2 and 1. The results of Experiment 3 supported the hypothesis that the FPM affect was not dependent upon declarative maintenance of the categories. The results of the Experiment 3 showed that recognition for the forget categories was significantly less than recognition of the remember categories. However, it is important to note that a significant difference existed between the facilitation of the forget category comparisons and remember category comparisons. This result is unique to experiment 3. In experiments one and two no significant difference existed between the speeds of category comparisons for remember and forget items.

A series of meta-analyses comparing the effect sizes between the three experiments was conducted in order to reconcile the subtle differences found between the comparison phases of each experiment.

**Continually Cumulating Meta-analyses**

Two continually cumulating (Braver, Thoemmes, & Rosenthal, 2014) meta-analyses were conducted to clarify effects from the three experiments. They examine the relationships between the stimuli types used in the category comparison phases across the three studies.

The first meta-analysis was meant to clarify the relationship between the remember and forget category comparisons across all three studies. Recall that the results from experiment 1 showed no significant difference in speed between remember and forget category comparisons. However, a significant difference was found between remember and forget category comparisons in experiment 3. A meta-analysis of the
difference between remember and forget category comparisons across experiments 1, 2, and 3 revealed that pooled Cohen’s $d = .15$, $p = .21$; $Q = .95$, $p = .62$, and $I^2 = .0$. This analysis shows that taken together the three experiments do not demonstrate a significant difference in speed between remember and forget category comparisons.

The second meta-analysis examined the relationship between the forget and neutral category comparisons across the three experiments. Recall that experiments 1 and 3 found significant facilitation of forget category comparisons over neutral category comparisons but experiment 2 did not. A meta-analysis of the speed difference between forget category comparisons and neutral category comparisons revealed that pooled Cohen’s $d = .36$, $p = .004$; $Q = 1.48$, $p = .48$, and $I^2 = .0$. As a series, the three experiments demonstrate a small but significant facilitation of forget comparisons over neutral comparisons.

The meta-analyses were conducted using a spreadsheet utility designed by Sibley (2008). Descriptions of the relative magnitude of Cohen’s $d$ effect sizes were adopted from Cohen (1988).
CHAPTER IV
GENERAL DISCUSSION

It has been hypothesized that the FPM effect is predominately procedural in nature. It was the general goal of the current investigation to test this hypothesis by dissociating the declarative and procedural elements relevant to the FPM effect. Three experiments were conducted in pursuit of this goal. Each of the three experiments, utilizing a DF paradigm, demonstrated a relative lack of recognition for forget items and categories compared to remember items and categories. Interestingly, the categorization of those same forget items, as is assumed to occur following the forget instruction, lead to facilitation in forget category comparisons. The very items that participants struggled to recognize were critical in producing the demonstrated FPM effect. It is suspected, therefore, that the mechanism underlying the FPM effect and that needed for the recognition task are qualitatively different. The evidence in this investigation supports the notion that FPM relies on procedural memories for categorization whereas the recognition task relies on episodic declarative memories for specific items and categories. If recognition relies on declarative memory, recognition failure in the presence of an FPM effect is evidence that FPM is less dependent or even independent of those same declarative elements. The results fit well into the procedural and declarative distinctions described in ACT-R.

Skill development in ACT-R occurs when new production rules (procedures) are acquired and by the strengthening of existing productions. In the FPM task the participant
must use a production such as *determine if [exemplar] is a [category]*. That is, after exposure to the memory load items, the participant is instructed to remember the items of one of the categories and forget the items of the other category. It is assumed then that the participant mentally reviews and categorizes the memory load items. The categorization of the memory load items is the procedural element that instantiates the FPM effect. The categorization procedures from the memory load are then repeated and thus facilitated during the category comparison phase. Therefore, the facilitation, which is presumably due to the strengthening of an existing procedure, can be characterized as skill development.

Anderson (1982) claimed that the first use of a procedure creates a new production rule allowing for strengthening of the rule upon subsequent use, following a typical learning curve. However, Anderson (1993) later discounted this explanation stating that it should require many instances of a production rule to become efficient, simply because that is the nature of a production rule. As Anderson (1993) stated, “…it seems more likely that it would require many trials to compile an efficient procedure, which is what a production really is.” (p. 154). Conceivably a production rule is not fully efficient after one use, but it is certainly inefficient on its first use.

The FPM task, although unique in its structure, does not represent a new production to participants. Rather, the procedures used in the FPM task are likely well learned. Item categorization is fundamental to human learning, and cognitive development. Put differently, human beings cognitive development is highly related to concept learning and categorization. Furthermore, on an almost constant basis individuals
are categorizing and categorization has even been associated with the basis of cognition (Harnard, 2005). Therefore, the general procedure used in the FPM tasks is not a new one. What is new is that within the context of the FPM task, specific exemplars and categories are activated in declarative memory but it is the procedure of identifying exemplars as belonging within a specific category that is strengthened. Put differently, the procedure of [exemplar] is a [category] becomes more efficient. Therefore, although the declarative representations of the problem are active during the categorization procedures, continued maintenance of declarative activation is not necessary for the efficient reuse of the procedure. The procedure remains facilitated regardless of whether the relevant declarative nodes have become inactive.

The procedural account of FPM has interesting implications for explanations of complex cognition. Indeed measures of FPM have been shown to account for unique variance in complex cognitions, including reasoning and reading comprehension, above and beyond that of working memory capacity (WMC) measures (Was, Dunlosky, Bailey & Rawson, 2012; Was & Woltz, 2007). More commonly, individual differences in complex cognition are predicted from measures of WMC (Conway, Kane & Engle, 2003). However, the limits of WMC struggle to account for the large amounts of information often required for complex cognition (Baddeley, 2012; Cowan, 1988; Erikson & Kintsch, 1995). Current estimates of WMC are only four bits of information (Cowan, 2001). Therefore, it seems clear that working memory (WM) is not alone in accounting for complex cognition. In fact, several theorists suggest that WM must have
efficient access to LTM. In this regard, FPM, which is thought to be procedural in nature, may be a mechanism by which WM efficiently interacts with LTM.

The declarative elements in a comprehension task will activate relevant procedures. Those procedures are then relatively more efficient upon subsequent use without actually having to maintain the declarative elements that initially instantiated them. The facilitated procedures then allow for efficient processing of relevant information without overloading WM.

This investigation has provided evidence that the facilitation of procedural memories is to some degree independent from relevant declarative memories. Namely, continued FPM does not necessitate continued maintenance of the declarative elements required to instantiate the procedures. Put differently, participants may have both explicit awareness and implicit learning or memory of the task, as described by Segar (1994), without continuing awareness of the specific items (cf. Schacter, 1992).

An alternative explanation for the results is based on Oberauer’s (2009) procedural working memory perspective. Recall that Oberauer described the bridge as activated procedures from long-term memory. The procedures are activated by relevant declarative elements in the region of direct access. A single declarative element activates multiple procedures, then task characteristics (e.g., goals) determine which procedure is then applied. Facilitation is defined by using a procedure in the bridge rather than having to search long-term memory for an appropriate procedure. During the FPM task, the procedure determine if X is a Y is retrieved from LTM into the bridge by the declarative elements (i.e., exemplars) in the memory load of the task. Later, when making category
comparisons, *determine if X is a Y* remains in the bridge, but the original declarative elements do not necessarily remain in the region of direct access. Indeed, our results indicate it is not necessary for those elements to remain for the procedure to still be in the bridge.

**Conclusion**

While the current investigation has potentially important implications for models of human cognition, there remain several questions about FPM. For example, it seems appropriate to have access to relevant long term-memory when engaging in a complex cognitive task such as comprehension but what purpose is served by having procedures facilitated up to and beyond 24 hours as was demonstrated by Was (2010)? Although there are many questions, the current investigation clearly indicates dissociation between the declarative and procedural aspects of the FPM task, suggesting that the active maintenance of declarative memory elements is not necessary for the facilitation of cognitive operations.
REFERENCES
References


