THE INFLUENCE OF DIVIDED ATTENTION ON DIRECTED FORGETTING

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Arts in Psychology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2017

Urbana, Illinois

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Abstract

In list-method directed forgetting (DF) paradigm, participants study two lists of items, with half of them being told to forget List 1 before studying List 2. The typical findings involve impaired List 1 memory in the forget group compared to the remember group (known as DF *costs*), and enhanced List 2 memory in the forget group compared to the remember group (known as the DF *benefits*). Previous research suggests that dividing attention during List 2 learning eliminates DF thereby serving as a boundary condition for obtaining DF (e.g., Conway et al., 2000). This study re-examined this claim, and included additional conditions not previously employed in prior research. In this study, attention was divided by holding a concurrent load of six-digits during encoding of List 1 or List 2, during both lists, or none of the lists. Contrary to the previous reports, DF was unaffected when attention was divided during List 2. This was observed across two experiments, where the lists were tested separately (Experiment 1) or simultaneously (Experiment 2). In contrast, the novel finding was that dividing attention during List 1 reduced DF costs compared to the undivided conditions (Experiment 1). DF benefits were overall unaffected by divided attention manipulation. The results were interpreted by proposing that divided attention impacted the strength of item-to-context associations formed encoding.

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CHAPTER 1

INTRODUCTION

Everyday forgetting is an inevitable process that largely occurs outside of conscious awareness, causing frustration and annoyance when unable to retrieve necessary information. Thus, most often many would rather avoid forgetting. However, there are also occasions where forgetting information can be functional and adaptive, by making unwanted memories (e.g. embarrassing or traumatic events) or incorrect information less accessible. For instance, sometimes in the classroom, teachers might inadvertently present wrong information and subsequently correct themselves. Students must then forget the incorrect information to maintain focus on the correct material. Actively controlling memory by engaging in behaviors or processes that reduce access to outdated or irrelevant information would allow updating long-term memory by keeping relevant information more accessible.

The laboratory paradigms that are used to study memory control include the think-no-think procedure (Anderson & Green, 2001) and the directed forgetting (DF) procedure (e.g., Bjork, LaBerge, & Legrand, 1968). The current study employs the list-method DF paradigm, and hence its methods and theories will be reviewed in greater detail. The purpose of this investigation was to provide a critical re-examination of one of the boundary conditions of DF – namely, the role of divided attention during post-cue encoding – which previous research suggests reduces or eliminates DF (Conway, Harries, Noyes, Racsmány, & Frankish, 2000; Soriano & Bajo 2007).

1.1 LIST-METHOD DF PARADIGM AND THEORIES

In the list-method DF paradigm, participants study two lists of items for a later test. After learning List 1, half of the participants are told to forget that list and that they will not be tested on it, whereas the remaining participants are told to remember List 1. After, all participants study List 2, and are given a free recall test on both lists. The *costs* of DF refer to impaired memory of List 1 items in the forget condition compared to the remember condition. The *benefits* of DF are demonstrated by an increase in memory for List 2 in the forget group compared to the remember group. However, DF benefits are obtained less reliably than the costs in the laboratory studies, and meta-analysis indicates that the benefits are more easily detected when List 2 is tested before List 1 (Pastötter, Kliegl, & Bäuml, 2012).

Initially, DF was interpreted to represent differences in encoding strength between the forget and remember groups, arising from the forget group terminating rehearsal of List 1 items and focusing mainly on rehearsing List 2 items, while the remember group keeps rehearsing both lists (Bjork, 1972; Elmes, Adams, & Roediger, 1970). However, the selective rehearsal account cannot account for significant DF in incidental learning (Geiselman, Bjork, & Fishman, 1983; Sahakyan & Delaney, 2005, 2010), or the absence of DF on recognition tests (e.g. Basden, Basden, & Gargano, 1993; MacLeod, 1999; but see Benjamin, 2006). Over time, the appeal of selective rehearsal as an explanation of list-method DF diminished, leading rise to retrieval inhibition account (Bjork, 1989; Geiselman et al., 1983).

According to the inhibitory account, the forget instruction triggers processes that inhibit List 1 items, impairing recall during the test. Inhibited List 1 items reduce proactive interference on List 2 items, leading to better memory for List 2 items compared to the remember group (e.g. Bjork, 1989; Bjork & Bjork, 1996, 2003; Geiselman et al., 1983; Zellner & Bäuml, 2006).

Although the inhibitory account describes the phenomena, the nature of inhibition is not well defined, with some researchers proposing that it is the items from List 1 items that are inhibited (Barnier, Conway, Mayoh, Speyer, Avizmil, & Harris, 2007; Conway et al., 2000; Racsmány & Conway, 2006; Racsmány et al., 2008), others claiming that it is the List 1 episode that is inhibited (Bjork, 1989; Bjork & Bjork, 1996), and yet others referring to inhibition of List 1 context (Anderson, 2005; Bäuml, 2008; Pastötter & Bäuml, 2010).

An alternative to inhibitory account proposed by Sahakyan and Kelley (2002) relies on the importance of contextual information at encoding and retrieval. Context refers to a set of internal and external cues that are present at the time of encoding of items – such as one's mood, thoughts, physical and social environment in which encoding takes place. Importantly, during free recall, participants probe memory using contextual cues to initiate retrieval. A match between the cues used at encoding and the cues used at retrieval facilitates recall (for a review, see Smith & Vela, 2001), whereas a mismatch impairs memory (e.g., Godden & Baddeley, 1975). According to the context-change account of DF (Sahakyan & Kelley, 2002), participants told to forget List 1 items engage in mental context change, distancing themselves from the context in which they encoded List 1 items. A new set of contextual cues are then associated with List 2 items. This impairs the ability for the forget group to reinstate List 1 context during test, since the context at test better matches List 2 than List 1, thereby producing DF costs. DF benefits are attributed to reduced proactive interference in the forget group from having encoded the lists in two separate contexts (for a quantitative process model of DF instantiating the context change hypothesis, see Lehman & Malmberg [2009]). Note that dissociations between the costs and the benefits of DF have also given rise to the two-factor accounts of DF (Sahakyan & Delaney, 2005; Pastotter & Bauml, 2010), arguing that the DF benefits occur due to a change in encoding strategy (Sahakyan & Delaney, 2005), or a reset of encoding processes during List 2 (Pastotter & Bauml, 2010).

1.2 BOUNDARY CONDITIONS FOR DF

There are several conditions that hinder the ability to obtain the DF effect that has assisted in furthering our understanding the underlying mechanism. For example, the need for post-cue learning (e.g., Gelfand & Bjork, 1985; cited in Bjork, 1989; Pastötter & Bäuml, 2007), and the similarity of materials across the two lists seem necessary for observing DF (e.g., Hupbach & Sahakyan, 2014; Lehman & Malmberg, 2011; Wilson, Kipp, & Chapman, 2003). The current study focuses on the effect of dividing attention on DF, which according to previous research eliminates DF. Specifically, Conway et al. (2000) divided attention during List 2 learning by having participants hold on to a concurrent memory load of 6-digits during List 2 learning, while List 1 was always studied with full attention. Under such conditions, there were no detectable DF costs (although the benefits were significant). Conway et al. (2000) argued that divided attention overloaded available resources, compromising ability to engage in inhibition, thereby eliminating DF. However, given that the control condition – where both lists are studied with undivided attention – was only included as a cross-experimental comparison, the null effect could also reflect a failure to obtain DF in that particular experiment. This concern is particularly noteworthy given that the sample size of the divided attention experiment was suboptimal for a between groups comparison (Simmons, Nelson & Simonsohn, 2011), with 12 forget participants and 12 remember participants. In addition to the sample size issue, there could also be alternative theoretical interpretations of the divided attention effect, a claim further elaborated below.

1.3 CURRENT STUDY AND PREDICTIONS

Experiment 1 re-examined the effect of divided attention during List 2 encoding (Divided-L_2 group), and also included novel divided attention conditions that have not been examined in previous research. A standard DF condition, where participants studied both lists with full attention (termed Undivided group), was also included to serve as a comparison for various divided attention conditions.

Although the literature has focused on inhibition, alternative theoretical interpretations could explain why dividing attention during List 2 impairs DF. According to the context account, performing a divided attention task only during one of the lists could have contributed to differentiation between the lists (i.e., one list is studied with concurrent task, whereas the other is not). This could provide additional retrieval cues, making it easier to reinstate List 1 context at the time of final test, reducing DF. To test this explanation, a group was included where attention was only divided during List 1 but not List 2 (Divided-L_1 group). The context account would predict reduced DF in both Divided-L_1 group and Divided-L_2 if list differentiation is a critical factor.

According to the inhibition viewpoint, DF should be unaffected when attention is only divided during List 1 because resources to engage in inhibition are intact when List 2 is studied with full attention. This is because inhibitory processes are presumed to be triggered during List 2 learning, and having intact resources is critical. However, although the inhibitory resources may be intact, the *need* for engaging in inhibition may be less pronounced in Divided-L_1 group. A weak List 1 might generate less competition when studying List 2 (i.e., weak List 1 items may be less likely to come to mind during List 2). This reduces the likelihood of triggering inhibitory response, leading to reduced DF in Divided-L_1 group.

This design included also a condition where attention was divided during both lists (Divided- L_1L_2 group). Unlike in Divided-L_1 group, dividing attention on both lists would make the lists roughly equal in strength, which according to the inhibitory account would cause competition that would trigger inhibition. Thus, there should be similar DF in Undivided group and Divided-L_1L_2 group. However, if the critical component behind divided attention effects is the extent to which they tax inhibitory resources (e.g., Conway et al., 2000), then the ability to engage in inhibition should be compromised in Divided- L_1L_2 group and Divided-L_2 because attention is divided during the critical list (i.e., during List 2), and this would lead to reduced DF. Also, since the Divided- L_1L_2 group performs divided attention during both lists, the lists would be less differentiated, and therefore from the perspective of the context-account, there should be similar magnitude of DF in the Undivided and Divided- L_1L_2 group.

CHAPTER 2

EXPERIMENT 1

2.1 METHOD

2.1.1 Participants

A total of 770 participants were recruited using Amazon Mechanical Turk and compensated for their time. Only those located in United States were eligible to participate. Participants were excluded from further analyses if they were over 65 years old (19 participants), if they did not follow or read instructions (28 participants), or if they self-reported unethical participation, such as copying down words or not paying attention to the screen (20 participants). The remaining participants ranged from 18 to 65 years old with a mean of 35.9.

2.1.2 Design

This experiment employed a Cue (Forget vs. Remember) by Group (Undivided vs. Divided-L_1 vs. Divided-L_2 vs. Divided-L_1L_2) pure factorial design. Participants were either told to forget or remember List 1 words following its presentation, and they held a concurrent 6-digit memory load during List 1, List 2, both lists, or none of the lists.

2.1.3 Materials

A set of 32 unrelated English words was selected from the Toronto Noun Pool and randomly assigned to List 1 and List 2 for each participant, resulting in two lists of 16 words.

The program randomly selected six unique digits to generate the string of numbers for the divided attention conditions.

2.1.4 Procedure

After giving consent, participants were randomly assigned to one of the experimental conditions. They were told that they were about to participate in a memory experiment, where they would be presented with two sets of words to study for the subsequent memory test and that they should not use any external aide, such as copying down the words during study. They were also forewarned that the experiment was about intentional forgetting of unwanted information and that the program will randomly determine whether they would be instructed to remember or forget List 1 following its presentation. It was further explained that they would only be tested on List 1 if they receive a remember instruction, but not if they receive a forget instruction. However, since they do not know in advance what the program would decide, they should put equal effort into learning List 1. Words were presented visually at a 4 s rate, separated by a 1 s inter-stimulus interval. After presentation of 16 List 1 words, half of the participants were told to remember them for a subsequent test, whereas the remaining half was told to forget List 1 words. To test whether participants read the remember or the forget cue, they were asked on a subsequent screen to select which cue they received. Those who did not select the correct cue were eliminated from analysis. Next, List 2 words were presented, followed by a 30 s distractor task involving solving arithmetic problems. Then, participants were instructed to recall both lists by typing the words into computer. They were given 90 s for recall of each list, and the order of the tested list was counterbalanced across participants.

In the divided attention task, participants held a concurrent memory load consisting of a string of six unique single digits while studying the words. The string of digits was presented for 8 s prior to the presentation of the word list, and participants were asked to memorize those digits for later recall. They were also told that they should memorize them in the exact same order in which they were presented. Immediately following the presentation of the word list, participants were instructed to recall the six digits. Participants performed the divided attention task during encoding of List 1 (Divided-L_1), List 2 (Divided-L_2), both List 1 and List 2 (Divided-L_1L_2), or not at all (Undivided). Those who were in the Divided-L_1L_2 condition received a different set of digits for List 1 and List 2.

At the end of the experiment, participants were asked to report encoding strategies for List 1 and List 2 words. Those in the forget group were also asked to select from multiple choice options what they did in order to forget. Participants who selected "Contrary to the instruction, I tried to remember them because I did not believe it" were eliminated from the analyses. All participants were then asked if they copied down any of the information shown, with those who responded "yes" excluded from analysis. Finally, they were asked to indicate whether they ethically participated in the experiment, which meant paying full attention to the experiment and participating to the best of their ability. Those who reported unethical participation were excluded from analysis.

2.2 RESULTS

2.2.1 Digit Task Performance

Performance on the digit task was counted as correct if all six digits were recalled exactly in the same order in which they were presented. Accuracy on the digit task is reported in Table 1. Previous research using a similar task indicates that approximately 80% of participants are able to successfully perform the digit task in the lab experiment (Soriano & Bajo, 2007).

The digit task during List 1 encoding was performed prior to receiving the remember or forget cue, hence, Divided-L_1 condition and Divided-L_1L_2 condition underwent equivalent procedure before performing the digit task. The accuracy on the digit task collapsing across Divided-L_1 and Divided-L_1L_2 was M=0.83, SD=0.38. However, performance on List 2 digit task might be impacted by whether or not participants previously engaged in the digit task for List 1, and/or whether they received a remember or forget cue. Thus, a Cue (Remember vs. Forget) x Group (Divided-L_2 vs. Divided-L_1L_2) Analyses of Variance (ANOVA) was conducted for the digit task performance on List 2. A main effect of Group, $F(1,382)=5.24$, $MSE=.175$, $p=.021$, $\eta^2=.01$, indicated that overall performance on digit task was lower in the Divided-L_1L_2 condition (M=0.73, SD=0.45) than the Divided-L_2 condition (M=0.83, SD=0.38), presumably due to interference from the digits on the previous list. There was neither a main effect of Cue ($F(1,382)=1.37$, $p=.243$), nor a interaction ($F<1$). Overall, the digit task performance rates in the current sample are similar to those reported by Soriano and Bajo (2007).

2.2.2 Analysis of Divided Attention on DF

This section investigates the impact of divided attention on DF. List 1 and List 2 recall was scored by ignoring list confusion errors (i.e., List 1 word recalled during List 2 test or List 2 word recalled during List 1 were both counted as correct) in order to approximate Conway et al. (2000) and Soriano and Bajo (2007), who tested recall of both lists simultaneously, without specifying the order of recalled lists.

2.2.2.1 DF Costs

The costs of DF were analyzed by using Cue (Forget vs. Remember) x Group (Undivided vs. Divided-L_1 vs. Divided-L_2 vs. Divided-L_1L_2) ANOVA on List 1 recall. The results are summarized in Figure 1. A significant main effect of Cue indicated that the Remember group performed better (M=0.33, SD=0.23) than the Forget group (M=0.23, SD=0.21), $F(1,695)=42.87$, $MSE=.049$, $p<.001$, $\eta^2=.06$. There was also a significant main effect of Group, $F(3,695)=3.09$, $p=.027$, $\eta^2=.01$. Divided-L_1 group (M=0.25, SD=0.22) had significantly lower List 1 recall than Divided-L_2 group (M=0.30, SD=0.25), $t(135)=2.32$, $p=.021$, Cohen's d=0.40, while none of the other groups significantly differed from each other. Importantly, there was a significant Cue x Group interaction, $F(3,695)=2.63$, $p=.049$, $\eta^2=.01$. To follow-up the interaction, a one-way ANOVA was conducted separately in Remember and Forget conditions using Group as a factor.

There were no significant differences in the Forget Condition ($F<1$), but there was a significant difference between the groups in the Remember Condition, $F(3,349)=4.61$, $MSE=.053$, $p=.004$, $\eta^2=.04$. The Divided-L_1 group had lower List 1 recall than both the Undivided group ($t(156)=2.34$, $p=.021$, d=0.37), and the Divided-L_2 group, $t(169)=3.41$, $p=.001$, d=0.52. The latter two groups did not differ from each other, $t(142)=1.27$, $p=.207$. List 1 recall was also lower in the Divided-L_1L_2 group compared to the Divided-L_2 group, $t(190)=2.34$, *p*=.02, *d*=0.34, and it was numerically lower compared to the Undivided group, *t*(180)=1.08, *p*=.28.

Dividing attention differentially impacted the magnitude of DF costs. In the Undivided condition, which serves as the comparison group, significant DF costs were reflected in lower List 1 recall in the Forget group than the Remember group, *t*(143)=4.23, *p*<.001, *d*=0.71. The costs were also detected in the Divided-L_1 condition, *t*(170)=2.02, *p*=.045, *d*=0.31, and the Divided-L_1L_2 condition, *t*(209)=2.05, *p*=.042, *d*=0.28, but they were of smaller magnitude in terms of the effect size. Contrary to the findings of previous reports in the literature, there were significant DF costs also in the Divided-L_2 condition, *t*(173)=5.02, *p*<.001, *d*=0.76, and the effect size was comparable to the Undivided condition.

To summarize, dividing attention during List 1 reduced the magnitude of DF costs in Divided-L_1 and Divided-L_1L_2 conditions by lowering recall in the Remember group, without affecting recall in the Forget group. However, DF costs were unaffected when attention was divided during List 2. In terms of the effect size, the magnitude of DF costs was robust and comparable across the Divided-L_2 and Undivided conditions, whereas DF costs were much smaller in magnitude and similar across the Divided-L_1 and Divided-L_1L_2 conditions.

2.2.2.2 DF Benefits

A Cue (Forget vs. Remember) x Group (Undivided vs. Divided-L_1 vs. Divided-L_2 vs. Divided-L_1L_2) ANOVA on List 2 recall was used to analyze DF benefits. The results are summarized in Figure 2. There was a significant main effect of Cue, *F*(1,695)=30.36, *MSE*=.068, *p*<.001, η^2=.04. Recall was higher in the Forget Group (*M*=0.40, *SD*=0.26) than the Remember Group (*M*=0.30, *SD*=0.26), denoting overall DF benefits, *d*=0.38. There was neither a main effect of Group (*F*<1), nor an interaction, *F*(3,695)=1.02, *p*=.385. In other words, dividing attention during different stages of learning (i.e., List 1, or List 2, or both lists) did not significantly affect the magnitude of DF benefits.

2.3 DISCUSSION

The purpose of Experiment 1 was to investigate the impact of dividing attention on DF and to provide a re-examination of one of its boundary conditions. The costs of DF were found in all four conditions, indicated by higher performance in the remember group than the forget group for List 1. However, DF costs were of smaller magnitude in Divided-L_1 and Divided-L_1L_2 conditions compared to Undivided and Divided-L_2 conditions. Reduction of DF costs was driven by reduced performance in the Remember conditions of the Divided-L_1 and Divided-L_1L_2 groups, but not in the Forget conditions, compared to the Undivided and Divided-L_2 groups. In addition, there were overall benefits of DF, denoted by higher performance in the forget group than the remember group for List 2, and there was no interaction between divided attention and DF benefits.

Despite testing a substantially larger sample, the results did not replicate the findings that dividing attention during List 2 eliminates or even reduces DF costs. Robust DF costs were found in Divided-L_2 group, and the effect size was comparable to the Undivided condition. One might wonder whether the manipulation used to divide attention was unsuccessful in the current study. However, Experiment 1 employed the same 6-digit concurrent task as what was used in previous research, and the performance rates on that task were comparable to those reported in prior literature. Furthermore, there was not a general failure of attentional manipulation since DF was impacted, just not in the ways that were immediately obvious. Namely, dividing attention during List 1 (rather than List 2) significantly reduced the magnitude of DF, and this was evident both in the Divided-L_1 group and in Divided-L_1L_2 group.

One potential factor that might explain the discrepancy between the current findings and the previous research is the format in which participants were tested. Specifically, Experiment 1 asked participants to recall List 1 and then List 2, or visa versa, whereas previous research asked participants to recall all studied word simultaneously (both List 1 and List 2). To evaluate whether the test format can explain the discrepant findings, Experiment 2 was conducted with simultaneous testing of both lists.

CHAPTER 3

EXPERIMENT 2

3.1 METHOD

3.1.1 Participants

A total of 241 participants were recruited from MTurk as in Experiment 1. The same exclusion criteria in Experiment 1 was used: 65+ years old (2 participants), did not follow or read instructions (11 participants), or if they self-reported unethical participation (3 participants). The remaining participants ranged from 19 to 63 years old with a mean of 35.54.

3.1.2 Design

This experiment employed a Cue (Forget vs. Remember) by Group (Undivided vs. Divided-L_2) pure factorial design. Participants were either told to forget or remember List 1 words following its presentation, and those in the Divided-L_2 held a concurrent 6-digit memory load during List 2 (akin to Experiment 1).

3.1.3 Materials

The materials were the same as in Experiment 1.

3.1.4 Procedure

The main difference between the procedures of the current study and Experiment 1 was that test order of lists was not controlled, and participants were given 180 s to recall both List 1 and List 2 simultaneously. In all other respects, the procedures followed Experiment 1. Participants performed the divided attention task – holding a concurrent load of 6-digits – during encoding of List 2 (Divided-L_2) or not at all (Undivided). Similar to Experiment 1, participants in the Divided-L_2 were asked to recall the 6-digits immediately following List 2 presentation.

3.2 RESULTS

3.2.1 Digit Task Performance

Performance on the digit task was scored in the same way as Experiment 1, all six digits had to be recalled exactly in the same order in which they were presented in order to be counted as correct. Overall accuracy on the digit task for the Divided-L_2 condition was 90% (Table 1), with no detectable difference between the Remember group (M=0.92, SD=0.28) and the Forget group (M=0.89, SD=0.32), t<1. This is consistent with the findings in Experiment 1.

3.2.2 Analysis of Divided Attention on DF

3.2.2.1 DF costs

The costs of DF were analyzed by using Cue (Forget vs. Remember) x Group (Undivided vs. Divided-L_2) ANOVA on List 1 recall (see Figure 3). A main effect of Cue reflected the costs of DF, $F(1,221)=6.45$, MSE=.054, p=.01, η^2=.03. The Forget condition (M=0.33, SD=0.21) demonstrated lower performance than the Remember condition (M=0.40, SD=0.25) for List 1 recall. There was neither a main effect of Group (F<1), nor an interaction between Cue and Group (F<1). Thus, the data demonstrates that the costs of DF were unaffected when attention was divided during List 2 – they were robust and significant despite the change in the testing procedure.

3.2.2.2 DF benefits

To analyze the benefits of DF, a Cue (Forget vs. Remember) x Group (Undivided vs. Divided-L_2) ANOVA was performed on List 2 recall. There was a main effect of Cue, $F(1,221)=11.36$, $MSE=.063$, $p=.001$, $\eta^2=.05$, showing that the Forget condition ($M=0.41$, $SD=0.22$) performed higher than the Remember condition ($M=0.30$, $SD=0.27$), reflecting DF benefits. There was also a main effect of Group, $F(1,221)=5.03$, $MSE=.063$, $p=.03$, $\eta^2=.02$, showing that List 2 recall was worse when attention was divided during List 2 ($M=0.33$, $SD=0.24$) compared to when it was undivided ($M=0.40$, $SD=0.27$). However, there was no interaction between Cue and Group ($F<1$). Overall, the benefits of DF were present across both conditions, but overall recall was lower in the Divided-L_2 condition.

3.3 DISCUSSION

Experiment 2 followed the procedure outlined in Conway et al. (2000), who proposed that dividing attention during List 2 impaired ability to engage in inhibition, eliminating DF costs. Using a larger sample size, the results from Experiment 2, however, reflected both the costs and benefits of DF. Dividing attention during List 2 using the same task and procedure as Conway et al. (2000) did not eliminate DF across the two experiments. Thus, both experiments failed to replicate Conway et al. (2000).

It turns out that previous research has also failed to fully replicate Conway et al. (2000). Soriano and Bajo (2007) used the same digit task to divide attention during List 2 learning to investigate differences between low-span and high-span participants. In their study, high-spans still showed DF costs under divided attention, whereas the low-spans did not. Under the assumption that effect of divided attention on DF emerges only in low-spans but not high-spans, it is still extremely unlikely that the current sample consisted solely of high-span participants, especially given the large size of the sample for both Experiment 1 and Experiment 2. Furthermore, working memory capacity has been previously found to moderate directed forgetting (Delaney & Sahakyan, 2007), such that low-span individuals are less able to engage in DF than high-span individuals in general (without divided attention manipulations). Thus, Soriano and Bajo's (2007) findings could be interpreted as a failure to replicate Conway et al.'s (2000) findings, while also replicating Delaney and Sahakyan's (2007) findings that low-spans show reduced DF.

CHAPTER 4

GENERAL DISCUSSION

In Experiment 1, attention was divided during List 1, List 2, both List 1 and List 2, and neither. DF costs were unaffected when attention was only divided during List 2, contradicting previous findings (Conway et al., 2000). Meanwhile, dividing attention during List 1 (Divided-L_1 group and in Divided-L_1L_2 group) showed reduced DF costs. Experiment 2 was done to replicate the Divided-L_2 condition in Experiment 1 using simultaneous testing to better follow the method used in previous research. Despite using a larger sample size and following the testing procedure outlined in Conway et al. (2000), I was unable to replicate their findings. Instead, DF costs were observed when attention was dividing during List 2 across both Experiment 1 and Experiment 2.

Given that Experiment 2 replicated Experiment 1 findings, in the sections that follow, I will evaluate the overall results in the context of existing theories and propose an explanation for the reduced DF effects in specific conditions.

According to the inhibition account, DF costs should be unaffected when inhibitory resources are available during List 2. In the Undivided and Divided-L_1 condition, resources to engage in inhibition were intact during the critical list (i.e., List 2) and hence the magnitude of the costs should be similar between these conditions. However, the results did not support these predictions. Instead, DF costs were reduced in Divided-L_1 compared to the Undivided group, while by contrast, Divided-L_2 produced comparable costs to Undivided group despite having reduced resources during List 2 learning. If one wants to propose that inhibition may not have been triggered in the Divided-L_1 group due to reduced competition between List 1 and List 2 (since they are not of equal strength), then it is still difficult to reconcile why Divided-L_1 and

Divided-L_1L_2 groups both demonstrated reduced DF, when only Divided-L_1 had lists of unequal strengths. The overall set of results cannot be explained by the inhibition account.

List differentiation did not appear to affect DF findings. DF was of different magnitude in Divided-L_1 and Divided-L_2 groups despite both group having potential list differentiation. By contrast, DF was of the same magnitude in the undifferentiated list condition (e.g., Divided-L_1L_2) or the differentiated list condition (e.g., Divided-L_1 group). It is possible that the divided attention task did not sufficiently differentiate the two lists to observe the effect of differentiation.

The selective rehearsal account is also unable to account for these findings, predicting that DF costs should be reduced when the remember group is prevented from actively rehearsing List 1 items during List 2 encoding. Impairment of rehearsal in the remember group would functionally equate it to the forget group. Thus, dividing attention during List 2 should lead to reduced DF costs, causing similar outcomes in the Divided-L_2 and Divided-L_1L_2 groups. Although the results showed reduced DF costs in the Divided-L_1L_2 condition, the DF costs were not reduced in the Divided-L_2 compared to the Undivided condition. Thus, the selective rehearsal account also provides inadequate explanation of the current set of results.

These results suggest that there is a critical component of List 1 encoding that was neglected in prior research. The context-change account emphasizes the importance of contextual information, and this critical factor might reflect the strength of contextual information encoded in episodic trace (i.e., strength of item-to-context associations established during encoding). Research suggests that dividing attention during encoding not only harms the encoding of items, but it also impairs memory for contextual information, including memory for the source of the item (e.g., Naveh-Benjamin, Guez, & Marom, 2003; Naveh-Benjamin, Guez, & Shulman, 2004;

Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Smyth & Naveh-Benjamin, 2016). When attention was divided during List 1, it might have interfered with the strength of associations formed between the items to their context. This would occur in both the forget and remember groups. These weak contextual associations would impair ability to reinstate the list context at retrieval compared to when strong associations were formed under full attention. In the divided attention conditions, poorer List 1 recall in the Remember group can be attributed to difficulty reinstating List 1 context during the final test due to compromised contextual encoding compared to the full attention condition. Impaired List 1 recall in the Forget group is explained by a change of context, causing reinstatement to be difficult regardless of weak associations to context. This explanation could account for reduced DF costs in the Divided-L_1 group and in the Divided-L_1L_2 group when compared to the Undivided and Divided-L_2 groups.

To support the proposed explanation, Experiment 1 data was further examined to see how participants initiated recall at test to assess context reinstatement across different experimental conditions. This was done using first response probability (FRP), which is a serial position function of the first retrieved item. This function is diagnostic of the type of cues participants use to search memory. Initiating retrieval from the end of the list, for example, would suggest that participants are using the recent list context to probe memory, whereas initiating from the beginning of the list indicates that they are reinstating the start of the study episode. According to the buffer model of memory, the first item of the list is more strongly associated with its context then the ensuing items in part because it marks the start of the list and affords an advantage in the rehearsal buffer (e.g., Lehman & Malmberg, 2013).

FRPs functions were created for the Remember and Forget groups across the four conditions during List 1 recall (see Figure 4). Consistent with previous research, participants started retrieval with the first item of the list on a delayed test (e.g., Lehman & Malmberg, 2009; Sahakyan & Hendricks, 2012; Spillers & Unsworth, 2011). The probability of initiating retrieval with the first item of List 1 was substantially higher than from remaining positions of List 1. Furthermore, those in the forget condition were less able to reinstate the context of the beginning of the list compared to the remember condition, as evidenced by lower recall of the first item in List 1 as shown in Figure 4. This finding fully replicates previous research on DF (Lehman & Malmberg, 2009; Spillers & Unsworth, 2011). Importantly, the results also provide supporting evidence for the proposed hypothesis, dividing attention impaired encoding of context and reinstatement of List 1. While there was little variability in the Forget condition across the four groups, the Remember groups of the Divided-L_1 and Divided-L_1L_2 conditions were less likely to initiate retrieval with the first item of List 1 compared to the Undivided condition or the Divided-L_2 condition. If encoding of context was harmed in the Divided-L_1 and Divided-L_1L_2 conditions, then the ability to reinstate context during the test would also be impaired. Impaired reinstatement of context makes it harder to initiate recall with the first item of List 1, as was evident in the Divided-L_1 and Divided-L_1L_2 conditions.

Other studies have indicated that encoding of context plays a crucial role in obtaining DF. For instance, massed items suffer less from DF than spaced items (Sahakyan, Delaney, & Waldum, 2008), and the effect is attributed to weaker contextual strength in episodic trace of the massed items compared to spaced items (Malmberg & Shiffrin, 2005). Likewise, low-span participants have deficits in encoding of contextual information (e.g., Sahakyan, Abushanab, Smith, & Smith, 2014), and they show smaller DF, as discussed earlier. Finally, whereas words typically do not show DF in a "yes/no" recognition tests, non-words do show DF, and the latter is also explained in terms of differences in strength of associations of non-words to their context

(Sahakyan, Waldum, Benjamin, & Bickett, 2009). Importantly, dividing attention during List 1 reduced DF costs, which is likely caused by the impact of divided attention on the strength of item-to-context associations.

In conclusion, the findings of this investigation call into question the previous claim that dividing attention during List 2 with concurrent six-digit load eliminates DF effect. On the contrary, while dividing attention during List 2 did not impact DF, dividing attention during List 1 reduced DF costs, which I interpreted in terms of the impact of divided attention on the strength of item-to-context associations.

TABLE AND FIGURES

Chapter 2 Figures and Tables

Table 1. Accuracy on the 6-digit Concurrent Memory Task.

Condition	List 1 Performance M (SD)	List 2 Performance M (SD)
Experiment 1		
Divided-L_1		
Remember	0.79 (0.41)	
Forget	0.83 (0.38)	
Divided-L_2		
Remember		0.86 (0.35)
Forget		0.80 (0.41)
Divided-L_1L_2		
Remember	0.84 (0.37)	0.75 (0.44)
Forget	0.83 (0.38)	0.71 (0.46)
Experiment 2		
Divided-L_2		
Remember		0.92 (0.28)
Forget		0.89 (0.32)

Figure 1. Recall for List 1 in remember and forget groups across the divided attention conditions in Experiment 1. Error bars represent the standard error of the mean.

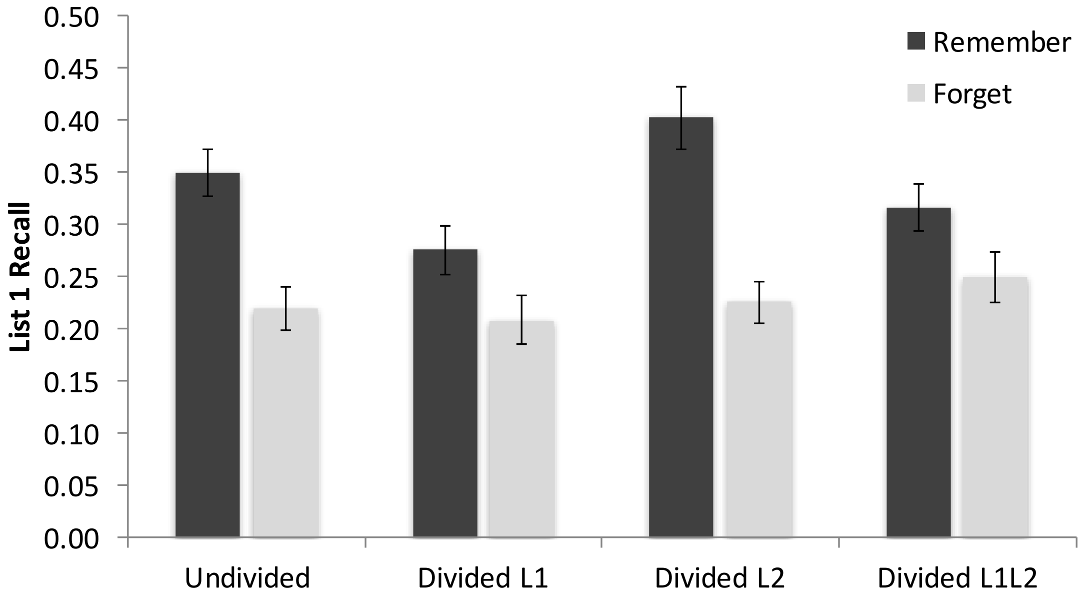
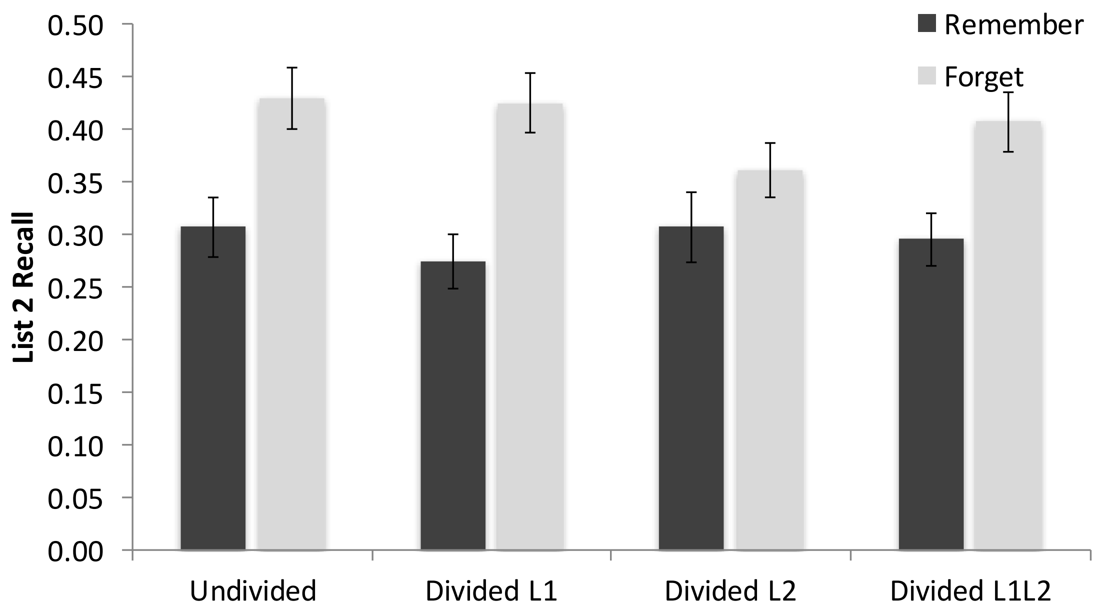
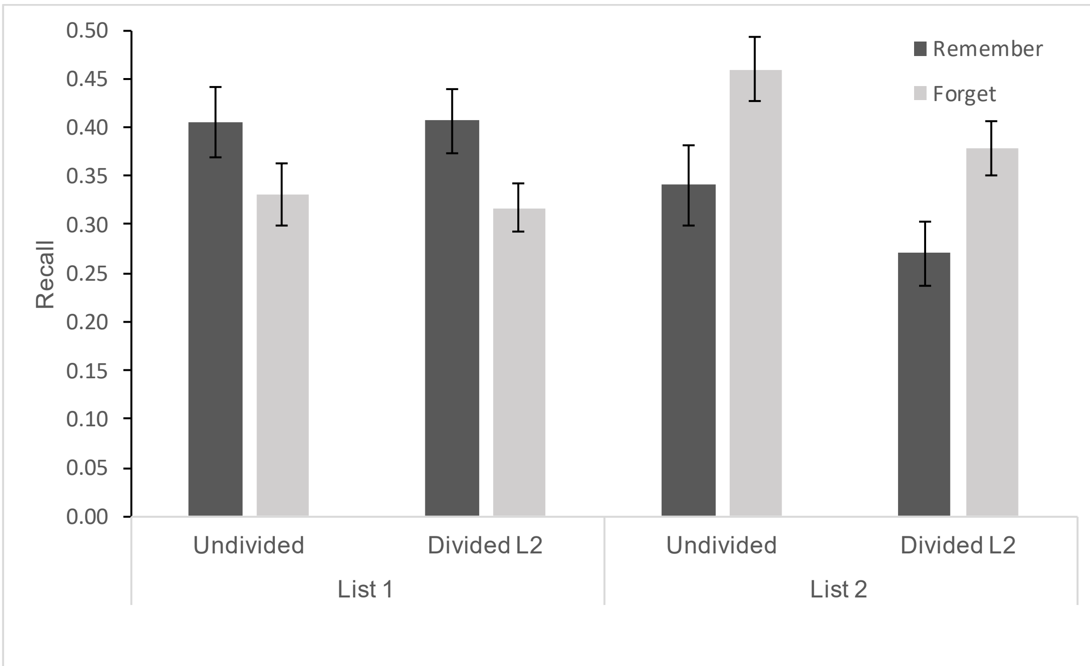


Figure 2. Recall for List 2 in remember and forget groups across the divided attention conditions in Experiment 1. Error bars represent the standard error of the mean.



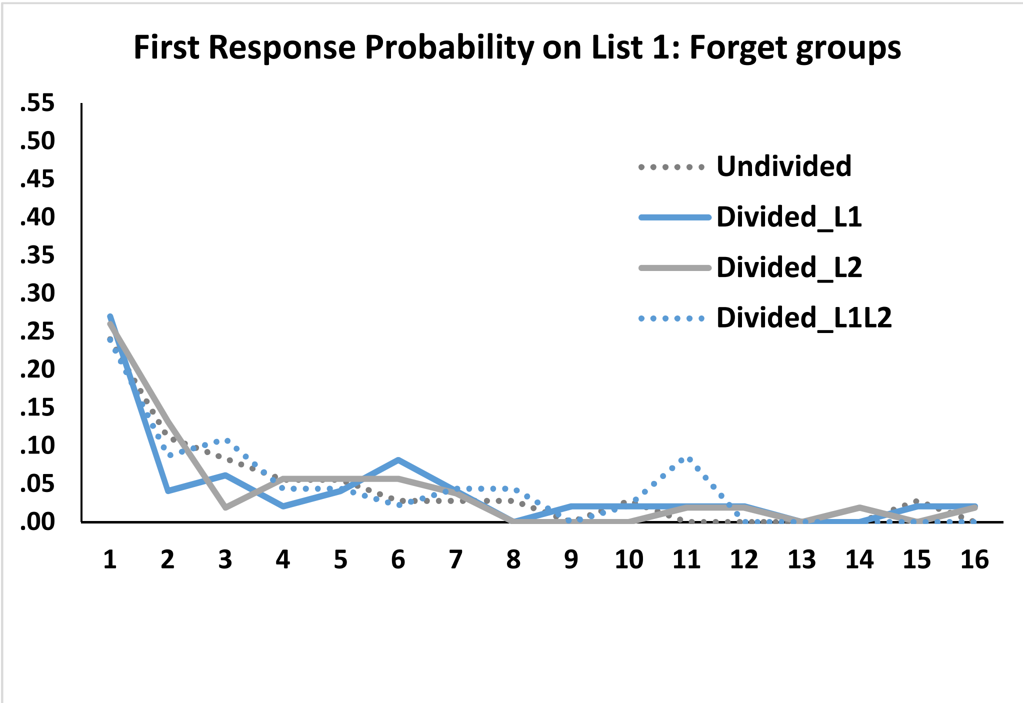
Chapter 3 Figures

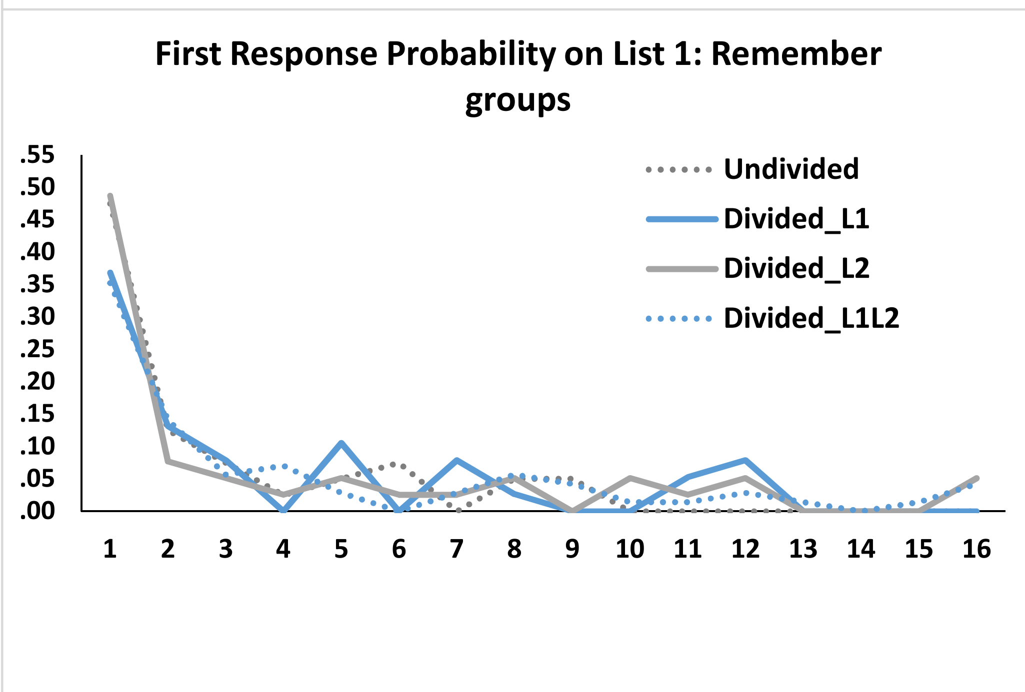
Figure 3. Recall for List 1 and List 2 in remember and forget groups across the Undivided and Divided-L_2 condition in Experiment 2. Error bars represent the standard error of the mean.



Chapter 4 Figures

Figure 4. First Response Functions of List 1 Recall in the Remember groups (top panel) and Forget groups (bottom panel) across the four experimental conditions in Experiment 1.





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