MECHANISMS BEHIND DIRECTED FORGETTING: EXPLORING THE SELECTIVE REHEARSAL AND ATTENTIONAL INHIBITION ACCOUNTS USING THE DOUBLE-ITEM METHOD PARADIGM

by

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Abstract

In an item-method directed forgetting paradigm, participants are instructed to remember some items from the study list and forget others. On a subsequent memory test, participants demonstrate better memory for remember items than forget items. This difference in performance is referred to as the directed forgetting effect. Two major accounts have emerged to investigate the underlying mechanisms for this effect. The selective rehearsal account states that the elaborative rehearsal of remember items followed by the passive decay of forget items is the primary process of directed forgetting. The attentional inhibition account suggests that the directed forgetting effect arises from the inhibition of forget items, which allows for remember items to be further processed. The current thesis explored the extent to which both of these accounts may contribute to directed forgetting. We used a novel variant of the paradigm where we presented participants with unrelated word pairs: On pure trials, participants were instructed to remember or forget both words; on mixed trials, participants were instructed to remember one word but forget the other. In Experiment 1, we found evidence in support of a selective rehearsal process with no evidence for passive decay or active inhibition of forget items. In Experiment 2, we introduced a novel neutral condition, and replicated and supported our findings of Experiment 1. Our findings suggest that selective rehearsal is the primary account of directed forgetting but that it must be modified to account for the fact that selection of information to be rehearsed is flawed.

Keywords: directed forgetting, selective rehearsal, attentional inhibition, memory

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DEDICATION PAGE

In the loving memory of Dr. Douglas John Kerr Mewhort,

Thank you for teaching me never to give up

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CHAPTER 1: INTRODUCTION

1.1 FORGETTING

Our ability to manipulate the contents of our memory is an essential component of a successful human memory system. Every day, we receive an endless amount of sensory information; some of which is relevant, but much of which is irrelevant, to our goals. To achieve our goals, we must deploy filtering mechanisms to differentiate between what is relevant and what is irrelevant. For example, we may store a new lock's combination in memory because we know that we will need that information the next time we want to open the lock. We may wish to retain the crucial details of goal-relevant information because we are more likely to need it at some point in our lives. However, we may wish to remember less of irrelevant or outdated information because it may negatively impact our daily functioning.

Consider a grocery shopping scenario in which in the morning, you generate a mental grocery list of the food you need. The memory challenge is that while at the grocery store, you must not only successfully recall your mental grocery list generated that morning, but you must also prevent any old mental grocery lists from intruding and interfering with your memory. In such scenarios, simultaneously remembering one memory (this morning's grocery list) and forgetting other memories (previous grocery lists) is essential for successful task completion (bringing home the correct groceries), highlighting that forgetting is actually a crucial aspect of human memory.

The benefits of forgetting are not often acknowledged, with more focus on forgetting as a failure of memory when we are unable to remember information needed for our goals. In general, forgetting is defined as the inability to retrieve or recall previously encoded information from long-term memory. Certainly, failures to remember negatively impact our lives, but we should not disregard the detrimental aspects of the inability to forget. Clearly, remembering every detail of every event we have been exposed to would quickly overload our limited capacity memory system and interfere with normal functioning. William James (1892, pp. 300) wrote that, “forgetting is as important a function as remembering”, and Colin MacLeod (1998, pp.1) wrote, “we need to forget, just as we need to remember”. As with James and MacLeod, we recognize that it is necessary to study both the process of remembering and forgetting, as they are both critical to any information processing system.

1.2 INTENTIONAL FORGETTING

We can distinguish between two types of forgetting: unintentional forgetting and intentional forgetting. Unintentional forgetting refers to the loss of memories with no conscious goal to forget. *Intentional forgetting*, then refers to situations in which we consciously control which information we want to forget. Intentional forgetting is important as it can be used to prevent irrelevant information from interfering with relevant information. We see many examples of intentional forgetting in our daily lives. For example, we want to intentionally forget a traumatic or emotional memory. We may want to intentionally forget when a professor presents incorrect information in a lecture, when a friend provides the wrong directions to an address, or when a judge orders the jury to disregard information during a trial (Thompson & Fuqua, 1998). Regardless of the scenario, intentional forgetting is a core part of our memory system.

Such intentional control over our memories has received substantial interest in the field of cognitive psychology. Intentional forgetting was first studied by Bjork and colleagues (Bjork, LaBerge, & LeGrand, 1968). In their first experiment, participants were presented with words with different backgrounds, with the backgrounds cueing whether a participant should remember or forget the item. For example, the colour of the background would change to red to indicate that the participant should forget the word presented. They predicted that an intention to forget should not affect memory recall but were surprised to find that participants were indeed able to forget on demand. As captured in MacLeod's (1998) review of intentional forgetting, the experiments of Bjork and colleagues led to an era that explored the mechanisms behind intentional forgetting (Bjork, 1970; Woodward & Bjork, 1971; Epstein, Massaro, & Wilder, 1972; Geiselman & Bagheri, 1985), developed novel paradigms to study intentional forgetting (Jongeward, Woodward, & Bjork, 1975; MacLeod, 1975; Geiselman & Bagheri, 1985), and pushed the boundaries of the stimuli used to study intentional forgetting (Geiselman & Riehle, 1975; Roediger & Tulving, 1979; Golding & Keenan, 1985; MacLeod, 1989).

Intentional forgetting has been applied to a number of domains, including industrial/organizational psychology (Ellwart et al., 2019; Kluge & Gronau, 2018) and artificial intelligence (Timm et al., 2018; Beierle & Timm, 2019). It also has clinical applications; it has been applied to trauma (Epstein & Bottoms, 2002; Geraerts & McNally, 2008; Blix & Brennan, 2011; Küpper, Benoit, Dalgleish, & Anderson, 2014), depression (Joormann, Hertel, Brozovich, & Gotlib, 2005), adult attention-deficit/hyperactivity disorder (White & Marks, 2004), obsessive-compulsive disorder (Demeter, Keresztes, Harsányi, Csigó, & Racsmány, 2014; Wilhelm, McNally, Baer, & Florin, 1996), and post-traumatic stress disorder (McNally, Metzger, Lasko, Clancy, & Pitman, 1998). It also has been applied to a number of participant populations including children (Aslan, Staudigl, Samenieh, & Bäuml, 2010; Howe, 2002; Lehman & Bovasso, 1993) and older adults (Sego, Golding, & Gottlob, 2006; Hogge, Adam, & Collette, 2008; Zacks, Radvansky, & Hasher, 1996). Intentional forgetting has further demonstrated its relevance to the study of autobiographical memories (Joslyn & Oakes, 2005; Barnier et al., 2007), false memories (Marche, Brainerd, Lane, & Loehr, 2005; Kimball & Bjork, 2002; Seamon, Luo, Shulman, Toner, & Caglar, 2002), and everyday human behaviours (Li, Wang, & Han, 2017; Sahakyan & Foster, 2009), like grocery shopping.

Intentional forgetting is often studied in the laboratory using either the *item-method* or *list-method* directed forgetting paradigms (for a review, see MacLeod, 1998). In the item-method paradigm, participants study a series of items one at a time. Each item is immediately followed by a cue to remember or forget the previous item. The items followed by an instruction to remember are referred to as the *R items* and those followed by an instruction to forget are referred to as the *F items*. Participants are explicitly told that they should forget the items followed by an F cue, because their memory for these items will not be tested. However, at a subsequent memory test, participants are tested on both the R and F items. The test phase typically consists of a free recall or old/new recognition memory test, although some studies have employed other tests, including a 2-alternative forced choice test (Ahmad, Tan, & Hockley, 2019; Montagliani & Hockley, 2019), think/no-think paradigm (Noreen & de Fockert, 2017), and stop signal paradigm (Hourihan & Taylor, 2006; Fawcett & Taylor, 2010). The key finding is that participants typically recall or recognize more R items than F items, with this difference in memory performance referred to as the *directed forgetting effect* (Bjork, 1972; for a review, see MacLeod, 1998).

In the list-method paradigm, participants receive two lists of items, each separated into a different block. Following the List 1 presentation, participants are told to either remember or forget all items from the previous list. If participants are told to remember List 1, they are told to continue remembering the List 2 as well. If participants are told to forget List 1, they are told that the first list was presented by accident and that, they should instead try to remember List 2. At a subsequent memory test, participants are tested on both the first and second list of items. A directed forgetting effect is observed where receiving a forget instruction after List 1 impairs memory of List 1 items and enhances memory of List 2 items (for a review, see MacLeod, 1998).

1.3 THEORETICAL ACCOUNTS OF DIRECTED FORGETTING

While both item-method and list-method directed forgetting paradigms are commonly used, researchers have suggested that they examine different aspects of intentional forgetting (Basden & Basden, 1996, but see, Sheard & MacLeod, 2005). The item-method is used to study intentional forgetting at encoding, which has been proposed to occur by exerting top-down control to limit information access to long-term storage (Fawcett & Taylor, 2008; Basden, Basden, & Gargano, 1993). In contrast, the list-method is employed to study intentional forgetting at retrieval (for a review, see Anderson & Hanslmayr, 2014). In the current study, we employed the item-method paradigm as our focus was to examine intentional forgetting at encoding.

Two accounts of directed forgetting have emerged to explain intentional forgetting at encoding. According to the *selective rehearsal* account, upon item presentation, but prior to cue presentation, participants retain each item in working memory via maintenance rehearsal (Greene, 1987) while anticipating the memory instruction. Following instructions to remember, participants elaboratively rehearse the item to encode it at a deeper level in memory. Following instructions to forget, participants terminate the further rehearsal of the item and allow the item's representation to decay from memory (Basden, Basden, & Gargano, 1993). Research comparing the memorial representations of R and F items in long-term memory demonstrated that participants recognize more specific or perceptual details of R items than F items regardless of whether the memory stimuli are words (Montagliani & Hockley, 2019; Lee, Lee, & Fawcett, 2013), complex pictures of scenes and objects (Ahmad, Tan, & Hockley, 2019), abstract images (Fawcett, Lawrence, & Taylor, 2016), or event segments (Fawcett, Taylor, & Nadel, 2013). The fact that specific or perceptual details are remembered better for R than F items confirms that elaborative encoding is engaged for R items and not F items. This is in line with the selective rehearsal account as it proposes that participants segregate the R and F items, so that R items can be selectively rehearsed, while the F items passively decay.

Golding, Long, & MacLeod (1994) provided evidence in favour of the selective rehearsal account when they investigated the influence of semantically related words versus semantically unrelated words on directed forgetting. Participants viewed one item at a time where each item was followed by an R or F instruction. On some trials, words from earlier on the list were semantically related to the words from later on the list (e.g., crab – leg). When the first word of the pair was followed by an R cue but the second was followed by an F cue, memory for both of words was similar to when both words were followed by an R cue. Thus, when semantically related, participants were predisposed to rehearse the second word from the pair, even when instructed to forget that second word.

More recently, Hourihan, Ozubko, & MacLeod (2009) observed a significant directed forgetting effect even when participants were unable to name the stimuli. They presented participants with symbols that were derived from modifying the Wingdings font and provided a verbal suppression task to reduce any residual verbal rehearsal. This task was designed to produce items that were not easily named and to prevent verbal rehearsal. Nonetheless, Hourihan et al. found a directed forgetting effect demonstrating that selective rehearsal does not depend on the ability to verbally rehearse the item. Instead, nonverbal or visual rehearsal was sufficient to produce a significant directed forgetting effect.

Given that the selective rehearsal account purports that directed forgetting arises from the further rehearsal of R items and the passive decay of F items, Bancroft, Hockley, & Farquhar (2013) manipulated the duration for which participants could execute these processes. With increased cue duration, they expected that the additional time would benefit the rehearsal of R items more than the F items, because participants should be able to quickly ignore the F items regardless of the cue duration. Across four experiments, they varied cue duration (Experiment 1: 300-900ms; Experiment 2: 300-900ms; Experiment 3: 1-3s; Experiment 4: 2-6s). They observed a significant directed forgetting effect with each cue duration. Furthermore, as expected, they found that increasing cue duration benefited performance for R items. However, they also found similar increases in memory for F items with increasing cue duration. While the benefit to the R items with cue duration was attributable to the selective rehearsal account, they were surprised that the recognition of F items increased with cue duration. Because this finding that F item recognition increases with cue duration was not consistent with the passive decay of F items, they proposed that, there may be two processes at play in directed forgetting. They suggested that the termination of the processing of F items could only be successfully achieved by a specific timepoint. In other words, forgetting is a time-dependent processes that, if not executed at a specific timepoint after encoding, it may be difficult to stop the continued processing of an unwanted item.

Along the same lines, Hourihan and Taylor (2006) found that the successful completion of forgetting processes relied on the duration between the item and cue presentation. They incorporated a stop-signal paradigm within the item-method paradigm. Participants were told to commit all items to memory, unless they received an F instruction. These instructions encouraged participants to perform elaborative rehearsal immediately at item presentation, rather than maintenance rehearsal to retain the item while waiting for a memory cue. Hourihan and Taylor manipulated the stimulus-onset asynchrony (SOA), where the duration between the item and the F cue varied between 1 and 10 s. They found that participants more successfully exerted control over the item following F instructions for shorter SOAs (e.g., 1s) compared to longer SOAs (e.g., 10s). Consistent with the interpretation of Bancroft et al. (2013), Hourihan and Taylor[1] proposed that forgetting could be successful for short encoding durations, but for longer durations, the item becomes too firmly entrenched in memory and not susceptible to forgetting processes. Taken together, these studies converge in concluding that R items benefit from additional rehearsal. However, there remains uncertainty regarding the processes, if any, that are applied to F items.

While most researchers accept the claim of the selective rehearsal account, some researchers have questioned the validity of the claim that F items simply passively decay (Fawcett & Taylor, 2008; 2012). As an alternative to the selective rehearsal explanation for the fate of F items, Zacks and Hasher (1994) provided an *attentional inhibition* account which proposed that forgetting is an active cognitive process. They suggested that with the presentation of an F cue, participants engage active mechanisms to suppress the previous item. These mechanisms involve the cognitively demanding withdrawal of attention from the representation of F items. This account predicts then that the directed forgetting effect arises from the initial inhibition of the F items, along with the additional processing of R items. However, Zacks and Hasher initially presented the attentional inhibition account with no empirical evidence to

[1] It is important to note that Hourihan and Taylor (2006) concluded their results were the most consistent with the attentional inhibition account, and thus, had conflicting conclusions to Bancroft, Hockley, and Farquhar (2013). While these two studies agreed that F instructions are not successfully implemented after a certain time point, they differ in their viewpoints of the accounts of directed forgetting. Nevertheless, both studies support that forgetting is dependent on time.

support their claims. To examine an inhibitory mechanism of directed forgetting, they later compared the magnitude of the directed forgetting effect between older and younger adults (Zacks, Radvansky, & Hasher, 1996). Older adults showed a smaller directed forgetting effect than younger adults. In comparison with younger adults, older adults recalled and recognized more F items, suggesting that they had more difficulty implementing inhibitory processes. They concluded that these results supported the attentional inhibition account because older adults had more difficulty suppressing F items than younger adults. However, their interpretation should be examined with caution because they did not control for confounds such as age-related difficulties in cognition (Fawcett & Taylor, 2008).

Over the past few years, Taylor and colleagues have supported the attentional inhibition account by providing stronger manipulations than Zacks and Hasher (1994) and Zacks et al. (1996). Taylor (2005) incorporated an inhibition of return (IOR; Posner & Cohen, 1984) manipulation in the item-method paradigm to further examine the inhibition account that active attentional withdrawal from F items plays a role in directed forgetting. Participants studied one word at a time with words presented either to the left or right of a central fixation point. Each word received an auditory R or F instruction immediately after its presentation. After 1200 ms, participants viewed a visual target that appeared either in the same location as the word or in the opposite location. The location of the target varied with equal probability. Participants were asked to indicate the location of the target by making a speeded button press response. This experimental design was based on an IOR paradigm, in which the standard finding is that participants respond more slowly to targets that appear in the same location as the previous peripheral onset cue, compared to the targets that appear in the opposite location (Posner & Cohen, 1984). This effect implies that attention is more readily withdrawn from the location of the initial peripheral cue onset. In Taylor's experiment, words served as the peripheral onset cues and attentional resource deployment following R and F instructions were compared. Taylor found a greater magnitude of IOR after F instructions than R instructions, indicating that F cues produced a greater withdrawal of attention from the cued location compared to R cues. Her findings were also replicated in Fawcett and Taylor (2010, Experiment 2), where participants had significantly longer response times to recognize a target in an IOR paradigm following F instructions than R instructions. These findings were inconsistent with the selective rehearsal account because the cognitively demanding shift of attentional resources after F instructions challenged the passive decay of forgetting.

Fawcett and Taylor (2008) also provided further evidence for the attentional inhibition account by implementing a probe detection task in the item-method paradigm. They presented a probe immediately following R or F instructions to observe how readily attention is withdrawn after memory instructions. Participants studied one item at a time, with each followed by either a cue to remember or forget the previous item. Following cue presentation, participants were presented with a probe where they provided a speeded button press response to indicate detection of the probe. Participants took longer to respond to probes following F cues compared to probes following R cues. These findings were in line with Fawcett and Taylor's predictions that implementation of forget processes was more cognitively demanding than implementation of remember processes. That is, Fawcett and Taylor concluded that forgetting is not passive, but actually an effortful process that requires the active withdrawal of attentional resources such that forgetting may even be more demanding than remembering.

Fawcett and Taylor (2012) replicated their previous findings by implementing a task called speeded colour discrimination task—a task more cognitively demanding than a probe detection task. Participants were presented with study words one at a time, with each followed by an R or F cue. Following the cue presentation, a probe word appeared on the screen. On half of the trials, the probe word was blue, and on the other half, the probe word was pink. Participants were trained to respond to the colour of the probe word and were instructed that they did not need to remember the colour of the probe words, as they would not be tested on it. Their intention for this manipulation was to test the extent to which participants encoded incidental memory for each probe word as a function of the memory cue. Fawcett and Taylor found that participants were slower to respond to the colour of the words following F instructions than R instructions. In addition, their test of incidental memory for the probe words revealed that incidental memory for probe words that were preceded by F cues was worse than incidental memory for probe words that were preceded by R cues. Taken together, these findings converge on the conclusion that forgetting is an effortful process that requires the cognitively demanding act of withdrawing attention away from irrelevant information. This attentional inhibition account then contrasts with the selective rehearsal account, which proposes that forgetting is a passive process.

In summary, the two main theories to account for the directed forgetting effect agree on the fate of the R items. That is, participants selectively choose the R items to further encode them in memory. This is performed by elaboratively rehearsing these items, producing stronger representations in memory. However, these two theories disagree on the fate of the F items. According to the selective rehearsal account, the termination of rehearsal of the F items accounts for the decreased memory performance for F items. Without the additional processing of F items, these items simply decay from memory, with no further mechanisms acting on their representations. The selective rehearsal account then suggests that the successful segregation of

R and F items allows for the deployment of different rehearsal techniques that then produce directed forgetting. According to the attentional inhibition account, the presentation of instructions to forget engages an active withdrawal of attentional resources away from the F items. In contrast to the selective rehearsal account, these weaker representations arise from an active and effortful process to keep F items from further encoding processes. The attentional inhibition account suggests that the directed forgetting effect is best explained by the initial inhibition of the F items, followed by further processing of R items.

1.4 CURRENT EXPERIMENTS

Over the past few years, several researchers have modified the item-method directed forgetting paradigm by implementing novel memory tests (Montagliani & Hockley, 2019; Ahmad, Tan, & Hockley, 2019; Noreen & de Fockert, 2017; Lee, Lee, & Fawcett, 2013; Fawcett & Taylor, 2010; Hourihan & Taylor, 2006), incorporating additional tests within the study phase (Fawcett & Taylor, 2012; Fawcett & Taylor, 2008), using semantically associative items (Hockley, Ahmad, & Nicholson, 2016; Marevic & Rummel, 2017; Golding, Long, & MacLeod, 1994), event-segmented videos as study items (Fawcett, Taylor, & Nadel, 2013), complex pictures (Ahmad, Tan, & Hockley, 2019; Fawcett, Lawrence, & Taylor, 2016; Hauswald & Kissler, 2008), faces (Quinlan & Taylor, 2014), and environmental sounds and spoken words (Ensor, Bancroft, & Hockley, 2019). Such variations to the item-method paradigm have provided substantial insights to our understanding of the mechanisms behind directed forgetting. Inspired by this line of research, our present thesis also introduced a novel variant of the item-method directed forgetting paradigm. In the original item-method paradigm, there is only one process, either remember or forget, operating during any single trial. However, this is an unrealistic representation of daily cognitive processes which require simultaneous remembering of task-relevant information and forgetting of irrelevant information. The purpose of our variant then was to investigate directed forgetting in a way that may better capture this challenge of simultaneously having to remember some information while forgetting other information. Furthermore, we examined the extent to which the two accounts of directed forgetting, selective rehearsal and attentional inhibition, provide a better account within our more ecologically-valid implementation of directed forgetting.

By utilizing a novel item-method paradigm, the purpose of the current thesis is threefold: 1) to elucidate the processes underlying remembering and forgetting in directed forgetting by exploring a novel paradigm in which cognitive resources are in competition, 2) to expand our understanding of the two major accounts of item-method directed forgetting: selective rehearsal and attentional inhibition, and 3) to investigate whether forgetting is a passive or active process.

In our novel paradigm, participants studied two unrelated words at a time, compared to the original paradigm where they study one item at a time. Following the presentation of the two study words, two cues were presented one for each study word. In the *pure-cue* condition, the two study words received the same cues (two Rs or two Fs). Words in this condition that were followed by an R instruction were referred to as *pure-cue R* words. Words in this condition that were followed by an F instruction were referred to as *pure-cue F* words. In the *mixed-cue* condition, one study word was cued with an R and one was cued with an F, instructing the participant to remember the R-cued word, but forget the F-cued word. The words that were in the mixed-cue condition that were followed by an R instruction were referred to as the *mixed-cue R* words. The words that were in the mixed-cue condition that were followed by an F instruction were referred to as the *mixed-cue F* words.

Our mixed-cue condition was key as it allowed us to examine a situation in which remembering and forgetting processes are in competition for cognitive resources. In Experiment 1, we were able to test the ability to remember and forget simultaneously, and to determine the extent that active rehearsal, passive decay, and attentional inhibition contribute to directed forgetting. In Experiment 2, we included a baseline condition called the *neutral* condition, in which items received minimal processing and were not cued to be remembered or forgotten. The goal for Experiment 2 was to first determine whether we could replicate the findings of our Experiment 1, and second, to provide converging evidence as to the extent to which selective rehearsal, passive decay, and attentional inhibition contribute to directed forgetting.

CHAPTER 2: EXPERIMENT 1

In the study phase of Experiment 1, for each trial, participants were presented with two unrelated words at a time, each followed by either an instruction to remember both words (*pure-cue R* condition), forget both words (*pure-cue F* condition), or remember one (*mixed-cue R* condition) but forget the other word (*mixed-cue F* condition). Following the presentation of all study words, participants completed an old/new recognition test that presented pure-cue R, pure-cue F, mixed-cue R, and mixed-cue F items as well as an equal number of *foil* words. Performance on this subsequent memory test was used to assess the magnitude of the directed forgetting effect in the pure-cue and mixed-cue conditions and the memory for the pure-cue R, pure-cue F, mixed-cue R, and mixed-cue F words. We aimed to test the following four hypotheses:

For our Hypothesis 1, we explored whether it is possible for participants to control their encoding processes when remembering and forgetting are simultaneously required. If this is possible, we predicted to find a directed forgetting effect in the mixed-cue condition. Specifically, we predicted that memory for mixed-cue R words would be greater than memory for mixed-cue F words.

For our Hypothesis 2, we explored the extent to which selective rehearsal explains directed forgetting. Assuming that the process of elaborative rehearsal to facilitate memory of R items demands cognitive resources, then on each mixed-cue trial, participants should be able to focus rehearsal on a single word, whereas in the pure-cue R condition, both words should require rehearsal. Thus, we hypothesized that if selective rehearsal is employed, then memory for mixed-cue R words should be better than memory for pure-cue R words.

For our Hypothesis 3, we examined the role of passive decay in forgetting. Assuming passive decay does not depend on cognitive resources, we expect that passive decay of two items would be as efficient as passive decay of a single item. That is, if passive decay is the only process that drives memory for F words, then memory for mixed-cue F words and pure-cue F words should be relatively the same.

For our Hypothesis 4, we explored the extent to which the attentional inhibition account predicts the underlying processes for F words. Assuming that there is an active inhibitory mechanism and that this process demands cognitive resources, then on each mixed-cue trial, participants would be able to focus inhibition on a single word, whereas in the pure-cue F condition, both words would require inhibition. Thus, we hypothesized that if active inhibition is employed, then memory for mixed-cue F words should be worse than memory for pure-cue F words.

Method

Participants

Fifty-two participants were recruited from the undergraduate subject pool at Queen's University. Participants were tested individually in experimental rooms with each session lasting no longer than 60 minutes. Participants received a course credit or a ballot in a monetary draw for a $50 gift card to Starbucks. All participants reported no previous participation in other directed forgetting studies, normal to corrected-to-normal vision, and fluency in the English language. Three participants were excluded for not following experimental instructions. Two participants were excluded due to below-chance performance. This resulted then in a total of 47 participants included in the analyses.

We conducted a power analysis using Monte Carlo simulations in R Commander to determine the appropriate sample size required to obtain a power level of .80 in a repeated measures Analysis of Variance (ANOVA). We used an effect size of .34 which was calculated by averaging the reported effect size based on previous studies of item-method directed forgetting (Hockley, Ahmad, & Nicholson, 2016), and selective directed forgetting (Delaney, Nghiem, & Waldum, 2009). We intentionally used a conservative effect size, compared to other studies of directed forgetting which have also reported effect sizes between .6 - .8 (Hourihan & Taylor, 2006; Fawcett & Taylor, 2008; 2012). The power analysis showed that 47 participants were required to achieve a power of .80. Following the removal of our participants, our final sample size of 47 remained sufficient to reach the required power.

Apparatus and Stimuli

The experiment was programmed using MatLab 2018 software and was conducted on Windows PC computers equipped with 16-inch CRT monitors. Each computer included a standard keyboard and Sony noise-cancelling MDR-ZX110 headphones that played brown noise on a loop. All stimuli were presented on a plain white background. Experimental instructions before the study and test blocks were presented at the beginning of each phase in size 20 Times New Roman black font.

A total of 200 words were collected from the MRC Psycholinguistic Database (Coltheart, 1981), with Kuçera-Francis frequency values between 11 and 220, and familiarity, concreteness, and imageability ratings between 400 and 600. These ratings were selected based on a previous study by Bancroft et al. (2013). The study list consisted of 52 trials, with the first two trials at the beginning and two at the end serving as primacy and recency buffers. These 8 words presented for the 4 buffer trials were not included in the test phase. Because we presented two unrelated words at a time, the study list without including the primacy and recency buffers consisted of 48 trials of 96 words. We programmed custom software on MatLab to randomly assign the 96 study words to each of our conditions from the master word list of 200 words. We performed this randomization to provide equal opportunity for each word in the master list to be presented within our conditions. This random assignment produced 24 pure-cue R words, 24 pure-cue F words, 24 mixed-cue R words, and 24 mixed-cue F words. We performed the randomization separately for each participant at the beginning of their session to ensure unique stimulus combinations across our conditions. These randomizations were programmed according to the instructions provided by Taylor, Quinlan, and Vullings (2018).

The test phase consisted of 192 trials with a single word presented on each trial. The 192 trials consisted of 96 critical words from the study list (24 pure-cue R, 24 pure-cue F, 24 mixed-cue R, and 24 mixed-cue F) and 96 foil words that were not presented during the study phase. The presentation order of the test words was randomized for each participant.

Procedure

Practice Phase. The experimenter used a PowerPoint presentation and verbal instructions to familiarize participants with the different cue conditions. Participants were presented with example trials from each condition and were asked to explain to the experimenter what each cue indicated (e.g., if they saw an R after a word, they were to remember the previous word). The experimenter continued the practice phase until they felt confident that the participant understood the instructions.

Study Phase. Each trial began with the presentation of a fixation stimulus in the centre of the computer screen for 1 s. This fixation stimulus was followed by the presentation of two unrelated words for 4 s, with one word presented above and one below the fixation stimulus. The words were presented 125 pixels above and below the fixation stimulus. The words were followed by a 3 s presentation of two memory cues—one for each word and presented in the same positions as the words. For the pure-cue R trials, both memory cues were the letter *R* indicating that they should remember both words. For the pure-cue F trials, both cues were the letter *F* indicating that they should forget both words. For the mixed-cue trials, one cue was an F and one was an R, indicating they should remember the R-cued word, but forget the F-cued word. We included two forms of the mixed-cue trials: On half of the trials, the R cue was presented above the fixation stimulus and the F cue below, and on the other half, the F cue was presented above the fixation stimulus and the R cue below. This was to control for item presentation location that may impact participants' memory performance. Participants were told that their memory for only the R items would be tested on a subsequent memory test. Following cue presentation, the next trial began. The total duration of each study trial was 8 s. The schematic representations of each study trial for our four conditions are presented in Figure 1.

Test Phase. Immediately following the study phase, the experimenter provided both on-screen and verbal instructions for completing an old/new recognition test. Critically, participants were instructed that, contrary to what they were told during the study phase, they would be tested for their memory of both the R and F words. Test words were presented one at a time in the centre of the computer screen with black 35 Times New Roman font on a white background. Participants were instructed to indicate whether each word was old or new. An old word was defined as a word seen during the study phase, regardless of whether it was followed by an R or F cue. A new word was defined as a word that was not presented during the study phase. Participants provided the old responses by pressing the *z* key and the new responses by pressing the */* key on the computer keyboard. Participants did not receive feedback to their responses and the next test trial proceeded upon a response from the participant. Participants were informed that the experimenter was not testing the speed of their responses, but rather the accuracy of their responses. The order of the test words was randomized, with a different random order for each participant.

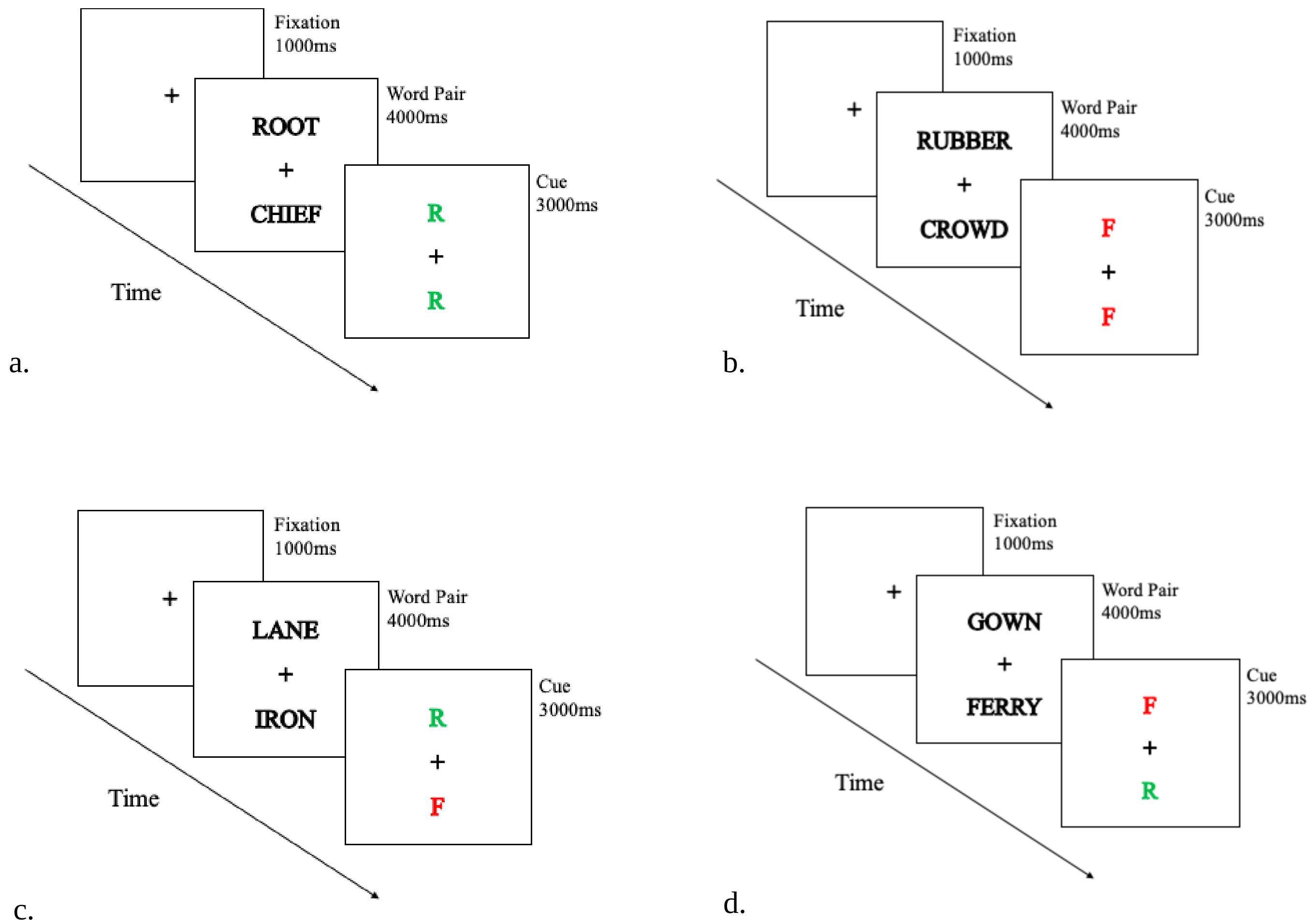

Figure 1. Schematic of a single study phase trial for the (a) pure-cue R condition, (b) pure-cue F condition, (c) mixed-cue condition, where the R cue was presented above the fixation stimulus and the F cue was presented below, and (d) mixed-cue condition, where the F cue was presented above the fixation stimulus and the R cue was presented below.

Results

For each participant, we calculated hit rates for each condition by dividing the number of words that were correctly identified as old by the total number of words in that condition. We calculated a collective false alarm rate for all experimental conditions by dividing the total number of new words that were incorrectly identified as old by the total number of new words presented. Finally, for each participant, we calculated corrected recognition scores for each condition, by subtracting their collective false alarm rate from their hit rate. Mean corrected recognition scores were then represented as the main dependent variable.

Mean corrected recognition scores for R and F items in the pure-cue and mixed-cue conditions are shown in Figure 2. Uncorrected hit rates are presented in Table 1 and show that memory did not approach ceiling. The mean false alarm rate to foils was 0.16. A 2 memory cue (R vs. F cue) x 2 item condition (pure-cue vs. mixed-cue condition) repeated-measures analysis of variance (ANOVA) was conducted on corrected recognition scores. There was a significant main effect of memory cue, $F(1,46) = 17.41$, $MSE = .144$, $p < .001$, $\eta^2_p = .274$, demonstrating the expected directed forgetting effect of better memory for R words than F words. The main effect of item condition was also significant, $F(1,46) = 117.44$, $MSE = .1.747$, $p < .001$, $\eta^2_p = .719$, showing that overall memory for the mixed-cue conditions was greater than that for the pure-cue conditions. The interaction was not significant, $F(1,46) < 1$. The lack of an interaction showed that the magnitude of the directed forgetting effect for the pure-cue and mixed-cue conditions did not differ. We calculated the magnitude of the directed forgetting effect by subtracting the corrected recognition scores for F words from the corrected recognition scores for R words. A paired samples *t*-test also confirmed that the magnitude of the directed forgetting effect for the pure-cue condition (*M* = .19, *SE* = .02) did not differ from that of the mixed-cue condition (*M* = .20, *SE* =.02), *t*(46) = .31, *p* = .755, *d* = .05.

We conducted two planned paired samples *t*-tests to compare mean corrected recognition scores for mixed-cue R words to pure-cue R words and mixed-cue F words to pure-cue F words. Mean corrected recognition scores for the mixed-cue R words (*M* = .47, *SE* = .03) was significantly higher than for the pure-cue R words (*M* = .41, *SE* = .03), *t*(46) = 3.09, *p* = .003, *d* = .45. Mean corrected recognition scores for the mixed-cue F words (*M* = .27, *SE* = .02) was also significantly higher than for the pure-cue F words (*M* = .22, *SE* = .02), *t*(46) = 2.37, *p* = .022, *d* = .35.

Table 1. Mean uncorrected hit rates as a function of memory cue (*R vs. F*) and item condition (*pure-cue vs. mixed-cue*).

	R	F
Pure-cue	0.57 (.03)	0.38 (.03)
Mixed-cue	0.63 (.03)	0.43 (.03)

Note. The uncorrected hit rates were calculated by dividing the number of words that were correctly identified as old by the number of items in the condition. Standard errors are presented in brackets.

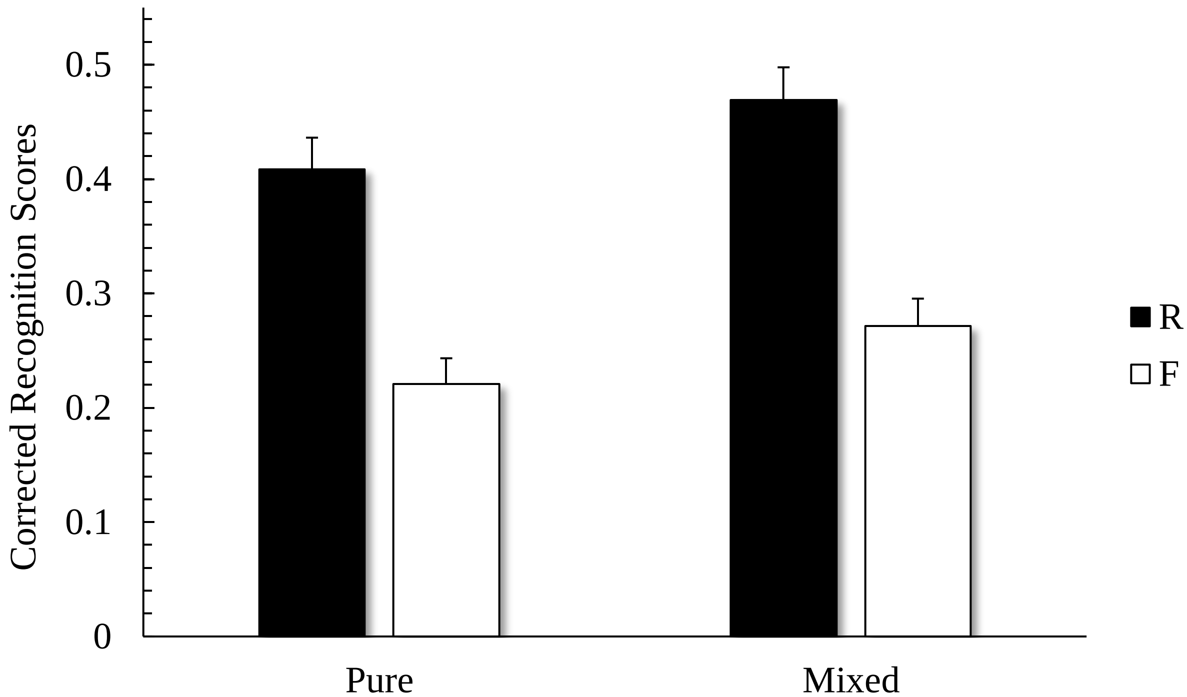

Figure 2. Mean corrected recognition scores as a function of memory cue (*R vs. F*) and item condition (*pure-cue vs. mixed-cue*); error bars represent one standard error.

Discussion

In Experiment 1, participants studied two unrelated words at a time, followed by a cue to remember or forget the previous word. We included two novel cue conditions. In the pure-cue condition, participants were asked to remember or forget both of the items. In the mixed-cue condition, participants were required to remember one but forget the other item. This crucial manipulation to the item-method paradigm allowed us to investigate, first whether it was possible to exert cognitive resources to remember and forget simultaneously, and second to determine which processes underlie directed forgetting.

Consistent with Hypothesis 1, there was a directed forgetting effect in the mixed-cue condition such that memory for mixed-cue R words was better than memory for mixed-cue F words. This suggests that it is possible to deploy resources to execute both remember and forget processes simultaneously.

Consistent with Hypothesis 2, we found that memory was higher in the mixed-cue R condition than in the pure-cue R condition. When there was only one R word to be remembered (mixed-cue R condition), participants allocated all rehearsal resources to this word. However, when there were two R words to be remembered (pure-cue R condition), participants had to split their rehearsal resources between both words. This finding then supports the hypothesis that there is a cognitively demanding rehearsal process that facilitates processing of R words. This finding is also consistent with the list-length effect, in which memory performance declines as the number of to-be-learned items increases (Gillund & Shiffrin, 1984; Roberts, 1972).

Based on the passive decay process proposed by the selective rehearsal account, our Hypothesis 3 predicted that memory for pure-cue and mixed-cue F words would be the same. Based on the active inhibition process derived from the attentional inhibition account, our

Hypothesis 4 predicted that memory for pure-cue F words would be better than for mixed-cue F words. Inconsistent with both of these hypotheses, we found that memory for pure-cue F words was actually worse than memory for mixed-cue F words. This pattern of results clearly does not support a cognitively demanding inhibition process, in which it is more difficult to inhibit two words than one word. It also does not seem to support a passive decay process in which decay is equivalent regardless of the number of items to be forgotten. This finding may indicate that in the mixed-cue condition, participants were unable to stop the processing of the mixed-cue F words when these were words were also paired with mixed-cue R words.

These findings then seem to be inconsistent with both the passive decay component of the selective rehearsal account and the attentional inhibition account of directed forgetting. However, because this is a novel paradigm, it seems that it would be prudent to first determine whether we can replicate the current findings before we draw strong conclusions. Experiment 2 then will provide a replication and include a neutral condition to provide converging evidence as to the processes underlying the directed forgetting effect.

CHAPTER 3: EXPERIMENT 2

The results of Experiment 1 support the hypothesis that there is a selective rehearsal process facilitating memory for R words. However, our findings did not support either a passive decay account or an active inhibition process underlying forgetting. In Experiment 2, we used the method of Experiment 1 with one key change—we introduced a *neutral* condition to provide further clarity on the extent to which facilitation of R words and inhibition of F words contribute to our directed forgetting effects. Thus, the purpose of Experiment 2 was twofold: 1) given the novelty of our double-item paradigm, we aimed to replicate the findings of Experiment 1, and 2) we introduced a neutral condition providing a baseline memory performance which should help provide converging evidence as to the remember and forget processes that contribute to directed forgetting.

In our neutral condition, participants were again presented with two unrelated words for 4 s. However, there was no 3 s cue duration following word presentation. That is, in the neutral condition, following study of a word pair, participants advanced immediately to the next word pair. The neutral condition then provides a baseline measure of memory for maintenance rehearsal of words. In summary, the R condition provides an additional 3 s to implement remember processes, the F condition provides an additional 3 s to implement any forget processes, whereas the neutral condition allows for no further implementation of any processes.

As with Experiment 1, we test the following four hypotheses: First, if it is possible to simultaneously execute remember and forget processes, we would find a directed forgetting effect in the mixed-cue condition such that memory for mixed-cue R words is greater than memory for mixed-cue F words. Second, if the selective rehearsal process demands cognitive resources, then memory for mixed-cue R words would be better than memory for pure-cue R words. Third, if passive decay is the only process that drives memory for F words, then memory for mixed-cue F words and pure-cue F words should be the same. Fourth, if active inhibition is employed, then memory for mixed-cue F words would be worse than memory for pure-cue F words.

Furthermore, the inclusion of the neutral condition allows for two additional hypotheses which will help inform which processes underlie directed forgetting. First, if selective rehearsal plays a role in directed forgetting, then memory for both mixed-cue R and pure-cue R words would be greater than memory for neutral words, as there is more opportunity for active selective rehearsal in the R conditions (Hypothesis 5). Second, if there is an active forgetting process, then memory for both mixed-cue F and pure-cue F words would be less than memory for neutral words, as there is more opportunity for active forgetting in the F conditions (Hypothesis 6). Third, if there is a passive decay process, then memory for both mixed-cue F and pure-cue F would be the same as the memory for neutral, as the F words and the neutral words should be equally susceptible to the same decay.

Method

Participants

Fifty-one participants were recruited from the undergraduate subject pool at Queen's University. Participants were tested individually in experimental rooms with each session lasting no longer than 60 minutes. Participants received a course credit or a ballot in a monetary draw for a $50 gift card to Starbucks. All participants reported no previous participation in other directed forgetting studies, normal to corrected-to-normal vision, and fluency in the English language. Two participants were excluded for not following experimental instructions. One participant was excluded due to overall below-chance performance. This resulted then in a total of 47 participants included in the analyses.

We conducted a power analysis using Monte Carlo simulations in R Commander to determine the appropriate sample size required to obtain a power level of .80 in a repeated measures ANOVA. We used an effect size of .37 which was calculated based on previous studies of item-method directed forgetting (Hockley, Ahmad, and Nicholson, 2016), and item-method directed forgetting with a neutral condition (Sahakyan and Foster, 2009; Taylor, Quinlan, and Vullings, 2018). Similar to Experiment 1, we chose a conservative effect size reported in the directed forgetting literature to ensure our required sample size promises the required power of .80. The power analysis showed that 45 participants were sufficient to achieve a power of .80. Following the removal of our participants, our final sample size of 47 remained sufficient and more than enough to reach our required power for our analyses.

Apparatus and Stimuli

The stimuli and apparatus were as described for Experiment 1, except that a neutral condition was added, changing the number of trials and words. With the addition of the neutral condition, the study phase was increased from 48 trials of 96 words to 60 trials of 120 words. This means that there were 24 Pure-Context Remember words, 24 Pure-Context Forget words, 24 Mixed-Context Remember words, 24 Mixed-Context Forget words, and 24 Neutral words presented during the study phase. We performed the identical randomization to Experiment 1 prior to collecting data from each participant to ensure unique stimulus combinations across conditions. The test phase was then increased from 192 words to 240 words, with 120 old words and 120 new words.

Procedure

Practice Phase. The procedure for these trials was as described for Experiment 1, except example trials for the neutral condition were also added to the PowerPoint presentation.

Study Phase. The procedure for the study phase was identical to Experiment 1, except that the experimenter provided additional instructions for the neutral condition. Participants were informed that after the word presentation, on most trials, they would see a memory cue for each word, instructing them to either remember or forget the preceding word. They were further informed that on some trials, that there would be no cue presentation; instead, they would simply be presented the next trials consisting of two more words. For these trials, participants were told to stop processing the preceding two words and attend to the new two words. The experimenter informed that participants that they did not need to remember or forget those words. Participants were again told that they would only be tested on the R words. The total duration of a study trial in which a memory cue was provided remained at 8s. The total duration of a neutral study trial was 5s. The schematic representations of each study trial for our pure-cue and mixed-cue conditions remained identical to Experiment 1. The schematic representation of the neutral condition study trial is presented in Figure 3.

Test Phase. Participants were given an old/new recognition task that was identical to that of Experiment 1, except that the definition of an old word was extended to include the neutral words. That is, an old word was defined as any word presented during the study phase, with it further clarified to participants that this included R, F, and neutral words. A new word was again defined as a word that was not presented during the study phase.

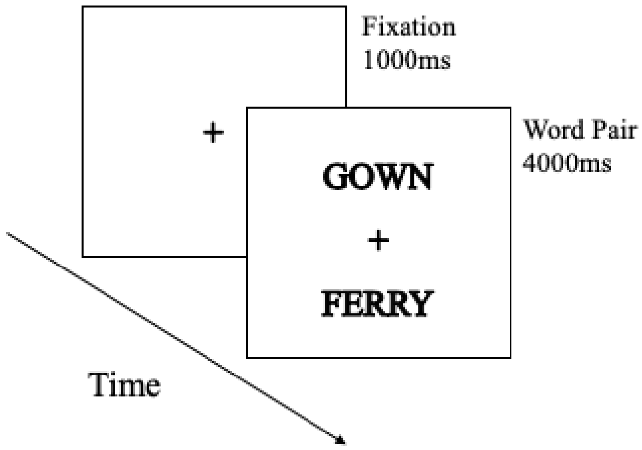

Figure 3. Schematic of a single study phase trial in the neutral condition, where the 3000ms cue presentation was removed and the next trial immediately began following word presentation.

Results

Corrected recognition scores were calculated using the same calculations as Experiment 1. Mean corrected recognition scores for R and F words in the pure-cue and mixed-cue conditions and for the neutral words are presented in Figure 4. Mean uncorrected hit rates for our pure-cue and mixed-cue conditions are presented in Table 2. The mean uncorrected hit rate for our neutral words was 0.417 with a standard error of .024. The mean false alarm rate to foils was 0.185. A 2 memory cue (R vs. F cue) x 2 item condition (pure-cue vs. mixed-cue condition) repeated-measures ANOVA was conducted on corrected recognition scores. We conducted this ANOVA to repeat our analysis from Experiment 1 without the neutral condition to determine whether we replicated our results from Experiment 1. There was a main effect of memory cue, $F(1,46) = 13.12$, $MSE = .150$, $p < .001$, $\eta^2_p = .222$, demonstrating the expected directed forgetting effect where mean corrected recognition for R words ($M = .38$, $SE = .02$) were significantly higher than mean corrected recognition for F words ($M = .32$, $SE = .02$). The main effect of item condition was significant, $F(1,46) = 108.18$, $MSE = 2.45$, $p < .001$, $\eta^2_p = .702$, showing that memory in the mixed-cue condition ($M = .46$, $SE = .02$) was significantly higher than memory in the pure-cue condition ($M = .23$, $SE = .02$). The interaction between these variables was not significant, $F(1,46) < 1$. The lack of an interaction showed that the magnitude of the directed forgetting effect for the pure-cue and mixed-cue conditions did not differ. We calculated the directed forgetting effect using the same calculations as Experiment 1. A paired samples *t*-test confirmed that the magnitude of the directed forgetting effect for the pure-cue condition ($M = .22$, $SE = .03$) did not differ from that of the mixed-cue condition ($M = .24$, $SE = .03$), $t(46) = .59$, $p = .560$, $d = .09$.

We conducted two planned paired samples *t*-tests to compare mean corrected recognition scores for R and F words in the pure-cue and mixed-cue conditions. Mean corrected recognition scores for the mixed-cue R words (*M* = .49, *SE* = .03) was significantly higher than mean corrected recognition scores for the pure-cue R words (*M* = .43, *SE* = .03), *t*(46) = 2.87, *p* = .006, *d* = .42, replicating our finding from Experiment 1. Mean corrected recognition scores for the mixed-cue F words (*M* = .26, *SE* = .02) was also significantly higher than mean corrected recognition scores for the pure-cue F words (*M* = .22, *SE* = .02), *t*(46) = 2.39, *p* = .021, *d* = .35. This was consistent with Experiment 1, where we also found that memory for mixed-cue F words was higher than for pure-cue F words.

To analyze our findings with the neutral condition, we conducted a 5-level (pure-cue R, pure-cue F, mixed-cue R, mixed-cue F, & neutral) one-way repeated-measures ANOVA. This analysis revealed that mean corrected recognition differed significantly across the memory cue conditions, *F* (4, 184) = 52.61, *MSE* = .775, *p* < .001, η^2_p = .534. Planned comparisons then compared memory for each condition relative to the neutral condition. Corrected recognition for the pure-cue R condition (*M* = .43, *SE* = .03) was significantly higher than for the neutral condition (*M* = .23, *SE* = .02), *F* (1,46) = 49.25, *MSE* = 1.812, *p* < .001, η^2_p = .517. Similarly, corrected recognition for the mixed-cue R condition (*M* = .49, *SE* = .03) was significantly higher than for the neutral condition, *F* (1,46) = 87.36, *MSE* = 3.211, *p* < .001, η^2_p = .655. However, corrected recognition for the pure-cue F condition (*M* = .21, *SE* = .02) did not significantly differ from the neutral condition, *F* (1,46) = 1.33, *MSE* = .026, *p* = .255, η^2_p = .028, and corrected recognition for the mixed-cue F condition (*M* = .26, *SE* = .02) did not significantly differ from the neutral condition, *F* (1,46) = 1.12, *MSE* = .028, *p* = .296, η^2_p = .024. In summary, both R conditions showed better recognition memory than the neutral condition, whereas recognition memory for neither of the F conditions differed from that for the neutral condition.

Table 2. Mean uncorrected hit rates as a function of memory cue (*R* vs. *F*) and item condition (*pure-cue* vs. *mixed-cue*)

	R	F
Pure-cue	0.61 (.03)	0.39 (.02)
Mixed-cue	0.68 (.03)	0.44 (.03)

Note. The uncorrected hit rates were calculated by dividing the number of words that were correctly identified as old by the number of words in the condition. Standard errors are presented in brackets.

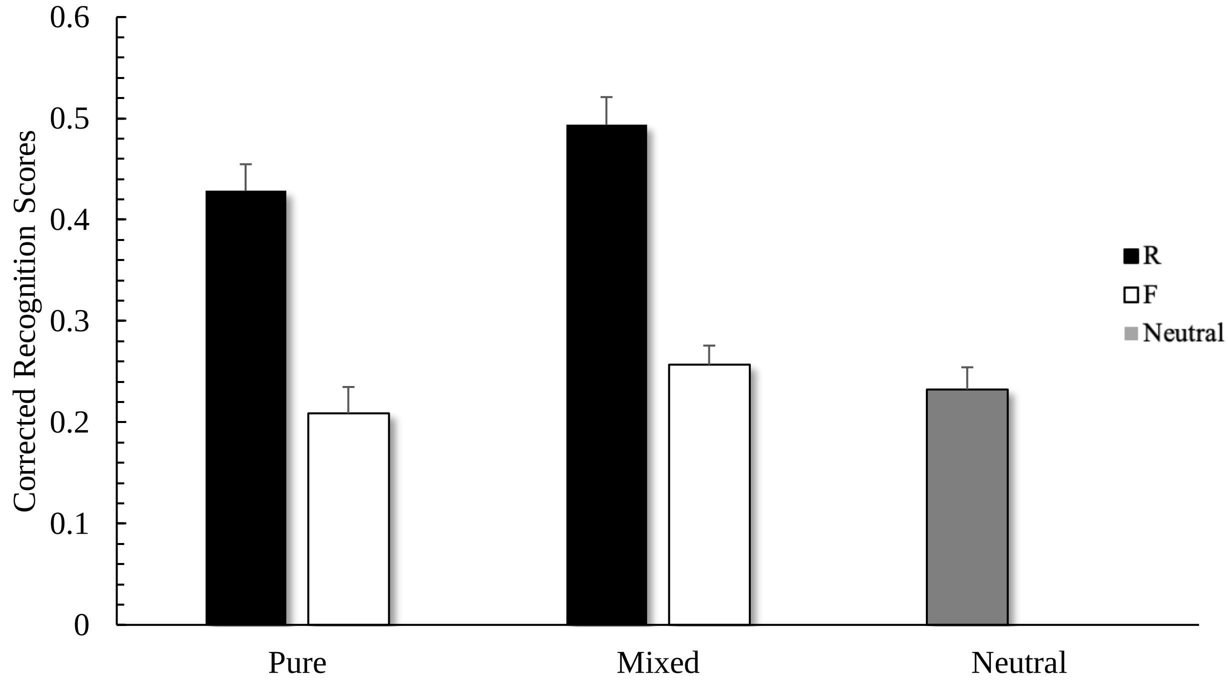

Figure 4. Mean corrected recognition scores as a function of memory cue (*R vs. F vs. Neutral*) and type of cue condition (*pure-cue vs. mixed-cue)*; error bars represent one standard error.

Discussion

The results of Experiment 2 replicated the findings of Experiment 1. We showed that it was possible to obtain a directed forgetting effect when both remember and forget processes are required (Hypothesis 1). We found that memory for mixed-cue R words was higher than memory for pure-cue R words, suggesting that cognitively demanding selective rehearsal contributes to directed forgetting (Hypothesis 2). We found that memory for mixed-cue F words was higher than memory for pure-cue F words, which was inconsistent with the suggestion that passive decay contributes to directed forgetting (Hypothesis 3) and that active inhibition contributes to directed forgetting (Hypothesis 4). The inclusion of a neutral condition provided converging evidence for the above findings. Specifically, we found that memory for both mixed-cue R and pure-cue R words was greater than memory for neutral words, again supporting the assertion that selective rehearsal contributes to directed forgetting (Hypothesis 5). Furthermore, we found that memory for both mixed-cue F and pure-cue F words did not differ from memory for neutral words, again failing to find any evidence that active forgetting contributes to directed forgetting (Hypothesis 6), but supporting a passive decay account of forgetting (Hypothesis 7).

This experiment provides clear evidence that selective rehearsal is the major process underlying the directed forgetting effect. Our findings suggest that we are able to strategically allocate rehearsal resources to promote the encoding of R words, but that we do not seem to be able to actively inhibit F words. In fact, we only have weak evidence that passive decay contributes to directed forgetting.

Our results are inconsistent with the attentional inhibition account and its claim of an active inhibition process. Although our results do not strongly support the passive decay component of the selective rehearsal account, we suggest that it still may provide the best explanation. That is, the selective rehearsal account suggests that directed forgetting involves the selection of task-relevant information, followed by the allocation of rehearsal resources to task-relevant information, with passive decay contributing to forgetting of task-irrelevant information. However, to account for our findings, we would extend the selective rehearsal account by proposing that selection is not perfect such that rehearsal resources may leak over and be inadvertently applied to task-irrelevant information. This would explain our finding of better memory for mixed-cue F words compared to pure-cue F words. That is, in the mixed-cue condition, participants may find it difficult to solely rehearse R words, leading to inadvertent rehearsal of the F words.

CHAPTER 4: GENERAL DISCUSSION

4.1 OVERVIEW OF FINDINGS

Using a modified item-method directed forgetting paradigm, our purpose was to examine the extent to which the two accounts, selective rehearsal and attentional inhibition, addressed the underlying mechanisms of directed forgetting. Our paradigm was unique in that it examined directly the allocation of attentional resources following cue presentation when remembering and forgetting processes were to be executed simultaneously. Furthermore, our paradigm provided a realistic representation of intentional forgetting in the laboratory, where there are multiple cognitive processes being implemented at a time.

In Experiment 1, participants studied two unrelated words at a time, each followed by either an R or F cue in either a pure-cue or mixed-cue condition. This allowed us to examine the extent to which participants employ different strategies to regulate their cognitive resources when implementing desired actions (either to selectively rehearse or inhibit items). We found that recognition was higher for mixed-cue R words than for pure-cue R words. Surprisingly, we also found that recognition was higher for mixed-cue F words than for pure-cue F words. These findings were consistent with the claim that selective rehearsal contributes to directed forgetting but suggested that active forgetting did not play a role, and possibly that passive forgetting also did not play a role.

In Experiment 2, we replicated the findings of Experiment 1 with one key change in the experimental design. We included a neutral condition to further examine the processes that contribute to directed forgetting. In this neutral condition, we removed the 3 s cue presentation, taking away the opportunity to implement further remember or forget processes. The results of Experiment 2 replicated Experiment 1 in supporting the conclusion that selective rehearsal drives directed forgetting with no role for active inhibition, and possibly not for passive decay. Furthermore, the inclusion of the neutral condition provided converging evidence for these conclusions by showing that memory for both pure-cue R and mixed-cue R conditions was better than for the neutral condition, but that memory for both the pure-cue F and mixed-cue F conditions did not significantly differ from the memory for the neutral condition. Thus, both experiments supported the role of selective rehearsal in directed forgetting but did not provide evidence for an active inhibitory mechanism.

4.2 INTERPRETATIONS OF OUR FINDINGS

Across our experiments, we obtained a significant directed forgetting effect, even when the R and F instructions were simultaneously presented. While the original item-method paradigm emphasizes the individual presentation of R and F cues to provide adequate opportunities for both remembering and forgetting processes to be engaged, we demonstrated the single cue presentation is not necessary to obtain a directed forgetting effect. Participants were still successfully able to produce a directed forgetting effect, even though the remembering and forgetting processes had to be simultaneously executed to their respective items. Given the novelty of our paradigm, these findings are exciting because we have laid the foundation for further experimental work to examine the limits to which directed forgetting is possible with simultaneous R and F cue presentation.

One of our most notable findings is that recognition for mixed-cue R words was higher than for pure-cue R words, which was consistent with the proposal that a cognitively demanding selective rehearsal process is a core process underlying directed forgetting. That is, this finding is consistent with the conclusion that in the mixed-cue condition, participants were able to successfully focus rehearsal resources on one word, whereas in the pure-cue condition, rehearsal was spread across two words. These findings were in line with the substantial amount of evidence that purports the selective rehearsal of R items in the item-method paradigm plays a large role in the directed forgetting effect (Basden & Basden, 1996; MacLeod, 1999).

In both experiments, we observed that memory for mixed-cue F words was higher than that for pure-cue F words. This was unexpected because it was not in line with the notion that forgetting is an active process and did not seem to be in line with a passive decay account. If forgetting is a cognitively demanding active process, as suggested by Fawcett et al. (2008, 2012), then memory for pure-cue F words should be higher than memory for mixed-cue F words. That is, in the mixed-cue condition, forgetting resources would be directed to a single F word, whereas in the pure-cue condition, forgetting resources would be distributed across both F words. Assuming that inhibition of a single item is less demanding than inhibition of two items, then inhibition of memory for pure-cue F words should be more difficult and so, should produce better memory than that for mixed-cue F words. In addition, the finding in Experiment 2 that memory for neutral words did not significantly differ from memory for pure-cue F and mixed-cue F words provided further evidence against the operation of an active inhibitory mechanism in intentional forgetting. The operation of such a mechanism would predict that memory for F words, regardless of the condition, should be lower than baseline memory performance. Our findings then suggest that active forgetting does not effectively reduce the encoding of an item in memory. That is, directed forgetting may not involve additional cognitive processes beyond simply ignoring or not attending to an item, and instead may represent passive decay.

If forgetting is a passive process, we expected that memory for mixed-cue F words would be relatively similar to memory for pure-cue F words. This was inconsistent with our finding of greater memory for mixed-cue F words than for pure-cue F words. Nonetheless, the selective rehearsal account may still provide the best explanation by suggesting that directed forgetting involves the selection of task-relevant information followed by the allocation of rehearsal resources to task-relevant information, with passive decay contributing to forgetting of task-irrelevant information. The selective rehearsal account must, however, be modified to account for our findings. We would propose that selection is not perfect, such that rehearsal resources may leak over and be inadvertently applied to task-irrelevant information. This would explain our finding of better memory for mixed-cue F words compared to pure-cue F words. That is, in the mixed-cue condition, participants may find it difficult to solely rehearse R words, leading to the inadvertent rehearsal of the F words.

The passive decay interpretation of F words is in line with recent studies of intentional forgetting using eye movement and pupillometry. Lee (2018) and Scholz and Dutke (2019) incorporated an ignore condition that was similar to our neutral condition, with the exception that they kept the cue duration the same following the ignore cue. Interestingly, they found that participants shifted their overt attention away from an F item by moving their eyes to a different location from where the study item was presented. In contrast, participants maintained their eyes on the same location where an R item was presented. Furthermore, using pupil diameter as an index of mental load, they found that an intention to forget required the same mental effort as simply ignoring an item, but an intention to remember demanded more mental effort.

These results and our findings together suggest that forgetting is not an active inhibitory mechanism, but rather it is a consequence of the allocation of resources to promote the encoding of relevant items via selective rehearsal. To account for our results, we have further proposed that the selection process is not perfect such that under some conditions, rehearsal resources may be inadvertently applied to task-irrelevant information. In our experiments, the inadvertent processing of task-irrelevant information might follow from perceptual load theory (Lavie, 1995). That is, in low load situations (i.e. just one task-relevant item), spare processing resources may be automatically allocated to task-irrelevant information. So, in the mixed-cue conditions of our experiments, there is just a single task-relevant word to be remembered. If that word does not consume all of the rehearsal resources, then some rehearsal resources may be unintentionally applied to the task-irrelevant F word, producing better memory for mixed-cue F words compared to pure-cue F words.

A second situation in which the selection process would be less than ideal is when the task-relevant and task-irrelevant items are associated with each other. In our experiments, the R and F words of the mixed-cue condition may be temporally associated in that they have the same temporal onsets and offsets. This might lead each mixed-cue F word to be bound to their simultaneously-presented mixed-cue R word. Previous research has suggested that in tests of associative item recognition and directed forgetting, participants retain associative information even for the items followed by an F cue (Hockley, Ahmad, & Nicholson, 2016; Bancroft et al., 2013). This indicates that the encoding of associative information may occur unintentionally prior to cue presentation. Jou (2010) demonstrated above chance performance for associative information even for tasks that did not explicitly require encoding and retrieval of such information. Hockley and Cristi (1996) also found that participants had above chance associative recognition for two items, even when these items were instructed to be encoded as two separate items. Based on this literature, it then seems plausible that in our paradigm, participants may have incidentally bound mixed-cue R and F words. This may lead to inadvertent rehearsal of the mixed-cue F words, explaining why we found better memory for mixed-cue F words relative to pure-cue F words.

Further evidence that it may be difficult to efficiently segregate R items for selective rehearsal comes from Golding et al. (1994). They demonstrated that when two words were semantically associated and one word was followed by an R cue while the other was followed by an F cue, participants were not able to successfully implement forget instructions. In other words, their study represents an example in which semantic-relatedness produces a failure to effectively segregate R and F items. By using a double-item presentation, our experiments were able to demonstrate how even unrelated items can impact the efficiency of selection. That is, our participants may have generated unintentional temporal binding between the R and F words, where the association between the words solely rise because the words were presented at the same time. This then highlights the critical role that effective selection of task-relevant information in the presence of task-irrelevant information plays in efficient memory control.

Unlike the other neutral or baseline conditions we are aware of in the directed forgetting literature (Scholz & Dutke, 2019; Lee, 2018; Zwissler, Schindler, Fischer, Plewnia, & Kissler, 2015; Taylor, Quinlan & Vullings, 2018; Sahakyan and Foster, 2009), our neutral condition was unique in that there was minimal processing of items. Although we believe that other approaches to baseline conditions including the remember-all (Taylor, Quinlan & Vullings, 2018; Sahakyan & Foster, 2009), uninformative items (Schindler & Kissler, 2018; Zwissler et al., 2015), and to-be-ignored items (Scholz & Dutke, 2019; Lee, 2018) have important implications in the item-method directed forgetting paradigm, our neutral condition presents a novel contribution to the measure of baseline memory. In our neutral condition, we removed the 3 s cue duration following word presentation in order to reduce any opportunities for participants to further rehearse the neutral words. The measurement of memory for these neutral words demonstrated participant performance with very minimal processing where the amount of cognitive resources acting on these items was minimal. While our primary reason to include such a neutral condition within our paradigm was to explore the extent to which facilitation and inhibition contribute to directed forgetting, we believe that this form of a neutral condition could benefit future research examining the role of maintenance rehearsal in directed forgetting.

We ran one additional experiment prior to conducting Experiment 1. This experiment was identical to Experiment 1 except that the length of the study and test lists were longer. Our study list consisted of 168 words (84 word pairs) and our test list consisted of 320 words (160 study words and 160 critical lures). The problem with this experiment is that we failed to replicate a standard directed forgetting effect in our pure-cue condition. Because the directed forgetting effect is robust and has been consistently replicated since Bjork (1972), it was clear that there was an issue with our experimental design making any experimental interpretations tenuous. It seems that the long study and test lists greatly reduced recognition memory performance overall with mean corrected recognition scores of .29 in the pure-cue condition and .28 in the mixed-cue condition. Possibly, because participants had so many words to study and recognize, their capacity to encode and recognize words was greatly exceeded reducing memory performance. Another possibility is that the long lists affected participant motivation such that the long lists overwhelmed participants such that they essentially gave up either during the study or recognition phase or both. Thus, because participants were not able to effectively complete the experimental task with the long study and test lists, we ran Experiment 1 which was identical except that it had shorter study and test lists. This use of shorter lists yielded a robust directed forgetting effect and a level of recognition performance more typically seen in the literature, indicating that with the shorter lists, participants had both the capacity and motivation to complete the task. Experiment 2 replicated the results of Experiment 1 in finding a standard directed forgetting effect suggesting that our pilot experiment failed to produce a directed forgetting effect because of the long lists and not because of an issue with our novel double-item paradigm.

The findings of the current thesis may help bridge attention and memory research. The current thesis highlights that intentional forgetting at encoding is a process that is dependent on the successful allocation of attention. We observed that participants were able to control their encoding processes to simultaneously perform remembering and forgetting. In such instances, attentional processes represent the bridge between the appropriate selection of information as either task-relevant or task-irrelevant and the application of the appropriate memory processes according to this selection (either to remember or forget the information). Items determined to be task-relevant would then be allocated the most attention in order to ensure the elaborative rehearsal and deeper encoding of these items. Items determined to be task-irrelevant would not receive much attention, which would ultimately result in shallow processing of these items leading to their poorer representations in long-term memory.

The current thesis brings the laboratory study of intentional forgetting a step closer to how intentional forgetting may occur in naturalistic situations. Traditional studies of item-method directed forgetting have been criticized as artificial and not applicable to real world situations. To expand this paradigm to everyday scenarios, Golding and Long (1998) studied how jurors intentionally forget when they are told by a judge to disregard information during a trial. They found that jurors instructured to forget information had similar recognition memory to those who were given instructions to ignore or no instructions at all. Such application of intentional forgetting to a “real world” situation demonstrates that intentional forgetting may not be accomplished as easily in real world situations as it is in laboratory setting. Nonetheless, the double-item method paradigm, and specifically the inclusion of the mixed-cue condition, brings the laboratory study of directed forgetting a step closer to the daily cognitive challenges of intentional forgetting where items receive conflicting memory instructions.

Our dual-item procedure may also have implications for studies of clinical disorders. For example, patients with post-traumatic stress disorder (PTSD) have been shown to suffer from intrusive memories about the traumatic event, memories they would like to forget. Cottencin et al. (2006) used a modified model of the list-method directed forgetting paradigm to test whether the consistent recall of intrusive memories could be due to patients' decreased ability to intentionally forget traumatic material after the event. Along with several other researchers (McNally et al., 1998; Blix and Brennen, 2011), they found that patients with post-traumatic stress disorder had a significantly smaller magnitude of directed forgetting effect, indicating that they recalled more F words than the healthy control participants. Specifically, most of the F words patients recalled were more trauma-specific words from the F list. Our dual-item procedure could be used to examine whether PTSD patients have even more difficulty forgetting when information must be simultaneously remembered and forgotten.

Our paradigm may also inform neuroscience studies of directed forgetting. Wylie, Fox, and Taylor (2008) found that when participants were trying to intentionally forget, they demonstrated higher activations in the frontal cortex compared to when participants were trying to intentionally remember or when they unintentionally forgot information. Our novel double-item method paradigm could then be implemented allowing one to further address the neural processes underlying directed forgetting. By providing conflicting memory instructions simultaneously, we could observe the extent to which the neural networks to remember and forget may overlap and thus, provide further implications to the exact mechanisms operating when we are intentionally forgetting.

4.3 FUTURE DIRECTIONS

We acknowledge that our paradigm has several limitations that must be addressed in future research. First, we propose that there may be an inadvertent failure to effectively select R words in our mixed-cue condition, either because of unintentional binding of the mixed-cue R and mixed-cue F words, or because of automatic allocation of spare rehearsal resources to the mixed-cue F words. Another possibility though is that participants process the mixed-cue F words simply because they fail to follow the instructions. A final possibility is that in the mixed-cue condition, more cognitive effort is required to interpret cues and differentially assign memory strategies. This additional cognitive effort may boost the encoding of both the mixed-cue R and mixed-cue F words relative to their pure conditions. Future research should modify the paradigm to account for this possible limitation. For example, following the initial presentation of the two unrelated words, there could be a manipulation where the two words and their respective cues appear on the screen at the same time. One way to accomplish this would be by presenting a rectangle around each word that changes colour according to the memory cue instructions. This would ensure that each word receives the appropriate assignment of the memory cues and would help ensure hat participants are exerting the correct cognitive processes on each item.

We further proposed that within our paradigm, participants may have inadvertently associated the two unrelated words due to temporal binding. Future research should examine the extent to which associative information contributes to the processing of simultaneously-presented R and F words. That is, it would be fruitful to manipulate the semantic relatedness between the two words to help elucidate the extent to which associations actually impact the selection of task-relevant information. Such an approach should contribute further novel findings to our understanding of the processes behind intentional forgetting. For example, future research could use the same study design as in these experiments, but with participants explicitly told to form associations between the two words presented on each trial. Following the study phase, instead of an old/new recognition test, participants could be given a word-pair recognition test, where they are presented with old study pairs and rearranged study pairs. This line of research would demonstrate the role of associative information in directed forgetting.

It would also be useful to investigate whether source monitoring plays a role in our novel double-item presentation. MacLeod (1975) suggested that participants are fairly accurate at identifying which item received which cue, demonstrating that each item is stored with their respective R or F cue as part of their memory trace. Perhaps for our paradigm, we could then ask participants if an item was an R or F item and whether it was a pure-cue or mixed-cue item. Incorporating such a test of source memory should help elucidate whether selection efficiency is impacted by an inability to appropriately link items to memory instructions.

4.4 CONCLUSIONS

By employing a novel double-item paradigm, we first demonstrated that directed forgetting is possible in a more realistic situation in which remembering of task-relevant information is required in the context of task-irrelevant information. Furthermore, we provided converging evidence for the important role of selective rehearsal in item-method directed forgetting, and demonstrated that an active inhibitory mechanism does not contribute to directed forgetting. To account, for our findings, we propose a modified version of the selective rehearsal account in which selection of task-relevant information for rehearsal is subject to inefficiencies that can lead to inadvertent rehearsal of task-irrelevant information.

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