THE COGNITIVE CONSEQUENCES OF FORGETTING: AN INVESTIGATION OF IOR IN ITEM-METHOD DIRECTED FORGETTING

by

Kate Thompson

Submitted in partial fulfilment of the requirements
for the degree of Doctor of Philosophy

at

Dalhousie University
Halifax, Nova Scotia
April 2015

DEDICATION PAGE

To those who have supported me: Mom, Dad, Sam, Chris. I love you.

TABLE OF CONTENTS

DEDICATION PAGE ii

LIST OF TABLES vi

LIST OF FIGURES vii

ABSTRACT viii

LIST OF ABBREVIATIONS USED ix

ACKNOWLEDGEMENTS x

Chapter 1 Introduction 1

1.2 On Forgetting 1

1.3 On Inhibition of Return 7

1.4 IOR and Directed Forgetting 15

Chapter 2 Four Locations are Better than Two 19

2.1 Abstract 19

2.2 Introduction 19

2.3 Experiment 1 23

2.3.1 Introduction 23

2.3.2 Method 24

2.3.3 Results 29

2.3.4 Discussion 33

2.4 Experiment 2 33

2.4.1 Introduction 33

2.4.2 Method 35

2.4.3 Results 36

2.4.4 Discussion 38

2.5 Experiment 3 39

2.5.1 Introduction 39

2.5.2 Method ... *40*

2.5.3 Results ... *40*

2.5.4 Discussion ... *42*

2.6 General Discussion ... 43

2.7 Author Note ... 48

Chapter 3 I Can See it in Your Eyes ... 49

3.1 Abstract ... 49

3.2 Introduction ... 49

3.2.1 Inhibition of Return ... *51*

3.2.2 IOR in Item-Method Directed Forgetting ... *53*

3.2.3 The Present Experiments ... *55*

3.3 Experiment 1 ... 57

3.3.1 Method ... *58*

3.3.2 Results ... *61*

3.3.3 Discussion ... *64*

3.4 Experiment 2 ... 64

3.4.1 Method ... *64*

3.4.2 Results ... *65*

3.4.3 Discussion ... *68*

3.5 Experiment 3 ... 68

3.5.1 Method ... *69*

3.5.2 Results ... *70*

3.5.3 Discussion ... *72*

3.6 General Discussion ... 73

3.7 Author Note ... 77

Chapter 4 Conclusion ... 78

4.1 Summary of Findings ... 78

4.1.1 Summary of Chapter 2 ... *78*

4.1.2 Summary of Chapter 3 ... *80*

4.2 Shared Mechanisms Between IOR and Intentional Forgetting ... 82

4.2.1 On the causes and effects of IOR, and where memory instruction could have its influence ... *82*

4.2.2 Differential withdrawal of attention *83*
4.2.3 Decreased mental salience of F items *86*
4.3 How Might F>R IOR be Related to Successful Forgetting? 90
4.4 Interactions Between Attention and Memory 92
4.5 Conclusion 94

References 96

Appendix A 111

LIST OF TABLES

Table 3.1: *Descriptive statistics of the proportion of retained study trials per condition in Experiment 1* 62

Table 3.2: *Descriptive statistics of the proportion of retained study trials per condition in Experiment 2* 66

Table 3.3: *Descriptive statistics of the proportion of retained study trials per condition in Experiment 3* 70

LIST OF FIGURES

Figure 1.1: Depiction of the trial progression in a standard cueing paradigm 8

Figure 2.1: Depiction of one study phase trial 27

Figure 2.2: Descriptive statistics for Experiment 1... 30

Figure 2.3: Inhibition of return (IOR) after remember (R) and forget (F) instructions across all three experiments 32

Figure 2.4: Descriptive statistics for Experiment 2 37

Figure 2.5: Descriptive statistics for Experiment 3 41

Figure 2.6: Scatterplot depicting the relation between the magnitude of the directed-forgetting effect (proportion of remember [R] items recognized – proportion of forget [F] items recognized) and the magnitude of the F > R IOR difference (F IOR – R IOR) across all three experiments 46

Figure 3.1: Progression of a trial in Experiments 1 and 2 60

Figure 3.2: Mean RT in ms after R and F memory instructions to targets appearing in the same and different locations compared to the word in Experiment 1 63

Figure 3.3: Mean RT in ms after R and F memory instructions to targets appearing in the same and different locations compared to the word in Experiment 2 67

Figure 3.4: Mean RT in ms after R and F memory instructions to targets appearing in the same and different locations compared to the word in Experiment 3 71

ABSTRACT

This dissertation investigated the occurrence of an increased magnitude of inhibition of return (IOR) after Forget (F) compared to Remember (R) memory instructions using a directed forgetting cueing paradigm. In such a paradigm, participants are presented with a word in a peripheral location, which is followed by an R or F instruction. A target then appears either at the same location as the previous word, or at a different peripheral location. Participants are required to respond to this target as quickly as possible. Typical results in this task show that participants are slower to respond to targets that appear in the same location as a previously presented word compared to targets appearing in a new location, this is known as IOR. Interestingly, there is an interaction between memory instruction and IOR such that the magnitude of IOR is greater after F compared to R instructions. Previous investigations of this F>R IOR difference suggested that it results from a bias against responding toward the location of F-items, and thus that memory instruction interacts selectively with the motoric form of IOR (Taylor & Fawcett, 2011). The experiments in Chapter 2 tested three alternative hypotheses but found no support for those alternative hypotheses. The experiments in Chapter 3 used eye tracking technology to control whether the oculomotor system was active or suppressed. This allowed an explicit test of whether memory instruction interacts with motoric IOR (which occurs when the oculomotor system is active) and with visual IOR (which occurs when the oculomotor system is suppressed). Contrary to Taylor and Fawcett's (2011) conclusion, memory instruction interacted with both the motoric and visual forms of IOR. I conclude that instantiating an instruction to forget involves a stage of processing that is shared between the motoric and visual forms of IOR. I discuss the possibility of this process being the differential withdrawal of attention from F compared to R items, or differential modification of the mental salience of information related to F compared to R items.

LIST OF ABBREVIATIONS USED

ANOVA	Analysis of Variance
DF cueing paradigm	Directed Forgetting Cueing Paradigm
DF effect	Directed Forgetting Effect
EEG	Electroencephalography
ERP	Event-Related Potential
F>R IOR	Greater magnitude of inhibition of return after forget compared to remember instructions
F	Forget
FA	False Alarm
fMRI	Functional Magnetic Resonance Imaging
FOE	Fixation Offset Effect
F items	Forget-instructed items
IOR	Inhibition of Return
IPS	Intra-Parietal Sulcus
R	Remember
RT	Reaction Time
rTMS	Repetitive Transcranial Magnetic Stimulation
R items	Remember-instructed items
S-R	Stimulus-Response
SC	Superior Colliculus
SOA	Stimulus Onset Asynchrony
TPJ	Temporo-Parietal Junction

ACKNOWLEDGEMENTS

Describing and interpreting the results of an experiment is ever so much simpler than thanking those who have guided and supported me throughout this process. In the place of statistical tests and figures with error bars, I have memories of times when I felt doubt, and found encouragement. Times when I felt lost, but found understanding. I would like to thank the following people for their truly significant effect on me, and for supporting and guiding me throughout the completion of this dissertation.

To my supervisor, Dr. Tracy Taylor-Helmick: You sparked an insatiable interest in cognitive psychology in me. You offered me an opportunity to work in your lab where I connected with other like-minded students, and my passion grew. When it came time to apply to graduate programs, you were happy to accept me into the lab as a student. You have been passionate, kind, relaxed, and understanding. My admiration and respect for you remains the same now as it was then, but I never could have imagined the wonderful feeling of transforming from your student into your friend and colleague. Thank you for your inspiration and instruction.

To my committee members, Dr. Gail Eskes and Dr. Ray Klein: I want to thank you both for the time and energy you have put into helping me design and evaluate my research. You have both been consistently insightful, and very patient with me. Our meetings were perhaps infrequent, but always enjoyable. I am lucky to have had access to your keen insights and expertise. Of course, I would also like to thank my external examiner, Dr. Colin MacLeod, whose research served as my introduction to the field of directed forgetting. Your expertise is so perfectly suited for assessment of this work, and your approval of its quality is something I would be proud of.

To my labbies Jon, Chelsea, and Tom: Thank you for stimulating academic discussions, and for necessary distractions. Here's to putting up tents indoors, cooking chicken in fondue, and not being afraid to break a few glasses. You all made my transition into the lab a time of such fun, and I will never forget it.

Not all of the support I have received has been academic in nature. My family and friends provide me with an abundance of unconditional love and encouragement. To my parents, Brian and Andrea Thompson: You somehow knew all along that I could do this. Thank you for never hesitating to support me emotionally or financially when I needed it. Thank you to my grandparents, Harley and Mona Thompson, and Geneva Babineau who have also never hesitated in their willingness to support my academic pursuits. To my brother Sam: I always know I can tell you anything, and I know you'll always be there for me with a sympathetic ear to listen, just as I will be for you. To my friends, Julia, Kim, Kimmie, Karyn, Amber, Jason, Shawn, and so many more: Thank you for listening to me talk about my research when I wanted to, and for distracting me when I needed to think about something else.

To Chris McCain: Thank you for being with me all this time, and thank you for wanting to be with me forever. We've been living our life together this whole time, but the completion of this dissertation in some ways signifies a new beginning for us. I can't wait to marry you. To Dave and Barb McCain, and Guy, Jane, and Claire LeBlanc: Thank you for making me a part of your family.

Chapter 1 Introduction

This dissertation investigates our ability to intentionally forget irrelevant information by assessing the cognitive consequences of instantiating an instruction to forget in an item-method directed forgetting paradigm. Prevalent theories of how we selectively remember and forget information in such a paradigm assume that forgetting is a passive process (Bjork & Woodward, 1973; Woodward, Bjork, & Jongeward, 1973; MacLeod, 1975; Basden, Basden, & Gargano, 1993). However, there is strong evidence that forgetting is very much an active, cognitively demanding process (Bastin, Feyers, Majerus et al., 2012; Fawcett & Taylor, 2008; Hauswald, Schulz, Iordanov, & Kissler, 2001; Hsieh, Hung, Tzeng, Lee, & Cheng, 2009; Lee, 2012; Lin, Kuo, Liu, Han, & Cheng, 2013; Paz-Caballero, Menor, & Jimenez, 2004; Ullsperger, Mecklinger, & Muller, 2000; van Hoof & Ford, 2011; Wylie, Foxe, & Taylor, 2008; Zacks, Radvansky, & Hasher, 1996). Researchers differ in opinion about the specific active mechanism/s that are associated with forgetting. This dissertation concerns the finding that participants redirect their attention away from unwanted information when they are told to forget, supposedly to stop it from being encoded (Taylor, 2005). This redirection of attention, while freeing attentional resources for the rehearsal of relevant information, has consequences for subsequent information processing related to the unwanted information and other information that is presented in close spatial or temporal proximity (Fawcett & Taylor, 2010; Fawcett & Taylor, 2012; Fawcett, Taylor, & Nadel, 2013; Hourihan, Goldberg, & Taylor, 2007; Taylor & Fawcett, 2011). I will investigate the nature of these consequences to determine what they can tell us about how we forget, and how forgetting impacts our behaviour.

1.2 On Forgetting

There are a few experimental paradigms designed to investigate intentional forgetting. The paradigm of interest for this dissertation is a type of directed forgetting paradigm (for reviews, see Basden & Basden, 1998; MacLeod, 1998). In a directed forgetting task, participants are presented with information during the study phase, some of which they are instructed to remember (R), and some of which they are instructed to forget (F). Participants are then given a memory test for both R and F items. Typically, recall is significantly better for R items than F items, a directed forgetting effect (DF effect). Depending on the specific methodology, one might enact different strategies to intentionally forget information. Ignorance of this fact was the source of some confusion in early research on directed forgetting, as investigators have noted (Basden et al., 1993; Basden, 1996; MacLeod, 1998; MacLeod, 1999). Researchers were using two fundamentally different paradigms to investigate intentional forgetting, and having trouble reconciling apparent discrepancies in their findings. These two different paradigms have come to be known as the list method and the item method, and differ with respect to the timing and frequency of instructions to remember and forget information (for reviews, see Basden & Basden, 1998; MacLeod, 1998).

In a list-method directed forgetting paradigm, participants are told that they will be presented with a list of items that they should try to remember for a later memory test. After this first list is presented, some participants are informed that they will actually need to forget those items (e.g., “That was just a practice list, you don’t need to remember it.”). Then, a second list is presented that all participants are told to try and commit to memory. In an item-method directed forgetting paradigm, participants are presented with items one at a time, and after each item participants are given either an R or F instruction. In both paradigms, once all study items have been presented, a memory test for both R and F items is administered. When a participant’s memory is tested with a free recall test, a DF effect emerges, and this effect is characterized by both costs and benefits of forgetting (MacLeod, 1998; Basden & Basden, 1998; Sahakyan & Goodmon, 2007; Sheard & MacLeod, 2005). There are ‘costs’ of forgetting because participants remember fewer F items compared to control participants who were not told to forget (i.e., participants successfully implement the instruction to forget). There are also benefits of forgetting because participants who were told to forget some items remember *more* R items than participants who were not told to forget. Thus, a participant’s memory for relevant information can be aided by having forgotten irrelevant information.

While the DF effect is robust in tests of item recall, early research found conflicting results when assessing the DF effect with recognition memory tests. That is, the DF effect did not emerge reliably when a recognition memory test was used. These apparently discrepant findings were eventually clarified by differentiating between the list and item methods (Basden et al., 1993; Basden, 1996; MacLeod, 1999). MacLeod (1999) conducted a thorough investigation of the differences between these two methods. Participants were presented with either an item-method or list-method directed forgetting study phase, which was followed by a recall memory test, a recognition memory test, and, finally, a tagging memory test in which participants were asked to identify the memory instruction that had been presented with each study item. Whereas a DF effect was found for both the item and list methods on the recall memory test, the same was not true of the recognition memory test. Only participants in the item-method paradigm displayed a significant DF effect on the recognition test. The lack of a DF effect in recognition for the participants in the list-method paradigm appeared to be due to increased memory for F items in these participants compared to participants in the item-method paradigm. This difference, along with evidence that participants were faster to recognize R items compared to F items in the item-method paradigm, suggested a fundamental difference in the way that F items are 'forgotten' in these two tasks.

The DF effect obtained in a list-method directed forgetting paradigm is best explained as either due to a temporary suppression of F items at the time of retrieval (retrieval inhibition; Bjork, 1989), or as resulting from mental context shifts between lists and at the time of test (Lehman & Malmberg, 2009; Sahakyan & Kelley, 2002). Thus, F items have been encoded, but some kind of mental restructuring occurs at test to impede recall of those items. According to the retrieval inhibition account, access to the episodic trace associated with the items in the to-be-forgotten list is blocked or inhibited, which impairs their retrieval compared to items in the to-be-remembered list (Bjork, 1989; Geiselman, Bjork, & Fishman, 1983). According to the contextual change account, the DF effect emerges because participants who were told to forget the first list are likely to think of the two lists as separate events. Participants told to remember both lists, on the other hand, are likely to think of the lists as one event. Thus, participants who are told to forget will create separate mental contexts for the two lists. Mental context can have a significant impact on retrieval such that matching study and test context is beneficial for retrieval whereas changing context between study and test can be detrimental (Eich, 1980; Sahakyan & Kelley, 2002). Participants who were instructed to forget have to access two separate mental contexts to retrieve study items, and this is particularly challenging for the to-be-forgotten list, whose context is no longer active. Participants who were not told to forget, however, only need to access one mental context that has been continuously active (Sahakyan & Kelley, 2002). Both the retrieval inhibition account and the contextual change account are consistent with the evidence that the DF effect in the list-method paradigm depends on search processes that are necessary with recall, but are not required when the items are directly presented to participants, as in a recognition memory test (e.g., Jacoby & Hollingshead, 1990; Tulving, 1976): The re-presentation of F items in a recognition test is thought to release the F items from inhibition (Bjork, 1989), or to reactivate the mental context associated with F items (Sahakyan & Kelley, 2002), allowing them to be remembered.

In an item-method paradigm, the evidence suggests that encoding processes resulting in deep encoding of R items and shallow encoding of F items are responsible for the DF effect. The Selective Rehearsal hypothesis (Bjork & Woodward, 1973; Woodward, Bjork, & Jongeward, 1973; MacLeod, 1975; Basden et al., 1993) states that study items undergo minimal processing until the memory instruction is presented. Maintenance rehearsal serves to keep the item in working memory, and further processing depends on the memory instruction. When an R instruction is presented, participants then engage in elaborative encoding of the study item. However, when an F instruction is presented, processing of the item stops to avoid encoding this information into long-term memory. This differential encoding results in the encoding of relatively more R items than F items. That fewer F items are successfully encoded is supported by the fact that the DF effect in the item method occurs even when F items are presented on a recognition test.

Thus, the re-presentation of items improves memory performance for F items in a list method paradigm by lifting retrieval inhibition and/or reinstating study context, but this clearly does not occur in an item-method paradigm – memory for F items is still poor on recognition tests. In an item-method paradigm, participants are also faster to recognize R items than F items, indicating that even when F items are remembered, the memory traces associated with these items are weaker than the traces associated with R items (MacLeod, 1999). Not only this, but it has been shown that participants are more likely to tag their false alarms (FAs; erroneous ‘yes’ responses to Foil items) as having been associated with an F instruction than an R instruction, suggesting that participants’ subjective experience of F item memories is relatively weak (as, supposedly, a FA memory would be; Thompson, Fawcett & Taylor, 2011). In the item method, F items are less likely to be encoded than R items, and the F items that are encoded are characterized by a weaker memory trace than R items.

Observation of the DF effect in the item method has been shown to be specifically dependent on differences in episodic/contextual memory associated with R and F items, not differences in familiarity/priming. A number of researchers have investigated the notion using a Remember/Know memory test instead of recognition (Basden, 1996; Gardiner, Gawlik, & Richardson-Klavehn, 1994). In a Remember/Know task (Tulving, 1985), participants are presented with a list of items at study that may undergo a variety of processing manipulations (e.g., a levels of processing manipulation; Gardiner, 1988). At test, instead of simply indicating whether they recognize each item with a yes/no response, participants are asked to categorize the items that they recognize as either Remembered or Known. If their memory for the item is associated with episodic or contextual details from the item’s presentation in the study phase, they should classify it as a Remember item. Making a Remember judgment indicates that the participant has an episodic memory of the item. If participants are fairly confident that the item was presented at study, but they do not have an explicit or concrete memory of the item’s presentation at study, they should classify it as a Know item. Making a Know judgment indicates that the item is familiar, but not associated with any episodic details (Tulving, 1985).

In an item-method directed forgetting paradigm, when participants are given a Remember/Know memory test, a DF effect is seen for Remember responses, but not for Know responses (Basden, 1996; Gardiner et al., 1994). Thus, it is the episodic details of F item presentation that are particularly vulnerable to forgetting. In addition, research has shown that the DF effect occurs only in direct tests of memory. While an early investigation by MacLeod (1989) demonstrated DF effects in both direct (recognition) and indirect (word fragment completion) memory tests, these results may have been contaminated by participants using direct memory strategies to complete the indirect memory test in that experiment. In fact, subsequent investigations have found the DF effect only in direct memory tests (Paller, 1990; Basden et al., 1993). This, like the Remember/Know results, shows that the impairment in memory for F items in the item-method is due in large part to a decrement in episodic encoding of F items compared to R items since direct memory tests are sensitive to differences in encoding of episodic/contextual details, whereas indirect memory tests are not (Basden et al., 1993; MacLeod, 1989; Paller, 1990; Tulving, 1985).

The Selective Rehearsal Hypothesis of the DF effect in item-method directed forgetting assumes that the cessation of rehearsal for F items is passive (Basden et al.; 1993). Some theorists, however, propose that forgetting is a cognitively effortful process (Fawcett & Taylor, 2008; Lee, 2012), potentially involving some kind of inhibitory process (e.g., Zacks et al., 1996). In recent years there have been a number of item-method directed forgetting studies that have used electroencephalography (EEG) to gain an understanding of the neural correlates of remembering and forgetting. These studies have yielded some fairly consistent results supporting the notion that instantiating instructions to remember and to forget involves qualitatively different kinds of processing. Investigations of event-related potentials (ERPs) during the study phase of an item-method directed forgetting task have shown that the onset of an F-instruction is associated with a frontally distributed positivity, whereas R-instructions are associated with a parietally distributed positivity (Hauswald et al., 2011; Paz-Caballero et al., 2004; Hsieh et al., 2009; van Hoof & Ford, 2011; Lin et al., 2013). The frontal positivity is usually described as an inhibitory process that serves to impede or suppress processing of F items. There have also been a number of functional magnetic resonance imaging (fMRI) investigations of item-method directed forgetting that converge on the notion that intentional forgetting involves frontal control processes in areas like the medial frontal gyrus, and is also associated with medial temporal activation that is distinct from activation associated with remembering (Bastin et al., 2012; Wylie et al., 2008). This might represent frontal control mechanisms acting on the medial temporal lobe to suppress episodic memory formation of F items.

Finally, there is also behavioural evidence that forgetting not only is an active process, but that it is initially even more cognitively demanding than remembering. Fawcett and Taylor (2008) presented participants with a target detection task after each memory instruction in an item-method directed forgetting paradigm and found that participants were significantly slower to detect targets after F compared to R instructions. Particularly relevant to the present dissertation is a series of studies conducted by Taylor investigating the relation between inhibition of return (IOR) and directed forgetting (Fawcett & Taylor, 2010; Taylor, 2005; Taylor & Fawcett, 2011). Before describing the results of these studies, which were the direct precursors to this dissertation, it is important to first gain an understanding of IOR, and what it can tell us about attentional allocation and the consequences of attentional withdrawal on subsequent information processing.

1.3 On Inhibition of Return

Research on the orienting of attention in visual space has shown that the processing of stimuli that fall within the current focus of attention is facilitated (Eriksen & Hoffman, 1972; Sperling, 1960), and that the processing of stimuli in locations from which attention has been withdrawn is impeded (Klein, 2000; Posner & Cohen, 1984). The Posner cueing paradigm (e.g., Posner, 1978; Posner, 1980; Posner & Cohen, 1984) has been extremely influential in this research. In this spatial cueing task, participants typically are presented with a central fixation stimulus, and two peripheral locations marked in some way with placeholders (e.g., two outline boxes). Participants are first presented with a visual cue followed after a delay by a target that requires some kind of response, such as localization (e.g., a manual button press with the left hand for a target on the left, or with the right hand for a target on the right; see Figure 1.1). When the stimulus onset asynchrony (SOA) between the cue and the target is relatively short (less than ~300 ms), participants' reaction time (RT) to respond to the target is faster and more accurate to targets appearing in the same location as the cue (i.e., cued targets) compared to targets appearing in the other location (i.e., uncued targets). This pattern of results is known as facilitation, and is thought to result from increased efficiency of processing at the cued location due to the automatic capture of attention by the cue (Posner, 1980; Posner, Snyder, & Davidson, 1980; Posner & Cohen, 1984).

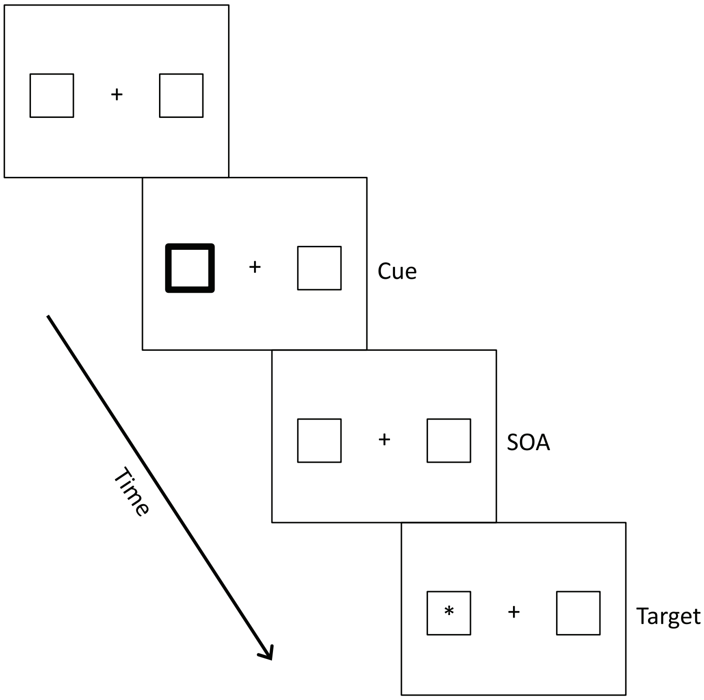


Figure 1.1: Depiction of the trial progression in a standard cueing paradigm.

A different pattern of results is observed in this task when the SOA is extended beyond ~300 ms. Instead of facilitation at the cued location, participants display increased RT at the cued location compared to the uncued location. This pattern has been termed Inhibition of Return (IOR; Posner, Rafal, Choate, & Vaughan, 1985), and has been the topic of a great deal of research over the past 30 years (for reviews, see Klein, 2000; Klein & Hilchey, 2011). IOR is commonly understood as a foraging facilitator – a mechanism that aids visual search of the environment by encouraging the inspection of previously uninspected locations (Klein & MacInnes, 1999; Klein, 2000; MacInnes & Klein, 2003; Wang & Klein, 2010). IOR is thought to be initiated at the onset of the cue, but will only be revealed in RTs after attention – and, therefore, facilitation – has been withdrawn from the cued location (Danziger & Kingstone, 1999; but see Lupianez, 2010).

There are a number of variations of the basic cueing paradigm that allow investigation of different kinds of attention. Research on attention has long differentiated between overt and covert orienting of attention (e.g., Posner, 1978). While overt behaviours like eye and head movements are typically synonymous with the orientation of attention (especially in everyday life), attention *can* be oriented covertly to peripheral locations while the eyes remain fixed (Klein, 2004; Posner, 1980; Wright & Ward, 2008). Thus, while attention and eye movements typically are paired, they can function separately. Manipulating whether participants must maintain fixation or make saccades to cues and/or targets in a cueing paradigm allows assessment of covert and overt attentional orienting, respectively.

Attention may be captured exogenously by sudden visual onsets, or it may be directed endogenously to locations that a participant knows – or is told – are likely target locations (Posner, 1980). When the cue is direct/peripheral (e.g., a peripheral onset), it automatically draws attention exogenously. Symbolic/central cues that indicate a peripheral location (e.g., centrally presented arrows) guide endogenous attention. In addition, the validity of the cue can influence endogenous orienting. If the cue is predictive of the target location (e.g., on 80% of trials the target appears in the cued location), the cue will be more effective in drawing endogenous attention than if the cue is not predictive of target location (e.g., the target is equally likely to appear at the cued or uncued location). Typically, a cueing task intended to assess exogenous attentional capture consists of non-informative peripherally presented cues. A task intended to assess endogenous attentional allocation consists of centrally presented cues that are predictive of target location (Klein, 2004; Posner, 1980; Wright & Ward, 2008).

It was originally thought that IOR was generated by oculomotor activation (Klein, 2000; Rafal, Calabresi, Brennan, & Sciolto; 1989). Rafal et al. (1989) presented participants with either peripheral or central cues, and had participants execute a saccade to the cue, prepare (but not execute) a saccade to the cue, or simply attend to the location indicated by the cue. When participants either prepared or executed a saccade to the cue, IOR was observed following both peripheral and central cues. However, when participants simply attended to the cue location while maintaining central fixation, IOR was only observed following a peripheral cue, and not a central cue. This last finding suggested that IOR requires activation of the oculomotor system. However, Rafal et al.'s findings have not been replicated (Chica, Klein, Rafal, & Hopfinger, 2010a; but see Hilchey, Klein, & Satel, 2014).

A series of experiments by Henderickx, Maetens, and Soetens (2012) provides evidence for another potential cause of IOR. They, and others (Sapir, Hayes, Henik, Danziger, & Rafal, 2004; Vivas, Humphreys, & Fuentes, 2006) have hypothesized that IOR results from modulation of a low-level visual saliency map. In exogenous cueing conditions, this occurs automatically as a result of the reflexive orienting of attention to the peripheral onset of the cue. However, in endogenous cueing conditions, the low-level saliency map must be modulated top-down. This could be done by initiating a saccade to the cued location (as has been done in previous investigations of IOR; Hilchey et al., 2013; Taylor & Klein, 2000), but could theoretically be accomplished in other ways as well. They tested this theory by presenting participants with a coloured fixation stimulus that indicated which peripheral location they should direct their attention to covertly (without making a saccade). Two coloured peripheral cues appeared simultaneously, with only one matching the colour of the central fixation stimulus. In some experiments, the peripheral cues appeared after the onset of the fixation stimulus, allowing time for the colour of the fixation point to be processed in working memory. In other experiments, the peripheral cues appeared either slightly before or simultaneously with the fixation stimulus. The peripheral cues were followed by a target that required a manual localization response. IOR was only seen in experiments where participants were provided with enough time for the fixation colour to be processed before peripheral cues appeared. Thus, Henderickx et al. (2012) found support for the hypothesis that IOR is generated any time a peripheral location is afforded processing that modulates the low-level spatial saliency of that location in a mental saliency map. This modulation occurs automatically when exogenous cues are used, but can also be accomplished by making a saccade to an endogenously cued location, or by covertly processing an endogenously cued location.

Regardless of whether IOR is generated by oculomotor activation (Hilchey et al., 2014; Klein, 2000; Rafal et al., 1989) or by the modification of the mental salience of visual locations or objects (Henderickx, et al., 2012), the subsequent effects on information processing have been shown to vary based on the state of the oculomotor system. That is, there are two forms of IOR that can be observed depending on whether the eyes are free to move to the location of the cue and/or target, or must remain fixed. When the eyes are free to move, IOR presents as a motor bias against making responses toward the cued location – the response itself (saccade or manual) is slowed. When the eyes remain fixed during the trial, the oculomotor system is suppressed, and IOR presents as a perceptual decrement for information arising at the cued location – it takes longer to process information at the cued location. The differentiation between these two forms of IOR (motoric and visual) was first supported empirically in a thorough investigation by Taylor and Klein (2000).

Taylor and Klein (2000) presented participants were presented with a cue followed by a target. They varied the type of cue and target (peripheral vs. central), the response required for the cue (none, manual localization, or saccadic localization), and the response required for the target (manual localization, or saccadic localization). They predicted that if IOR was motoric in nature, a motor bias against responding toward a cued location would emerge any time the cue caused the programming of a saccade to that location (in this experiment, this would occur with peripheral cues or when a saccade was made to a central cue). On the other hand, if IOR was visual in nature, slowed perception of information at the cued location, rather than a motor bias, would emerge. To assess whether the observed IOR was the result of a motor bias or a perceptual decrement, they were particularly interested in whether a centrally presented target would result in IOR. Since a central arrow does not require perception of the cued location itself to make a response, but instead endogenously drives the target response, observing IOR in response to central targets supports the notion that IOR is motoric in nature. A critical finding from this investigation was that IOR was observed anytime a saccade was made to the location indicated by a cue or target, *even if the target was a centrally presented arrow*. As just described, this slowed RT to cued targets could not be explained by slowed perception of information at the cued location because central targets do not require perception of the peripheral location. However, they also found that when no saccades were made during the trial, IOR *was not observed* in response to central targets, even when a peripheral cue should have reflexively activated saccade programming. Thus, direct stimulation of the peripheral location is required to observe IOR when the oculomotor system is suppressed. Taylor and Klein (2000) concluded that IOR reflects slowed or degraded perception of information appearing at the cued location when the oculomotor system is suppressed (i.e., IOR is only observed to targets that appear at the cued location where perception is slowed, not central targets directing responses to the cued location). When the eyes are free to move, IOR reflects a motor bias against responding toward the cued location (Taylor & Klein, 2000), and can therefore be measured in responses to central as well as peripheral targets.

To summarize, Taylor and Klein (2000) found evidence of two distinct types of IOR. When the eyes remain fixed, IOR presents as impaired perceptual processing of information at the location of a previously presented cue. This visual/perceptual form of IOR, then, is only observed in tasks that require detailed perception of information at the cued location to make the required response. This includes any response to a peripherally presented target, including non-spatial discrimination responses such as a colour discrimination. When the oculomotor system is active and the eyes are allowed to move during the task, IOR presents as a motor bias against responding toward the cued location. This motoric form of IOR is observed anytime a response is made toward the cued location. Critically, the target itself does not necessarily have to appear at the cued location. This is because it is the response itself (saccade or manual) that is slowed, not perception of the target (Taylor & Klein, 2000).

Further investigation has supported the distinction between the motoric and visual forms of IOR. Hunt and Kingstone (2003) found a double dissociation between visual and motoric IOR. They manipulated target luminance such that half of the targets were bright and half were dim. This is a perceptual manipulation that should only influence the visual form of IOR (Hunt & Kingstone, 2003; Reuter-Lorenz, Jha, & Rosenquist, 1996). They also incorporated a fixation offset manipulation where on half of all trials the fixation point remained visible throughout the trial, and on the other half of trials the fixation point was removed when the target appeared. This manipulation is known to result in a fixation offset effect (FOE; also known as the gap effect; Abrams & Dobkin, 1994; Saslow, 1967) where saccadic RT is faster to peripheral targets when the fixation stimulus is removed compared to when it remains visible. The FOE has been shown to interact with IOR such that the magnitude of IOR is greater on fixation offset trials compared to when fixation remains visible. This interaction suggests that both IOR and the FOE involve the inhibition of saccade production (a motoric account of IOR; Abrams & Dobkin, 1994). Hunt and Kingstone (2003) found that when the eyes remained fixed, IOR interacts with target luminance, but does not interact with the FOE. Conversely, when saccades are made to targets, IOR does not interact with target luminance, but does interact with the FOE. Thus, when the eyes remain fixed, IOR reflects impaired perceptual processing of information at the cued location, and does not involve oculomotor processes related to a response bias. When the eyes move, IOR reflects a response bias against the cued location, and does not involve perceptual processes.

Other research has shown that the visual and motoric forms of IOR do not co-occur in behavior, and that they are therefore dissociable from one another (Taylor & Klein, 2000; Chica, Taylor, Lupiáñez, & Klein, 2010b; Hilchey, Klein, & Ivanoff, 2012). If the motoric and visual forms co-occurred (i.e., were additive with one another), it would be expected that the magnitude of IOR would be greater when saccades were made to peripheral compared to central stimuli. This is because responding to a peripheral target involves a motoric component – the saccade – as well as a perceptual component – the inspection of the previously cued peripheral location. However, Hilchey et al. (2012) found that the magnitude of IOR is the same when participants are required to make saccades regardless of whether the cues and targets are presented centrally or peripherally (see also Taylor & Klein, 2000). Similarly, Chica et al. (2010b) did not observe typical visual IOR effects when participants were required to make saccades to cues or targets.

The distinction between motoric and visual forms of IOR is also supported by neurophysiological research. Patients with right brain damage resulting in left visual neglect showed facilitation rather than IOR on trials that required manual responses to targets and no eye movements, but showed normal IOR on trials that required saccadic localization of targets (Bourgeois, Chica, Migliaccio, Thiebaut de Schotten, & Bartolomeo, 2012). Thus, they showed impaired visual IOR, but intact motoric IOR. In a follow up to this experiment, a similar dissociation was observed in healthy participants after repetitive transcranial magnetic stimulation (rTMS) to either the right intra-parietal sulcus (IPS) or the right temporo-parietal junction (TPJ; Bourgeois, Chica, Valero-Cabre, & Bartolomeo, 2013). Disruption of both the right IPS and TPJ resulted in impaired visual IOR for right-sided targets, but intact motoric IOR was observed. For left-sided targets, disruption of the right IPS resulted in impairments of both visual *and* motoric IOR, but disruption of the right TPJ did not impair either form of IOR. Clearly, these two forms of IOR are associated with at least partially distinct neural processes.

Despite these two distinct consequences of attentional withdrawal on information processing (visual and motoric IOR), the phenomenon of IOR is still generally interpreted in a unitary way as a mechanism that supports visual search for novelty, as described above (although see Hilchey et al., 2014). It is likely that the two forms are caused by, or at least share, some of the same processes. Perhaps, for example, both are associated with a decrease of the mental salience of the cued locations in a mental salience map (Henderickx et al., 2012). Regardless of whether this decrease in mental salience results in slowed visual/perceptual processing or a motor bias (depending on the state of the oculomotor system), the end result is functionally the same: We are discouraged from reinspecting or responding to information that we have recently attended (Klein & MacInnes, 1999; Klein, 2000; MacInnes & Klein, 2003). This allows us to direct our attention to new, behaviourally relevant information. While IOR is generally interpreted with reference to processes relevant to visual search of the environment, the idea that similar principles could be involved in directing attention to mental structures like the contents of memory has long been present in research on attention (Posner, 1980), and has continued to be influential (Ciaramelli, Grady, &

Moscovitch, 2008; Cabeza, 2008; Silver & Kastner, 2009). Indeed, we have found support for this notion in our research on intentional forgetting.

1.4 IOR and Directed Forgetting

The first investigation of IOR in directed forgetting was by Taylor (2005). Taylor (2005) created an item-method directed forgetting cueing paradigm (DF cueing paradigm) in which participants were presented with a word in one of two peripheral locations (the word here serves as the cue for generating IOR). Each word was followed by an auditory instruction to either Remember or Forget it, then, after a relatively long SOA with respect to the onset of the word (1200 ms), a target appeared in one of the two peripheral locations. Participants were required to make a manual localization response to the target. Taylor found that the magnitude of IOR (the difference between RT at the cued vs. uncued location) was significantly greater after F compared to R instructions (F>R IOR). Compared to a no-memory control condition, the magnitude of IOR is consistently magnified following F instructions, and sometimes reduced after R instructions (Taylor, 2005; Fawcett & Taylor, 2010; Taylor & Fawcett, 2011). Thus, while it appears that some participants allow their attention to dwell on R items (leading to reduced IOR), the F>R IOR difference is primarily due to increased IOR after F instructions.

While IOR is thought to be initiated by the cue, it is not revealed in RTs until attention has been withdrawn from the cued location (Danziger & Kingstone, 1999). That is, facilitation and IOR are thought to be independent, additive effects that co-occur after the onset of the cue. While IOR begins with cue onset, slowing responses to the cued location, the speeded processing due to attentional capture by the cue is initially stronger, leading to faster RTs at cued vs. uncued locations. However, because the cue (or study item in the case of DF cueing) is not indicative of the subsequent target’s location, attention is removed from the periphery to a location equidistant from all potential target locations to maximize the speed of target responses. Once attention has been removed, IOR at the cued location is no longer masked by facilitation, and is revealed as slowed RTs to cued vs. uncued locations (Klein, 2000; Danziger & Kingstone, 1999). On this basis, Taylor (2005) thus concluded that the F>R IOR difference suggests that participants more readily withdraw their attention following F than R instructions. She reasoned that a more ready withdrawal of attention after F compared to R instructions leads to differential unmasking of IOR generated by the cue by removing the facilitatory effects of attention directed at the item location. The redirection of attention is cognitively demanding, and therefore converges with the idea that intentional forgetting is effortful (Fawcett & Taylor, 2008). Given the important role attention has for encoding in most models of memory (Broadbent, 1958; Atkinson & Shiffrin, 1968), freeing attentional resources so that they might be redirected to relevant information, while limiting the processing of irrelevant information, might be partially responsible for successful forgetting.

Since Taylor's (2005) first DF cueing experiment, the F>R IOR difference has been further investigated to determine what processes are shared between IOR and intentional forgetting in the item-method paradigm (Fawcett & Taylor, 2010; Taylor & Fawcett, 2011). Taylor and Fawcett (2011) manipulated the type of response required to the target in the DF cueing paradigm to determine whether memory instruction interacts with both the visual and motoric forms of IOR. In one experiment, participants were required to localize the target with a manual button press. IOR in this type of task should be motoric in nature since eye movements are not restrained, and a motoric response toward the target location is required (Chica et al., 2010b; Hilchey et al., 2012; Hunt & Kingstone, 2003; Taylor & Klein, 2000). In another experiment, participants were required to make a non-spatial discrimination response. Targets were either upright or inverted triangles that could appear at either the cued or uncued location. Regardless of target location, participants pressed one button when the target was an upright triangle, and another when it was inverted. IOR in this type of task should be visual in nature since the response requires detailed perception of the target's identity, but the spatial location of the target is irrelevant (but see Chica et al., 2010b, and Hilchey et al., 2012). When participants made a localization response to the target, there was an F>R IOR difference, replicating Taylor's (2005) results. However, when participants made a non-spatial discrimination response to the target, the F>R IOR difference was not observed. Taylor and Fawcett interpreted this as evidence that memory instruction in item-method directed forgetting interacts with the motoric form of IOR, but not the visual form. They concluded that instantiating an instruction to forget results in a motor bias against making responses to the source (in this case, spatial location) of irrelevant information, which is the same kind of bias that results in motoric IOR (Taylor & Klein, 2000), and may also be similar to inhibition of prepotent overt responses in tasks such as stop-signal inhibition (Fawcett & Taylor, 2010; Hourihan & Taylor, 2006). They proposed that such a bias might serve the purpose of allowing the additional accumulation of information from a dubious source. This would effectively allow more careful scrutiny of the nature of the information before allowing it access to limited processing resources.

This dissertation builds upon the results of Taylor and Fawcett (2011) to more thoroughly test the conclusions that were reached in that investigation, and to understand the implications of F>R IOR for theories of item-method directed forgetting. Chapter 2 contains a manuscript published in *Attention, Perception, & Psychophysics* that tests a number of alternative hypotheses that could rival the conclusions reached by Taylor and Fawcett (2011). We found that attentional momentum cannot account for the F>R IOR difference, F>R IOR is not due to suppression of automatic stumulus-response code activation by the F instruction, and it is not due to slowed execution of responses made with a particular effector (hand). Ruling out these alternative interpretations of the F>R IOR difference lends some indirect support for Taylor and Fawcett's interpretation of the interaction as resulting from a bias against responding toward unreliable sources of information. Chapter 3 contains a manuscript published in *Attention, Perception, & Psychopysics* that makes use of eye tracking technology to more precisely manipulate whether the DF cueing task is visual or motoric in nature, allowing a more controlled test of the interaction of directed forgetting with these two forms of IOR. Interestingly, when carefully controlling eye movements, we found F>R IOR in both motoric *and* visual IOR tasks. This contradicts the conclusions reached by Taylor and Fawcett (2011), and the discrepancy between their investigations and our own are reconciled in a replication of their discrimination experiment in the context of our eye tracking paradigm. Whereas they failed to observe F>R IOR in a discrimination task where participants' eye movements *were not* restricted, we did find a significant F>R IOR difference when participants' eye movements *were* restricted. Finally, in Chapter 4, I conclude with a discussion of how our research has changed the view of the F>R IOR difference, and how this interaction informs us about the processes associated with intentional forgetting. I end with a full consideration of the processes that are thought to be involved in successful intentional forgetting, and consideration of how these results fit into the wider literature on attention and memory.

Chapter 2 Four Locations are Better than Two[1]

2.1 Abstract

In the item-method directed-forgetting paradigm, the magnitude of inhibition of return (IOR) is larger after an instruction to forget (F) than after an instruction to remember (R). In the present experiments, we further investigated this increased magnitude of IOR after F as compared to R memory instructions (dubbed the F > R IOR difference), to understand both the consequences for information processing and the purpose of the differential withdrawal of attention that results in this difference. A word was presented in one of four peripheral locations, followed by either an F or an R memory instruction. Then, a target appeared in either the same location as the previous word or in one of the other locations. The results showed that the F > R IOR difference cannot be explained by attentional momentum (Exp. 1), that spatial compatibility of the response options with target locations is not necessary for the F > R IOR difference to emerge (Exp. 2), and that the F > R IOR difference is location-specific rather than response specific (Exp. 3). These results are consistent with the view that F > R IOR represents a bias against responding to information emanating from an unreliable source (Taylor & Fawcett, 2011).

2.2 Introduction

Understanding how we are able to intentionally forget irrelevant information is critical to understanding how human memory works. Intentional forgetting is studied in the laboratory using a directed-forgetting paradigm. There are variations of this paradigm, and the present experiments focus on the item method (for reviews, see Basden & Basden, 1998; MacLeod, 1998). In this method, participants are presented at study with a list of items (usually words; although see, e.g., Quinlan, Taylor, & Fawcett, 2010) one at a time. Each item is followed with equal probability by an instruction to forget (F)

---

[1] This chapter has been reprinted with minor edits and with kind permission from Springer Science and Business Media, and has been previously published as: Thompson, K.M., Hamm, J.P., & Taylor, T.L. (2014). Effects of memory instruction on attention and information processing: Further investigation of inhibition of return in item-method directed forgetting. *Attention, Perception, & Psychophysics, 76*, 322-334.

or to remember (R). Once all items have been presented, participants are tested for their memory of both F-instructed items (F items) and R-instructed items (R items). In both recognition and recall tests of explicit memory, participants typically remember more R than F items, a pattern referred to as a directed-forgetting effect. Importantly, this effect does not appear to be due to demand characteristics (MacLeod, 1999).

Historically, forgetting has been viewed as the passive decay of information from memory (Bjork & Geiselman, 1978; Ebbinghaus, 1885). Thus, in the case of intentional forgetting, the directed-forgetting effect was thought to be due solely to preferential elaborate encoding of R items. However, recent studies have shown that in the item-method paradigm, an active process is also associated with instantiating an instruction to forget. Behavioral evidence that responding is slowed after F as compared to R instructions (e.g., Fawcett & Taylor, 2008) suggests that forgetting is more cognitively demanding than remembering. In addition, a plethora of neurophysiological data suggests that an active mechanism is associated with forgetting (Cheng, Liu, Lee, Hung, & Tzeng, 2012; Hauswald, Schulz, Iordanov, & Kissler, 2011; Ludowig, Möller, Bien, Münte, Elger, & Rosburg, 2010; Paz-Caballero & Menor, 1999; PazCaballero, Menor, & Jiménez, 2004; Ullsperger, Mecklinger, & Müller, 2000; van Hooff & Ford, 2011; Van Hooff, Whitaker, & Ford, 2009; Wylie, Foxe, & Taylor, 2008).

To better understand the active processes involved in intentional forgetting, Taylor (2005) investigated the withdrawal of attention after F and R memory instructions. To do this, she combined an item-method directed-forgetting paradigm with a cueing paradigm designed to test for inhibition of return (IOR; Posner & Cohen, 1984). IOR manifests as slowed reaction times (RTs) to targets that appear in the same location as a previous peripheral onset cue, relative to targets that appear in a different location (Posner & Cohen, 1984). Even though IOR is likely generated by the cue onset (e.g., Dorris, Klein, Everling, & Munoz, 2002; Klein, 2000; Tian, Klein, Satel, Xu, & Yao, 2011), the effect is generally only revealed in RTs once attention has been withdrawn from the location of the initial cue onset (Danziger & Kingstone, 1999). In Taylor (2005), participants were presented with words one at a time either to the left or right of an initial fixation stimulus. The word served as the peripheral onset cue used to generate IOR.

Each word was followed by an auditorily presented F or R instruction. Then, after a relatively long stimulus onset asynchrony (SOA; 1,200 ms), a visual target appeared with equal probability either in the same location as the word or in the opposite location. Participants were to indicate the location of the target by making a speeded spatially compatible buttonpress. Taylor found a greater magnitude of IOR after F than after R instructions (F > R IOR). She inferred from this result that attention is more readily withdrawn following F than following R instructions (see also Fawcett & Taylor, 2010).

Endorsing the view that the F > R IOR difference is likely caused by the differential withdrawal of attention from F- and R-item representations, Taylor and Fawcett (2011) further investigated this difference to determine the consequences that it has for subsequent information processing on F and R trials (see Taylor & Klein, 1998, for detailed discussion of the distinction between causes and effects of IOR). They presented peripheral words, followed by an F or an R instruction, and then by a visual onset target that required a simple detection, a choice localization, or a choice nonspatial discrimination (i.e., determining whether a target triangle was upright or inverted). Across a wide range of SOAs, an F > R IOR difference occurred for the choice localization response, but not for the simple detection or the nonspatial discrimination response. This pattern of results demonstrated that the interaction of memory instruction and IOR did not influence perceptual/attentional processing or response selection stages of information processing. Instead, using the distinction between perceptual and motor “flavors” of IOR (see Chica, Taylor, Lupiáñez, & Klein, 2010b; Hilchey, Klein, & Ivanoff, 2012; Taylor & Klein, 2000), Taylor and Fawcett (2011) argued that the F > R IOR difference reflects a bias against making subsequent responses toward the F-item location. Because the motor “flavor” of IOR is characterized as a bias against responding toward targets that arise in a previously cued location, this conclusion is premised on the notion that the bias—an aftereffect of the peripheral word onset—is enhanced by an intervening F instruction. Taylor and Fawcett suggested that this bias is not necessarily a mechanism by which successful instantiation of the memory instruction is accomplished (although see Fawcett & Taylor, 2010); instead, it may be a consequence of the intention to remember or forget. If so, this would suggest that an F instruction has the immediate effect of causing the rehearsal of the to-be-forgotten item to cease (see Hourihan &

Taylor, 2006), as well as the longer-term effect of biasing subsequent responses away from a source of information that has been deemed unreliable or irrelevant. In this way, an F instruction could influence not only the to-be-forgotten item, but also other information presented in close spatial or temporal proximity with it (e.g., Fawcett & Taylor, 2012).

Although the notion that responses are subsequently biased against the F-item location is an intriguing possibility, a response bias is not the only late-stage mechanism that could account for the F > R IOR difference that occurs for target localization but not for target detection or nonspatial discrimination responses. To understand the consequences that F and R instructions have for subsequent information processing, it is critical to determine whether a response bias is the only viable mechanism that might be operating. The fact that the F > R IOR difference does not occur for a choice discrimination response but does occur for a choice localization response rules out differences in response selection following F and R instructions. However, several other candidate operations must also be ruled out to provide a confident understanding of the processing consequences of F and R instructions. The experiments presented here attempt to test and rule out three such hypotheses.

In three experiments, we presented participants at study with a central fixation box surrounded by four peripheral boxes (located in the top right, top left, bottom right, and bottom left of the computer screen). On each trial, a study word was presented with equal probability at one of the four peripheral locations, which was followed by an auditory F or R memory instruction. Then, a visual target requiring a speeded buttonpress response appeared with equal probability at one of the four peripheral locations.

In contrast to previous studies that have assessed the F > R IOR difference using only two word–target locations (Fawcett & Taylor, 2010; Taylor, 2005; Taylor & Fawcett, 2011), we used four word–target locations, which allowed us to differentiate between differences arising from IOR (slowed responses at word locations) and those arising from attentional momentum (speeded responses at locations opposite the word; Pratt, Spalek, & Bradshaw, 1999; Snyder, Schmidt, & Kingstone, 2001; Spalek & Hammad, 2004)—a distinction not possible when only two locations are used. Using four word–target locations also allowed us to isolate the processing stages that are affected by the differential withdrawal of attention after F and R instructions. Experiment 1 thus determined whether the F > R IOR difference arises primarily due to slowed responding to targets arising in the location of a previous F item or to speeded responding at the opposite location. Experiment 2 removed any spatial compatibility between the response options and target locations, to see whether this correspondence was necessary for observing the F > R IOR difference. Finally, in Experiment 3, we assessed whether the F > R IOR difference reflects slowed execution of responses with the particular effector (hand) associated with responses to the location of a previous F item.

2.3 Experiment 1

2.3.1 Introduction

Previous examinations of the F > R IOR difference with target localization have presented participants with a study word to the left or right in the visual periphery, followed by an auditory memory instruction, and then a target to the left or right (Fawcett & Taylor, 2010; Taylor, 2005; Taylor & Fawcett, 2011). The present experiment replicated this general paradigm, but used four word–target locations instead of the typical two. This allowed us to differentiate IOR from attentional momentum (Pratt et al., 1999; Snyder et al., 2001; Spalek & Hammad, 2004) while also providing an independent replication of the F > R IOR effect.

Whereas IOR refers to relatively slowed responding to targets that appear at the same location as a peripheral cue/ word, attentional momentum refers to relatively speeded responding to targets that appear at a location opposite a peripheral cue/word. This speeded responding to opposite targets theoretically occurs because, after attention is removed from the peripheral cue/word, “momentum” carries attention along the line of motion. Because attention is thought to move toward central fixation, due to the fact that this location is equidistant from potential target locations, the momentum that carries attention farther along the vector of motion facilitates target responses at the location mirror opposite the cued location, on the opposite side of central fixation (Pratt et al., 1999). IOR and attentional momentum are independent effects that are potentially additive (see Snyder et al., 2001). As a result, when only two word–target locations are utilized, IOR and attentional momentum are conflated: Relatively longer RTs to targets that appear in the same location as a preceding word may be due to slowed responding at that location and/or to speeded responding at the mirror opposite location, on the other side of fixation. It thus follows that the F > R IOR difference reported by Taylor (2005; see also Fawcett & Taylor, 2010; Taylor & Fawcett, 2011) could reflect differences in IOR and/or attentional momentum on F and R trials. If attentional momentum could account for the F > R IOR difference, this would be in conflict with the current interpretation of this difference as resulting from relative magnification of the IOR effect by an F instruction, and would suggest that a different mechanism underlies the interaction of memory instructions and the purported IOR effect.

Using four word–target locations allowed us to assess target RTs at locations that were not occupied by the word, but that were also not positioned in the mirror-opposite location on the other side of fixation (in this case, diagonally from) the word location. If there were no RT differences across the three locations where no word had been presented, this would counter the suggestion that attentional momentum is responsible for the F > R IOR difference (see Pratt et al., 1999; Snyder et al., 2001; Spalek & Hammad, 2004). If there were such differences in RTs across these three locations, then if the F > R IOR difference persisted even after the location diagonally opposite the target was excluded from the analysis (thereby removing the effects of attentional momentum), this would demonstrate that the magnitude of the IOR effect per se does indeed differ following F and R trials, above and beyond any influence of attentional momentum.

2.3.2 Method

Participants

Twenty participants were recruited from the undergraduate subject pool at Dalhousie University and received one credit point for participating. All of the participants reported normal or corrected-to-normal vision and a good understanding of the English language.

Materials

The experiment used PsyScope 5.1.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) on a Macintosh G4-400 computer running OS9. Stimuli were presented on either a 17-in. 1,024 × 768 resolution Macintosh Studio Display color monitor or a 17-in. 1,024 × 768 resolution ViewSonic PT775 color monitor. Responses were recorded using a Macintosh Universal Serial Bus keyboard. The stimuli were presented in Arial 24-point font, as black text against a white background. Participants viewed the computer monitor from a distance of approximately 45 cm.

A master word list of 320 nouns was selected from the Paivio, Yuille, and Madigan (1968) Word Pool using an online generator (www.math.yorku.ca/SCS/Online/paivio/). The words had a mean Kučera and Francis (1967) word frequency of 32.4 (ranging from 0 to 100, SD = 34.6), a mean imagery rating of 5 (ranging from 1.8 to 7, SD = 1.4), and a mean concreteness rating of 5 (ranging from 1.2 to 7, SD = 1.9). The words ranged in length from three to 13 letters (M = 7, SD = 2.1). For each participant, custom software randomized this word list and split it into four lists of 20 F items, four lists of 20 R items, and 160 foil items. Two buffer lists of the same five words (ten words total) were used for all participants.

Each trial in the study phase began with the presentation of five identical outline boxes. Each outline box measured 5 × 5 deg of visual angle. One box was centered on the computer monitor. The remaining four boxes were positioned peripherally in the top left, top right, bottom left, and bottom right of the screen. The distance from the center of the middle box to the center of each of the peripheral boxes was 10 deg of visual angle. A fixation stimulus (+) (same font and size as the words) was presented in the middle outline box.

Two auditory tones, one relatively high-pitched (1170 Hz) and one relatively low-pitched (260 Hz), were used as memory instructions. The assignment of memory instruction to tones was counterbalanced, such that half of the participants were told that the high-pitched tone was an F instruction and the low-pitched tone was an R instruction, whereas the other half of the participants were told the opposite (i.e., low tone = F, high tone = R). An asterisk (also same font and size as the words) was used as the target.

Procedure

Participants were given verbal instructions detailing the task, which were reiterated with onscreen instructions prior to participation. The participants were informed that they were to do their best to follow the memory instruction for each word, and that they were to respond to all targets as quickly and as accurately as possible. Participants were told that the study phase would be followed by a memory test, but they were not told that they would be tested for their memory of the F as well as the R items.

Tone familiarization phase: Before the experiment began, participants were presented with ten tone familiarization trials. On each trial, a verbal description of the tone–instruction relation (e.g., “High tone–FORGET”) was presented centrally, and remained onscreen for 2,000 ms. The corresponding tone was played over the headphones 500 ms after the verbal description appeared, and lasted for 400 ms. The intertrial interval was 1,000 ms.

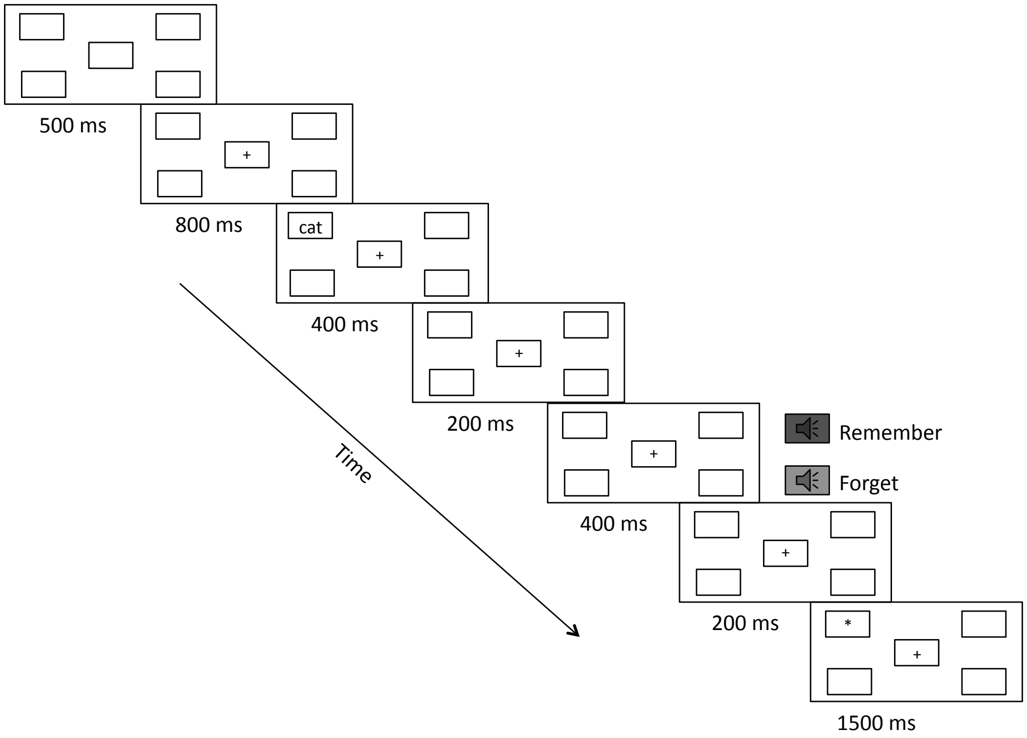


Figure 2.1: Depiction of one study phase trial. This figure depicts a "same location" trial, since the target appears in the same location as the word.

Study phase: A depiction of each trial is presented in Figure 2.1. Five outline boxes (central, top left, top right, bottom left, and bottom right) appeared at the beginning of each trial and remained on the screen for 4,000 ms. A fixation cross ("+") appeared 500 ms after the start of the trial in the center of the central box and remained onscreen until the end of the trial. A word appeared 800 ms after the onset of the fixation cross. The word appeared randomly in the center of one of the peripheral boxes and remained visible for 400 ms. An F or an R memory instruction (high- or low-pitched tone) was presented auditorily 200 ms after the offset of the word, and lasted 400 ms. A target ("*") appeared 200 ms after the removal of the memory instruction. The target appeared randomly in the center of one of the peripheral boxes. Participants were given 1,500 ms from the onset of the target to make a response. They were told to indicate which location the target appeared in by pressing the “f” key with the middle finger of their left hand when the target appeared in the top left location, the “j” key with the middle finger of their right hand when the target appeared in the top right location, the “v” key with the index finger of their left hand when the target appeared in the bottom left location, and the “n” key with the index finger of their right hand when the target appeared in the bottom right location. RTs and accuracy were measured. If the participant did not respond within 1,500 ms of target onset, a message indicating that they had missed was displayed centrally (“Too Slow!”).

Four trial types were presented: same location (i.e., word and target appear in the same location), same side (e.g., word appears in top left, target appears in bottom left), across (e.g., word appears in top left, target appears in top right), and diagonal (e.g., word appears in top left, target appears in bottom right). Each type of trial included 20 F items and 20 R items so that, with the ten buffer trials, the study phase consisted of a total of 170 trials.

Each study phase began and ended with five buffer trials, to reduce primacy and recency effects. The buffer trials were identical to the other study phase trials, except that the words were drawn randomly from one of the lists of buffer words, and all buffer words were followed by an R instruction. The words and targets on buffer trials appeared randomly with equal probability in one of the four peripheral locations. Buffer words were not included in the following memory test.

Recognition phase: After all study items had been presented, participants completed a yes–no recognition task. All F and R items from the study phase were presented, along with an equal number of foil items. Thus, 160 study items plus 160 unstudied foil items were presented randomly, making a total of 320 trials in the recognition phase. The words were presented centrally on the computer monitor one at a time. Participants were to indicate whether they recognized the word from the study phase. Importantly, they were told to indicate recognition regardless of whether they had been instructed to remember or forget the word. If they recognized the word, they were told to press the “y” button; if they did not, they were told to press the “n” button. After all of the study and foil words had been presented, participants were debriefed and had any questions answered by the experimenter.

2.3.3 Results

Recognition Accuracy

To ensure that participants were able to follow the memory instructions presented during the study phase, the data from the recognition test were analyzed using a one-way repeated measures analysis of variance (ANOVA), with word type (F, R, foil) as the independent variable and the proportion of "yes" responses as the dependent variable. We found a significant main effect of word type [$F(2, 38) = 58.022$, $MSE = .011$, $p < .001$], such that R items ($M = .54$) were recognized at a higher rate than F items ($M = .39$) [$t(19) = 4.280$, $p < .001$]. This was the expected directed-forgetting effect (better memory for R than for F items). Both R and F items were recognized at higher rates than foil items ($M =.16$) [$t(19) = 8.632$, $p < .001$, and $t(19) = 9.055$, $p < .001$, respectively].

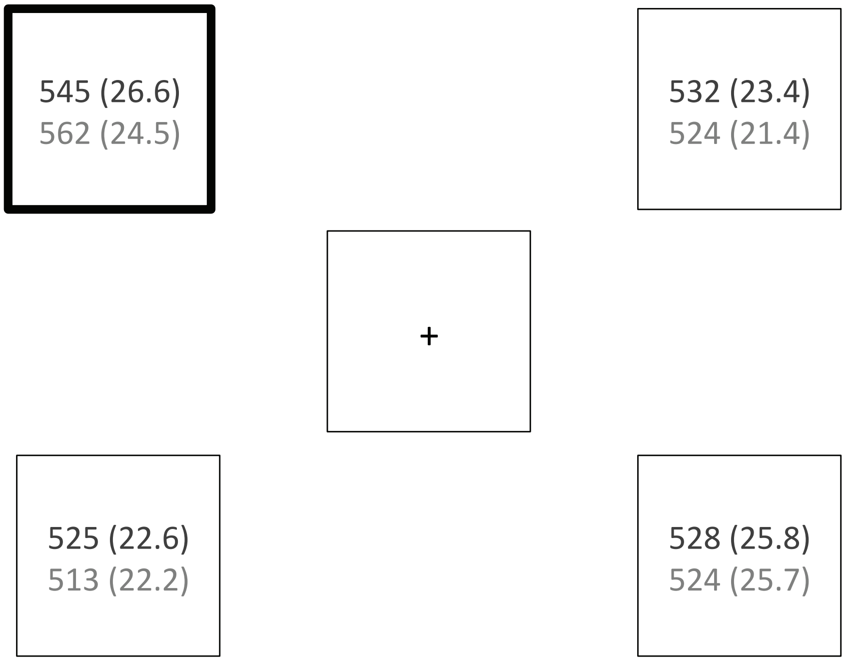


Figure 2.2: Descriptive statistics for Experiment 1. The top number in each box shows the mean RT (and *SE*) after a remember instruction. The bottom number is the mean RT (and *SE*) after a forget instruction. For the sake of this depiction, we have represented the data as though the top left location had contained the word, such that the *same* location is the top left box (*bold outline*).

Target RTs

See Figure 2.2 for descriptive statistics. To assess effects of attentional momentum in eiter the R- and F-instruction conditions, two one-way repeated measures ANOVAs were conducted with different-location type (same side, across, diagonal) as the independent variable and RTs to respond to the targets as the dependent measure. RTs did not differ between targets appearing at the three different locations in either the F- or the R-instruction condition (all Fs < 1). This suggested that attentional momentum did not play a role in the target RTs on either F or R trials. Thus, to assess differences in IOR, we collapsed the word–target location variable from four levels (same location, same side, across, and diagonal) to two (same and different), so that RTs for the same-side, across, and diagonal locations were averaged together to produce the different condition.

A 2 (word–target location: same, different) × 2 (memory instruction: F, R) repeated measures ANOVA was conducted on target RTs. We found a significant main effect of word–target location [$F(1, 19) = 15.940$, $MSE = 1{,}046.746$, $p = .001$], with slower RTs to targets in the same location as the previous word, as compared to the other locations (an IOR effect). The main effect of memory instruction was not significant ($F < 1$). Finally, we found a significant word–target location × memory instruction interaction [$F(1, 19) = 5.410$, $MSE = 563.627$, $p = .031$]. This interaction was due to a greater magnitude of IOR in the F-instruction (M =41 ms) than in the R-instruction (M = 17 ms) condition [$t(19) = 2.326$, $p = .031$; see Figure 2.3].

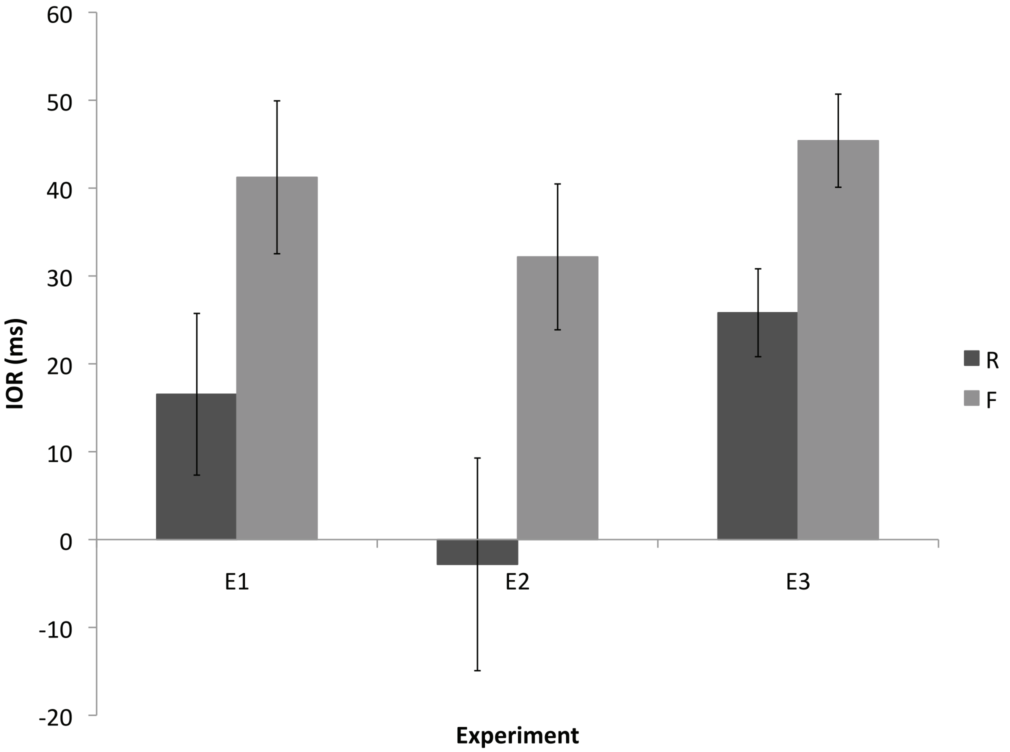


Figure 2.3: Inhibition of return (IOR) after remember (R) and forget (F) instructions across all three experiments. Error bars represent *SE*s. IOR is calculated as the RT to targets in different locations subtracted from the RT to targets in the same location for Experiments 1 and 2 (E1 and E2), and as the RT to targets in the same-side and across locations subtracted from the RT to targets in the same location for Experiment 3 (E3).

Analogous analyses were run on response accuracy. Two one-way repeated measures ANOVAs (one for the F- and one for the R-instruction condition) were conducted with other-location type (same side, across, diagonal) as the independent variable and accuracy of responses to targets as the dependent measure. No differences were found in either the F- or the R-instruction condition (all Fs < 1). Thus, all further analyses were collapsed across the three different locations, leaving two levels of the word–target location variable: same and different.

In a 2 (word–target location: same, different) × 2 (memory instruction: F, R) repeated measures ANOVA on response accuracy, both the main effects of word–target location and memory instruction failed to reach significance (both Fs < 1). The only significant effect was an interaction [F(1, 19) = 4.587, MSE = .002, p = .045], due to the fact that accuracy tended to be greater when the target appeared in the same location after an R instruction, as compared to when it appeared in a different location [t(19) = 2.013, p = .059]. Thus, after an R instruction slowed RT at the same location compared to the other locations was qualified by increased accuracy at the same location compared to the other locations (what appears to be a speed-accuracy trade-off). Critically, similar differences in accuracy following F instructions were not seen.

2.3.4 Discussion

Experiment 1 replicated the F > R IOR difference in a paradigm with four peripheral locations. Participants were presented with a word in one of four peripheral locations, followed by an F or R memory instruction. Then, a visual target requiring a speeded spatially compatible buttonpress response appeared in one of the four locations. We found a significant directed forgetting effect, suggesting that participants were successfully able to follow the memory instructions.

An analysis of the target RTs revealed no differences on either F or R trials for responding to targets at the three uncued locations. In other words, since RT was not particularly speeded at the diagonal/ mirror opposite location, the results cannot be readily accounted for by attentional momentum. Thus, the F > R IOR difference that we replicated in this experiment is, in fact, due to differences in the IOR effect per se on F and R trials.

2.4 Experiment 2

2.4.1 Introduction

In Experiment 1, we replicated the F > R IOR difference using four locations in a paradigm that required a spatially compatible localization response to report the target. This demonstrated that the pattern of results is, in fact, due to changes in IOR from memory instructions and is not due to interactions of the memory instruction with attentional momentum. Nevertheless, because Experiment 1 required a spatially compatible localization response (see also Fawcett & Taylor, 2010; Taylor, 2005; Taylor & Fawcett, 2011), it remains unclear whether interpretation of the F > R IOR difference as being due to the magnification of the motor “flavor” of IOR by an F instruction as suggested by Taylor and Fawcett is the most parsimonious or accurate account. The present experiment tests an alternative hypothesis that F > R IOR might be due to greater suppression of the abstract spatial code associated with an F item, as per the following rationale based on the Simon effect.

The Simon effect is defined as faster responding when a response is spatially compatible with the target location, rather than incompatible, and occurs even when target location is task-irrelevant (De Jong, Liang, & Lauber, 1994; Kornblum, Hasbroucq, & Osman, 1990; Metzker & Dreisbach, 2011; Simon, 1969). The Simon effect occurs because the spatially compatible stimulus–response (S–R) code is automatically activated even when it is not task relevant. This automatic activation speeds task-relevant responses when they align spatially, but also slows down task-relevant responses when they conflict.

Interestingly, the Simon effect tends to be observed only on trials that are preceded by a compatible S–R pairing (e.g., Hommel, Proctor, & Vu, 2004; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; and see Stoffels, 1996, for similar results in a task in which target location was task-relevant). The fact that the Simon effect does not occur after trials on which the task-relevant response conflicts with the compatible S–R code suggests that the automatic activation of compatible S–R codes might be supressed in some cases—for example, in the face of response conflict (Stürmer et al., 2002). Given that an F instruction operates analogously—even if not identically (Fawcett & Taylor, 2010)—to a stop signal (see Hourihan & Taylor, 2006), it follows that the response conflict generated by an instruction to stop the unwanted commitment of a word to memory may have the effect of suppressing automatic S–R code activation at the F-item location. This is especially true given that the representation of a peripherally presented F item includes its spatial location (see Hourihan, Goldberg, & Taylor, 2007).

To date, all demonstrations of an F > R IOR difference have occurred for localization responses that were spatially compatible with the target location (Exp. 1; see also Fawcett & Taylor, 2010; Taylor, 2005; Taylor & Fawcett, 2011), and not for responses that required a detection or nonspatial discrimination response (Taylor &

Fawcett, 2011). We know that IOR can interact with the Simon effect to produce larger effects of S–R compatibility at the cued than at the uncued location (Ivanoff, Klein, & Lupiáñez, 2002; Klein & Ivanoff, 2011). It thus follows that reducing the impact of the automatic S–R code activation (normally associated with the Simon effect) should have a greater impact at the cued than at the uncued location. To wit, when a location is made task-relevant by virtue of a spatially compatible localization response, it follows that suppression of the automatic S–R code activation by an F instruction would lead to relatively slower responding to targets that appeared subsequently in the location where the word was presented, rather than elsewhere. This would manifest in behavior as the F > R IOR difference that occurs for spatially compatible localization responses.

To investigate whether F instructions might be suppressing automatic S–R code activation, in Experiment 2 we replicated the methodology of Experiment 1 but eliminated the spatial correspondence between the target locations and response options. This was accomplished by arranging the response options horizontally on the keyboard ("j," "k," "l," and ";"). By requiring what we will refer to as spatially neutral responses, we removed the opportunity for spatially compatible S–R code activation to benefit any responses. If the F instruction results in suppression of the automatic S–R code activation, this suppression would not be manifest in the RTs for making these spatially neutral responses. In other words, if the F > R IOR difference is due to suppression of automatic S–R code activation, this pattern should not occur in the results of Experiment 2.

2.4.2 Method

Participants

Twenty participants were recruited from the undergraduate subject pool at Dalhousie University and received one credit point for participating. All participants reported normal or corrected-to-normal vision and a good understanding of the English language.

Materials

The materials used were identical to those of Experiment 1.

Procedure

The procedure was identical to that of Experiment 1, with the exception of the responses required for the target localization task. Instead of indicating where the target appeared by using response keys that were spatially compatible with the target locations, participants' response keys were neutral with respect to the spatial arrangement of the target locations. Specifically, participants were to indicate the location of the target by pressing the "j" key (index finger, right hand) when it appeared in the top left, the "k" key (middle finger, right hand) when it appeared in the top right, the "l" key (ring finger, right hand) when it appeared in the bottom left, and the ";" key (pinkie finger, right hand) when it appeared in the bottom right.

2.4.3 Results

Recognition accuracy

To ensure that participants were able to follow the memory instructions presented during the study phase, the data from the memory test were analyzed using a one-way repeated measures ANOVA with word type (F, R, foil) as the independent variable and the proportions of "yes" responses as the dependent measure. We found a significant main effect of word type [$F(2, 38) = 100.477$, $MSE = .009$, $p < .001$], such that R items ($M = .58$) were recognized at a higher rate than F items ($M = .39$) [$t(19) = 6.396$, $p < .001$]. This was the expected directed-forgetting effect (better memory for R than for F items). Both R and F items were recognized at a higher rate than foil items ($M = .15$) [$t(19) = 11.922$, $p < .001$, and $t(19)=9.813$, $p < .001$, respectively].

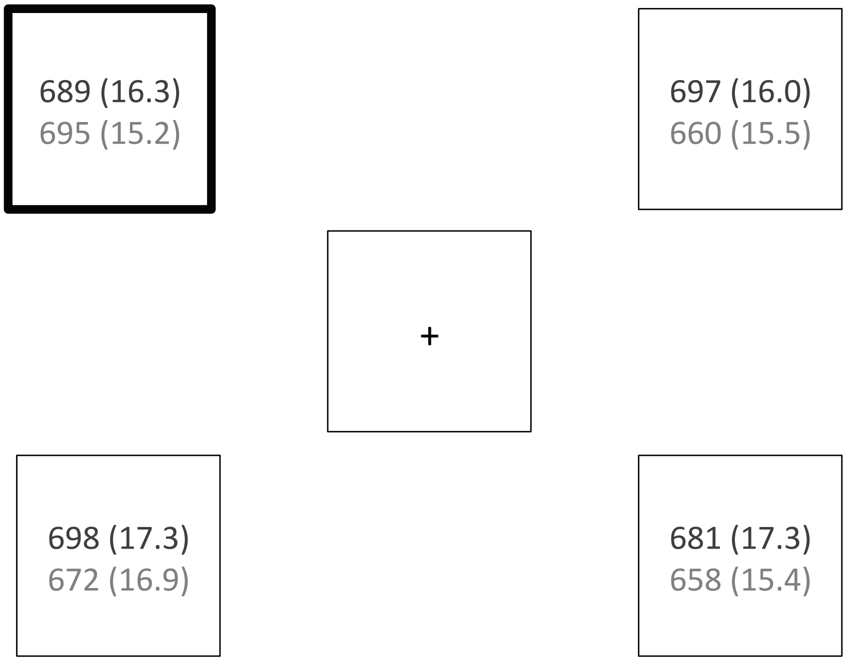


Figure 2.4: Descriptive statistics for Experiment 2. The top number in each box shows the mean RT (and *SE*) after a remember instruction. The bottom number is the mean RT (and *SE*) after a forget instruction. For the sake of this depiction, we have represented the data as though the top left location had contained the word, such that the *same* location is the top left box (*bold outline*).

Target RTs

See Figure 2.4 for descriptive statistics. To assess any contributions from attentional momentum on F and R trials, we conducted two separate one-way repeated measures ANOVAs, with different-location type (same side, across, diagonal) as the independent variable and RTs to respond to the targets as the dependent measure. RTs did not differ between targets appearing at the three different locations in either the F- or the R-instruction condition (all Fs < 1). Having shown no evidence of attentional momentum in either condition, we averaged across the three different locations, to reduce our design to two levels of the word–target location variable: same and different.

A 2 (word–target location: same, different) × 2 (memory instruction: F, R) repeated measures ANOVA was conducted on the target RTs. Both the main effects of word–target location and memory instruction failed to reach significance (both Fs < 1). The only significant effect was the word–target location × memory instruction interaction [F(1, 19) = 7.895, MSE = 775.541, p = .011]. This interaction was due to a greater magnitude of IOR in the F-instruction (M = 32 ms) than in the R-instruction (M = −3 ms) condition [t(19) = 2.810, p = .011; see Figure 2.3]. In fact, the IOR difference was only significant after an F instruction [t(19) = 3.873, p = .001], and not after an R instruction (t < 1).

Analogous analyses were run on response accuracy. Two one-way repeated measures ANOVAs were conducted with other-location type (same side, across, diagonal) as the independent variable and accuracy of responses to the targets as the dependent measure. No differences were found in either the F- or the R-instruction condition (all Fs < 1). Thus, all further analyses were collapsed across the three different locations, leaving two levels of the word–target location variable: same and different.

In a 2 (word–target location: same, different) × 2 (memory instruction: F, R) repeated measures ANOVA on response accuracy, no significant effects were found (all Fs < 1).

2.4.4 Discussion

In Experiment 2, we assessed whether a spatially compatible response is necessary to observe the F > R IOR difference during a target localization task. Participants made a spatially neutral localization response to the target. A significant directed-forgetting effect occurred, suggesting that participants were able to successfully follow the memory instructions. We found no evidence of attentional momentum following either memory instruction, and the magnitude of IOR was greater after F items than after R items.

These results suggest that the response options for the localization task do not need to be spatially compatible with the target locations to observe the F > R IOR difference. In fact, a 2 (memory instruction: F, R) × 2 (experiment: 1, 2) mixed ANOVA on the magnitude of IOR showed that the patterns of results were not significantly different between Experiments 1 and 2. Thus, whereas there was a significant difference between the magnitude of IOR after F and R instructions [$F(1, 39) = 14.547$, $MSE = 1{,}561.155$, $p < .001$], we observed no significant effect of experiment, nor an interaction (both $Fs < 1$). The conclusion from these findings is that the F > R IOR difference is not associated with the suppression of automatic S–R code activation. Rather, any localization response specific to the previous word's location shows a bias when it is F-instructed rather than R-instructed. This is true regardless of whether the response and stimulus locations correspond spatially.

2.5 Experiment 3

2.5.1 Introduction

In all previous investigations of IOR and directed forgetting in which the F > R IOR difference has occurred, each potential target location was assigned its own unique response. Thus another potential alternative hypothesis regarding the F > R IOR difference could be that the differential withdrawal of attention from F and R items results in the slowed execution of responses with the particular effector uniquely associated with the F-item location. In the present experiment, participants indicated on which side of the screen the target appeared by depressing one of two keys to report "left" or "right." This directional response thereby mapped the four peripheral word–target locations onto only two responses, such that the response required for a target that appeared in the same location as the previous item was the same as the response for a target in the other location in the same horizontal hemifield. Thus, the target response was not unique to an individual location. In other words, we required participants to make the same overt responses (left–right) as in previous investigations of F > R IOR (in which only two locations were used), but we expanded the target conditions that elicited these responses. Our question was whether RTs to uncued targets that shared a response with cued targets would be similar to those that did not share the same response. If the F > R IOR difference is associated with slowed execution of responses associated with a particular effector (hand, in this case), RTs should be equally slowed at uncued locations that require the same response as the word location.

2.5.2 Method

Participants

Sixty-six participants were recruited from the undergraduate subject pool at Dalhousie University and received one credit point for participating. All reported normal or corrected-to-normal vision and a good understanding of the English language.

Materials

The materials used were identical to those of Experiments 1 and 2.

Procedure

The procedure was identical to that of Experiments 1 and 2, with the exception of the target localization task. Instead of localizing the target with one of four responses, participants were asked to indicate the side on which the target appeared (a distinction with only two possibilities—left or right). When the target appeared on the left, they were to press the "f" key with the index finger of their left hand. When the target appeared on the right, they were to press the "j" key with the index finger of their right hand.

2.5.3 Results

Recognition accuracy

To ensure that participants were able to follow the memory instructions presented during the study phase, the data from the recognition test were analyzed using a one-way repeated measures ANOVA with word type (F, R, foil) as the independent variable and the proportions of "yes" responses as the dependent variable. We observed a significant main effect of word type [$F(2, 130) = 258.387$, $MSE = .012$, $p < .001$], such that R items ($M = .60$) were recognized at a higher rate than F items ($M = .43$) [$t(65) = 9.908$, $p < .001$]. This was the expected directed-forgetting effect (better memory for R than for F items). Both R and F items were recognized at higher rates than foil items ($M = .17$) [$t(65) = 18.174$, $p < .001$, and $t(65) = 16.846$, $p < .001$, respectively].

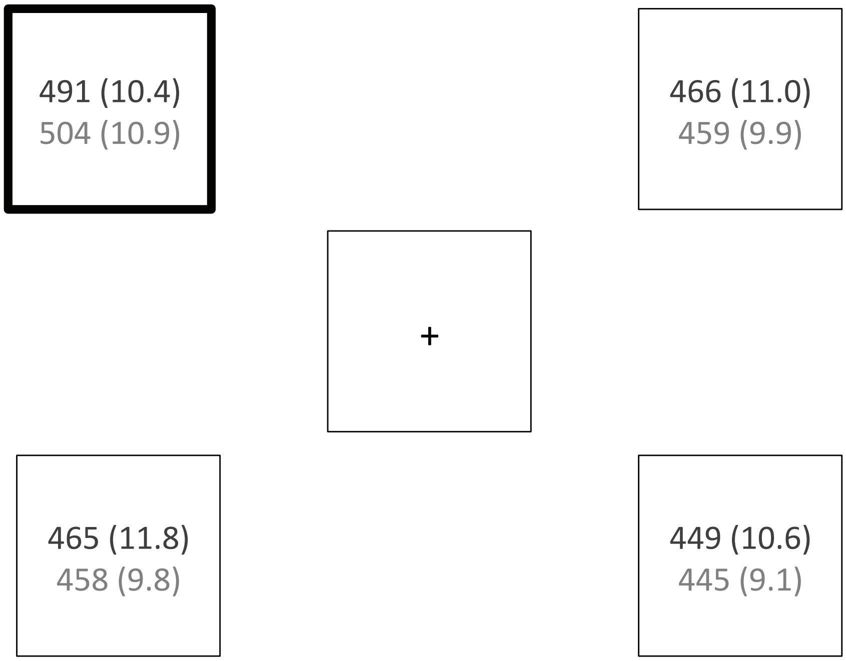


Figure 2.5: Descriptive statistics for Experiment 3. The top number in each box shows the mean RT (and *SE*) after a remember instruction. The bottom number is the mean RT (and *SE*) after a forget instruction. For the sake of this depiction, we have represented the data as though the top left location had contained the word, such that the *same* location is the top left box (*bold outline*).

Target RTs

See Figure 2.5 for descriptive statistics. To assess RTs at the uncued locations on F and R trials, we conducted two separate one-way repeated measures ANOVAs, with different-location type (same side, across, diagonal) as the independent variable and RTs to respond to the targets as the dependent measure. Unlike in Experiments 1 and 2, we found a significant effect of different-location type after both the F instructions [F(2, 130) = 4.649, MSE = 837.254, p = .011] and the R instructions [F(2, 130) = 7.879, MSE = 752.050, p = .001]. In both cases, the effect was due to faster RTs occurring at the diagonal location than at the same-side and across locations [after an F instruction, t(65) = 2.899, p = .005; after an R instruction, t(65) = 3.604, p = .001]. This pattern suggested a contribution from attentional momentum on both F and R trials. Critically, however, no significant difference in RTs occurred between same-side and across locations on either F or R trials (all ts < 1).

To provide a measure of IOR that was not contaminated by attentional momentum, we compared RTs at the same location to the average of the RTs at the same-side and across locations, excluding the diagonal location from the analyses. A 2 (word–target location: same, different) × 2 (memory instruction: F, R) repeated measures ANOVA was conducted on target RTs. We observed a significant effect of word–target location [F(1, 65) = 77.699, MSE = 1,076.869, p < .001]. This was due to longer RTs to targets in the same location, as compared to targets at the same-side and across locations (an IOR effect). The main effect of memory instruction did not reach significance (F < 1), but a significant interaction did emerge between word–target location and memory instruction [F(1, 65) = 9.373, MSE = 674.961, p = .003]. Although the magnitude of IOR was significant after both F instructions [M = 45 ms; t(65) = 8.555, p < .001] and R instructions [M = 26 ms; t(65) = 5.170, p < .001], the interaction was due to a greater magnitude of IOR after F than after R instructions [t(65) = 3.062, p = .003; see Figure 2.3].

Analogous analyses were run on response accuracy. In a 2 (word–target location: same, different) × 2 (memory instruction: F, R) repeated measures ANOVA on response accuracy, we found no significant effects (all Fs < 1).

2.5.4 Discussion

Experiment 3 determined whether the F>R IOR difference would emerge after a directional response. Participants were presented with a word in one of four peripheral locations, which was followed by an F or an R instruction. Then, a target appeared in one of the four locations, and participants indicated on which side of the screen the target had appeared (left or right). The results revealed a significant directed-forgetting effect, demonstrating that participants were able to accurately follow the memory instructions. In addition, we found a significant F > R IOR difference. Critically, RTs to targets that appeared in the uncued location on the same side as the word were statistically equivalent to those that appeared in the uncued location across from the word. Thus, the critical factor in producing relative slowing of RTs to targets at the word location is the correspondence of the location and not the correspondence of the response effector. This fact is consistent with the view that the IOR effect—and, by implication, the F > R IOR difference—is not associated with slowed motor execution at the level of the effector.

Unlike in Experiments 1 and 2, RTs to targets that appeared in the location opposite the word were relatively speeded on both F and R trials, which is indicative of an attentional momentum effect (Pratt et al., 1999; Snyder et al., 2001; Spalek & Hammad, 2004). Importantly, in Snyder et al.'s investigation of attentional momentum, they concluded that attentional momentum, rather than a competing explanation for the differences in RTs that are typically attributed to IOR, is a separable and unique effect that occurs in addition to, but likely has no bearing on, IOR. Even so, we elected to exclude the contributions of attentional momentum from our evaluation of IOR. After having done so, we continued to replicate the F > R IOR difference using the two-alternative directional choice in Experiment 3.

2.6 General Discussion

The present experiments investigated both the causes and consequences of F > R IOR in item-method directed forgetting. We presented participants with a word in one of four peripheral locations, followed by an F or R instruction, and then a target in one of the four locations. In Experiment 1, participants localized these targets with a spatially compatible buttonpress. Participants were overall slower to respond when the target appeared in the same location as the word rather than the other locations, and the magnitude of this IOR difference was greater following F than following R instructions. We replicated these results in Experiment 2, in which participants localized the targets with a spatially neutral buttonpress. Again, in Experiment 3, the results were replicated with a directional (left vs. right) response. To assess whether the magnitude of this difference in IOR after F and R instructions differed across experiments, we conducted a 2 (memory instruction: F, R)×3 (experiment: 1, 2, 3) mixed ANOVA with the magnitude of IOR as the dependent measure (see Figure 2.3). We found a significant main effect of memory instruction [$F(1, 103) = 20.271$, $MSE = 1{,}345.939$, $p < .001$], reflecting the fact that the magnitude of IOR was greater after F than after R instructions. A marginally significant effect of experiment also occurred [F(2, 103) = 3.007, MSE = 2,254.405, p = .054]. Critically, the interaction did not approach significance (F < 1). Thus, in all three experiments reported here, F > R IOR was observed, and the magnitude of this difference was approximately equal across experiments, also suggesting that the speeded RT at the diagonal location in Experiment 3 (attentional momentum) did not, in fact, modify the F > R IOR difference.

From the findings of Taylor and Fawcett (2011), we know that no significant difference in IOR is found between F- and R-instruction conditions when the target response is a detection or nonspatial discrimination response. This suggests that the difference does not reflect delayed perceptual processing at the location of the F items, nor delayed response choice. We know from the present experiments that the difference does occur when a directional (left–right) response is made to the target, but this increased RT is unique to the word location, and does not generalize to other responses made with the same effector. This suggests that the difference is not associated with slowed response execution specific to the particular effector associated with the F-item location, so F > R IOR likely does not reflect inhibition of motor cortex or very late-stage changes in muscle activity in the fingers (e.g., pulling the finger away from the key). We learned from Experiment 2 that the localization response does not have to be made on keys that are arranged in a manner spatially compatible with the stimulus display, suggesting that the difference does not reflect suppression of the automatic activation of spatially compatible S–R codes. Finally, Experiments 1 and 2 confirmed that the F > R IOR difference arises from slowed RTs at the location of a previous F item rather than speeded RTs at the opposite location, and Experiment 3 showed that the effect occurs even if the diagonally opposite location is not included in the analysis. Taken together, our results rule out viable alternative explanations of the F > R IOR difference, and in so doing, converge on the account offered by Taylor and Fawcett (2011).

Adopting the characterization offered by Taylor and Fawcett (2011) and drawing on our present findings, we thus argue that the memory instructions in an item-method directed-forgetting task lead to a differential withdrawal of attention from F and R items, thereby revealing a bias against responding toward targets that arise subsequently at the F rather than the R item location. The differential withdrawal of attention likely accounts for the fact that instantiating an F instruction is initially more effortful than instantiating an R instruction (Cheng et al., 2012; Fawcett & Taylor, 2008) and seems to engage frontal mechanisms to cease rehearsal and prevent the commitment of these items to memory (Hsieh, Hung, Tzeng, Lee, & Cheng, 2009; Ludowig et al., 2010; van Hooff & Ford, 2011; Wylie et al., 2008). The subsequent bias prevents information from unreliable sources (in this case, location) from repeatedly gaining control over responding, and is reflected in the F > R IOR difference. Insofar as the IOR effect is the result of a mechanism that facilitates a visual search for novelty (Klein, 2000; Klein & MacInnes, 1999; MacInnes & Klein, 2003), the increased delay in responding toward the source of an F item allows information at this location to accumulate and be scrutinized before issuing a response. In this way, the F > R IOR difference may functionally increase the time available for limited-capacity resources to process information that arises from a source that was recently deemed unreliable. In so doing, an F instruction not only limits further processing and commitment of the F item to memory, it also impacts subsequent information processing in the short term (see also Fawcett & Taylor, 2012).

Whether the influence of an F instruction on subsequent information processing reflects a mechanism by which forgetting is accomplished or is a consequence of the attempt to instantiate the instruction is uncertain at present. Whereas Taylor and Fawcett (2011) found no significant relation between the F > R IOR difference and the magnitude of the directed-forgetting effect, Fawcett and Taylor (2010) found that the F > R IOR difference was driven by trials on which the intention to forget was successful. To further explore this issue, we conducted a simple regression, collapsing the data from all three experiments to investigate any possible relation between the magnitude of the F > R IOR difference and the magnitude of the directed-forgetting effect. In fact, we observed a significant relation: Larger F > R IOR differences were associated with larger-magnitude directed forgetting effects in subsequent recognition [see Figure 2.6; $r = .255$, $t(104) = 2.684$, $p = .008$—a small- to medium-sized effect, per Cohen, 1992]. That said, however, we also conducted a conditional analysis to determine whether the RT on a given trial was associated with later recognition performance for that word. A 2 (memory outcome: remembered, forgotten) × 2 (word–target location: same, different) repeated measures

ANOVA was conducted separately for F and R trials, with RT as the dependent measure. In both the F- and R-instruction conditions, only a significant main effect of word–target location occurred, reflecting IOR [F(1, 105) = 92.249, MSE = 2, 249.709, p < .001, and F(1, 105) = 19.052, MSE = 2,872.182, p < .001, respectively]. No other effects were significant (all Fs < 1). Thus, we did not find that the magnitude of IOR varied as a function of whether the study item was later recognized at test for either F or R items. These inconsistent findings leave open the possibility that some independent mechanism is at least partially responsible for successful forgetting and that the bias associated with the F > R IOR difference reflects an aftereffect of the F instruction rather than the outcome of a mechanism by which the F instruction is successfully instantiated.

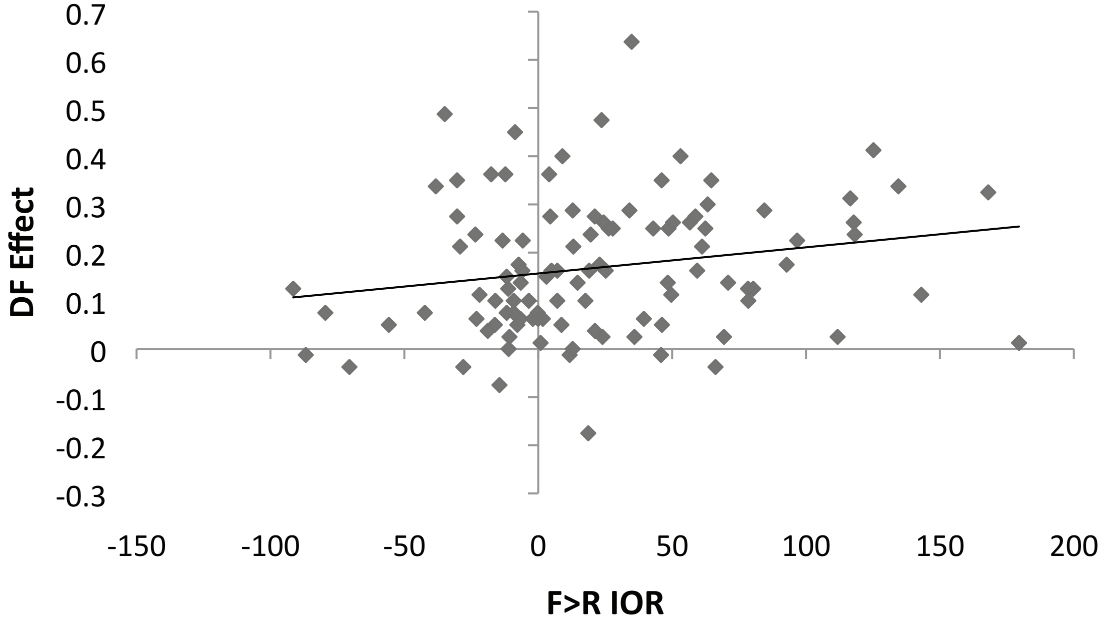


Figure 2.6: Scatterplot depicting the relation between the magnitude of the directed-forgetting effect (proportion of remember [R] items recognized – proportion of forget [F] items recognized) and the magnitude of the F > R IOR difference (F IOR – R IOR) across all three experiments. IOR is calculated as the RT to targets in different locations subtracted from the RT to targets in the same location for Experiments 1 and 2, and as the RT to targets in the same-side and across locations subtracted from the RT to targets in the same location for Experiment 3.

Even if the mechanism that gives rise to the F > R IOR difference is not directly related to the success of instantiating the intention to forget, it may nevertheless contribute indirectly to the effectiveness of the F instruction by limiting the availability of cognitive resources during presentation of the F item. Lee (2012) demonstrated that the effectiveness of an F instruction is inversely related to the availability of cognitive resources, such that automatic encoding of the F item occurs in the absence of a high cognitive load. Conversely, intentional forgetting in an item-method task is more successful when fewer cognitive resources are available for this automatic processing of the F item (see also Lee & Lee, 2011). Thus, intentional forgetting might depend on the removal of processing resources, even if the forgetting is not accomplished by this removal per se. If so, the withdrawal of attention that reveals the F > R IOR difference may not cause intentional forgetting, but may nevertheless set the stage for successful instantiation of the intention to forget.

A withdrawal of processing resources from the F-item representation and a bias against responding to subsequent information presented in close spatial and temporal proximity to the F item might also subserve forgetting indirectly by weakening the episodic trace. It has been fairly well established that the directed-forgetting effect in the item method paradigm is only apparent in explicit tests of memory, and that no difference between F and R items is seen for implicit tests of memory (Basden, Basden, & Gargano, 1993; MacLeod & Daniels, 2000; Van Hooff et al., 2009). According to Racsmány and Conway (2006), explicit tests of memory tap into the episodic memory of the study phase. Conversely, implicit memory tests tap into semantic or lexical representations. Since the directed-forgetting effect is only observed when explicit memory tests are used, the effect could be a result of the modification, degradation, or inhibition of episodic information related to the F items (Racsmány & Conway, 2006).

In support of this notion, Hourihan et al. (2007) found that F-item memory was aided significantly by having the word presented in the same location where it had been at study, but that R-item memory was not so affected. This result is consistent with the view that F items have a “shortage” of episodic information, and are thus relatively more difficult to remember than R items. However, when contextual information from study is provided, memory is improved for these episodically impoverished F items. R items already have a rich episodic memory due to elaborative rehearsal at study, and therefore the benefit of repeating contextual information at test is minimal. Characterizing directed forgetting in terms of degradation of the F-item representation also accounts for the fact that directed-forgetting effects occur for detailed but not for gist representations (see Fawcett, Taylor, & Nadel, 2013); for the observation that false alarms to unstudied foil items are more often due to misattributions as F items than as R items (Thompson, Fawcett, & Taylor, 2011); and for the finding that instructional designation elicits more "don't know" responses for F than for R items (Goernert, Widner, & Otani, 2007).

Considered in this light, our present findings thus suggest that the effects of an F instruction may be multifaceted, leading to potential degradation of the episodic trace—perhaps due to the withdrawal of attention from its representation (see Taylor, 2005; Taylor & Fawcett, 2011)—as well as changes in the processing of items presented subsequently within a short temporal window following the F instruction. These changes may help bias the system against repeatedly responding to information that arises from an unreliable source (Taylor & Fawcett, 2011), while also limiting incidental encoding of information that follows subsequently (Fawcett & Taylor, 2012). In this way, an F instruction influences not only the item to which it refers, but also overt (buttonpress) and covert (incidental-encoding) responses to information that appears shortly thereafter. It is currently unclear whether these effects on subsequent information processing reflect the successful instantiation of an F instruction or an aftereffect of the memory intention that it forms. In any case, it seems likely that—whether directly or indirectly—the processes reflected in the F > R IOR difference enable intentional forgetting by limiting the availability of cognitive resources that would otherwise lead to automatic processing of the F item and/or by weakening the episodic representation of the F item and its links to information that follows shortly thereafter in the same epoch.

2.7 Author Note

We thank Carl Helmick for writing the custom software that randomized and distributed study words to lists, as well as the undergraduate students who volunteered their time to participate in our study. This research was supported by a fellowship from the Dalhousie Faculty of Graduate Studies to K.M.T. and by an NSERC Discovery Grant to T.L.T.

Chapter 3 I Can See it in Your Eyes[2]

3.1 Abstract

In the item-method directed forgetting paradigm, the magnitude of inhibition of return (IOR) is larger after an instruction to Forget (F) than after an instruction to Remember (R). The present experiments further investigated this increased magnitude of IOR after F compared to R memory instructions to determine whether this F>R IOR pattern occurs only for the motoric form of IOR, as predicted, or also for the visual form. In three experiments, words were presented in one of two peripheral locations followed by either an F or R memory instruction. Then, a target appeared in either the same location as the previous word, or the other location. In Experiment 1, participants maintained fixation throughout the trial until the target appeared, at which point they made a saccade to the target. In Experiment 2, participants maintained fixation throughout the entire trial and made a manual localization response to the target. The F>R IOR difference in reaction times occurred for both the saccadic and manual responses, suggesting that memory instructions modify both motoric and visual forms of IOR. In Experiment 3, participants made a perceptual discrimination response to report the identity of a target while the eyes remained fixed. The F>R IOR difference also occurred for these manual discrimination responses, increasing our confidence that memory instruction modifies the visual form of IOR. We relate our findings to postulated differences in attentional withdrawal following F and R instructions and consider the implications of our findings for successful forgetting.

3.2 Introduction

Our ability to learn from and remember characteristics of our environment is, arguably, one of the key factors underlying the sophistication of human functioning. Not

---

[2] This chapter has been reprinted with minor edits and with kind permission from Springer Science and Business Media, and has been previously published as: Thompson, K.M., & Taylor, T.L. (2015). Memory instruction interacts with both visual and motoric inhibition of return. *Attention, Perception, & Psychophysics*, DOI 10.3758/s13414-014-0820-2

only does memory provide us with a sense of self and continuity through time (Gallagher, 2000), but information from long-term memory influences even the most basic cognitive functions, such as perception and attention – this is at the heart of well known interactions between top-down and bottom-up processing (e.g., Duncan & Humphreys, 1989; Posner & Petersen, 1990; Ciaramelli, Grady, & Moscovitch, 2008).

In the study of memory, it is clear that forgetting irrelevant information that might otherwise interfere with successful encoding or retrieval can be just as important for creating an accurate representation of the world as remembering relevant information (MacLeod, 1998). For example, it serves us well to forget an instructional error made by a professor. If we were unable to forget such irrelevant information, it might interfere with our memory for the accurate information (Postman & Underwood, 1973; Anderson, Bjork, & Bjork, 1994; Anderson & Neely, 1996). The intentional forgetting of irrelevant or misleading information is studied in the laboratory using the directed forgetting paradigm.

In a directed forgetting paradigm, participants are presented with information (typically words, but a wide variety of stimuli have been used e.g., Quinlan, Taylor, & Fawcett, 2010; Hourihan, Ozubko, & MacLeod, 2009), and are asked to remember some things and to forget others. There are two main procedures that can be used: the list method and the item method. The present investigation concerns the item method (for a review of both methods see MacLeod, 1998, or Basden & Basden, 1998). Participants in an item-method directed forgetting paradigm are presented with items one at a time, and each is followed by an instruction to Remember (R) or Forget (F). After all items have been presented, participants' memory of *both* R and F items is tested with some kind of explicit test of memory (often yes/no recognition; although see Thompson, Fawcett, & Taylor, 2011). Typical results show greater memory performance for R items compared to F items – the directed forgetting effect (DF effect). Researchers are confident that this effect is not simply the result of demand characteristics on the part of participants (MacLeod, 1999).

The main explanation of the DF effect, the selective rehearsal hypothesis, posits that better memory for R than F items is achieved primarily by selective elaborative rehearsal of R items over F items (e.g., Bjork & Woodward, 1973; Woodward, Bjork, & Jongeward, 1973; MacLeod, 1975). While R items are afforded as much distinctive processing as possible to ensure they are encoded, processing of F items stops when the F instruction is received to limit the transfer of this information to memory.

Interestingly, there exists much evidence to suggest that, rather than passively dropping F items from working memory, instantiation of an instruction to forget is achieved by an active, cognitively effortful process (Fawcett & Taylor, 2008; Wylie, Foxe, & Taylor, 2008; Nowicka, Marchewka, Jednorog, Tacikowski, & Brechmann, 2011; Saletin, Goldstein, & Walker, 2011; Bastin, Feyers, Majerus, et al. 2012). Relevant to the present experiment, there has been a substantial amount of research on inhibition of return (IOR) in item-method DF tasks, which has informed our understanding of the cognitive consequences of instantiating an instruction to forget (Taylor, 2005; Fawcett & Taylor, 2010; Taylor & Fawcett, 2011; Thompson, Hamm, & Taylor, 2014). As will be described below, instantiating memory instructions at encoding produces interactions with IOR that implicate a differential withdrawal of attentional resources from Forget versus Remember items (see Taylor, 2005; Taylor & Fawcett, 2011). The fact that this interaction seems specific to a motor form of IOR further suggests that the allocation of limited-capacity attentional resources during encoding not only determines the contents of memory in the long term but also influences subsequent information processing in the short term. In this way, limiting the further encoding of unwanted or irrelevant items in working memory invokes a complex interplay of attentional, memorial, and motor systems.

3.2.1 Inhibition of Return

In an IOR cueing paradigm, participants are presented with an uninformative visual cue to the left or right (e.g., the brightening of an outline box) which participants are instructed to ignore. This cue is followed by a target to the left or right that requires a speeded response. If the stimulus onset asynchrony (SOA) between the cue and the target is relatively short (less than ~300ms), RTs to respond to the target are faster at the cued location compared to the other, uncued location. This facilitatory effect for target RTs occurs because the cue automatically draws attention to it and attention increases the speed and efficiency of visual processing (Posner, 1980). However, if the target is presented at a longer SOA (more than ~300ms), RT is *slower* at the cued location compared to the uncued location. This latter pattern is known as IOR (Posner & Cohen, 1984). Critically, IOR is observed in RTs only after attention has been withdrawn from the cued location; it is otherwise masked by the opposing facilitatory effects of attentional capture (Danziger & Kingstone, 1999).

IOR can be understood as reflecting a mechanism that promotes efficient search strategies by decreasing the likelihood that a previously inspected location will be reinspected (Klein & MacInnes, 1999; Klein, 2000; MacInnes & Klein, 2003). IOR is initiated by the activation of the oculomotor system by a stimulus (Rafal, Calabresi, Brennan, & Sciolto, 1989; Taylor & Klein, 1998; but see Chica, Klein, Rafal, & Hopfinger, 2010a), and/or by modulations of mental spatial saliency maps after attention is withdrawn from a non-informative cue (Henderickx, Maetens, & Soetens, 2012). Critically, though, the subsequent effects on information processing (i.e., the particular kinds of processing that are slowed at the cued relative to the uncued location) vary depending on the state of the oculomotor system. When the oculomotor system is active (i.e., eye movements – or saccades – are allowed/required to the cue and/or target), IOR manifests as a motoric bias against responding toward the cued location. Conversely, when the oculomotor system is suppressed (i.e., saccades are prevented during the task by requiring that participants maintain fixation in one location), IOR manifests as a perceptual deficit for information presented in the cued location (Taylor & Klein, 2000; Hunt & Kingstone, 2003; Chica, Taylor, Lupiáñez, & Klein, 2010b; Hilchey, Klein, & Ivanoff, 2012). These two forms of IOR are dubbed motoric and visual, respectively (Taylor & Klein 2000).

Importantly, these two forms of IOR do not co-occur in behavior (Taylor & Klein, 2000; Chica et al., 2010b; Hilchey et al., 2012). For example, Hilchey et al. (2012) found that the magnitude of IOR was the same when participants were required to make saccades regardless of whether the cues and targets were presented centrally or peripherally. If the motoric and visual forms co-occurred, it would be expected that the magnitude of IOR would be greater when saccades were made to peripheral cues (this type of task involves a motoric component – the saccade – as well as a perceptual component – the stimulation of the target location by a peripheral cue). Similarly, Chica et al. (2010b) found that typical visual IOR effects are not observed when participants are required to make saccades to cues or targets. Finally, in investigations of IOR using event-related potential (ERP) technology, reductions in P1 (an early sensory component) occur under conditions that elicit the motoric as well as those that elicit the visual form of IOR. However, these P1 modulations correlate with behavior only when the oculomotor system is suppressed (Satel, Hilchey, Wang, Story, & Klein, 2012). The distinction between these two forms of IOR is also supported by neurophysiological evidence that they are differentially affected by brain damage and rTMS manipulations, where double dissociations have been observed (Bourgeois, Chica, Migliaccio, Thiebault de Schotten, & Bartolomeo, 2012; Bourgeois, Chica, Valero-Cabré, & Bartolomeo, 2013).

3.2.2 IOR in Item-Method Directed Forgetting

Taylor (2005) first investigated IOR in item-method directed forgetting by creating a directed forgetting cueing paradigm (DF cueing paradigm). In this paradigm, participants were presented with a word to the left or right (serving as the ‘cue’ that initially draws attention) followed by an auditory R or F memory instruction. Then, after a relatively long SOA (1200ms from word onset) a target dot was presented to the left or right, which participants localized using a manual button-press. Taylor found that the magnitude of IOR (RT to ‘cued’ targets – RT to ‘uncued’ targets) was greater after an F compared to an R instruction (F>R IOR). Because IOR appears in RTs after attention has been withdrawn from the cued location (Danziger & Kingstone, 1999), the relative magnification of IOR by an F instruction was interpreted as a more ready withdrawal of attention following F instructions than following R instructions. This explanation converges with demonstrations that instantiating a forget instruction is relatively more cognitively demanding than instantiating a remember instruction (Fawcett & Taylor, 2008) and engages frontal mechanisms implicated in executive control over attention (Wylie, Foxe, & Taylor, 2008; Nowicka, Marchewka, Jednorog, Tacikowski, & Brechmann, 2011; Saletin, Goldstein, & Walker, 2011; Bastin, Feyers, Majerus, et al. 2012).

The differential withdrawal of attention following F and R instructions also accounts for the fact that these instructions impact processing of subsequent task-irrelevant information that appears in close spatial and temporal proximity to the study item (Fawcett & Taylor, 2012). Importantly, when the F instructions occur after the disappearance of the study items, there is no evidence for the reorienting of processing resources to the opposite location (Taylor & Fawcett, 2012); this establishes that the F>R IOR pattern does, in fact, reflect relative magnification of IOR by an F instruction (i.e., rather than being due to attentional facilitation at the opposite location; see also Thompson et al., 2014). Thus, participants actively withdraw their attention from F items, and this active process may be partially responsible for successful intentional forgetting. However, IOR is a complex phenomenon, and further investigation was necessary to determine specifically what kinds of processing might be shared between intentional forgetting and IOR that would result in their interaction. In particular, investigating whether memory instruction interacts with both the motoric and visual forms of IOR should elucidate which specific mechanisms (motoric or perceptual) are associated with intentional forgetting.

Taylor and Fawcett (2011) replicated Taylor's (2005) methodology, but, in two conditions relevant to the current study, had participants make either a spatially compatible localization response (button-press on the left for a target that appeared on the left, button-press on the right for a target that appeared on the right), or a perceptual discrimination response (one button-press to report the identity of a target as an upright triangle, a different button-press to report the identity as an inverted triangle). The F>R IOR difference emerged only when participants localized the target, not when they reported its identity. The spatial localization response required that a response be made toward the location of a target, whereas the perceptual discrimination response required an analysis of the perceptual quality of the target. As described above, depending on the state of the oculomotor system, IOR may manifest as either a bias against responding to targets that arise at the cued location (the motoric form of IOR) *or* as impaired/delayed perception of information at the cued location (the visual form). Because the interaction between memory instruction and IOR was observed only with a localization response, Taylor and Fawcett (2011) concluded that the interaction was specific to the motoric form of IOR. They presumed that selective enhancement of the motoric form of IOR by an F instruction could indicate a bias against responding to a source of unreliable information (see Thompson et al., 2014 for additional support for this hypothesis). This reluctance to respond to information arising from the same location as previous mis-information suggests that instructions to forget impact not only the encoding of to-be-forgotten items, but also subsequent information processing. To the extent that episodic memory keeps a record of goal-directed behavior (Conway, 2009), an alteration in behavior due to instantiation of an encoding instruction might provide a means for an encoding instruction to influence memory not only for the instructed item itself, but for the larger episodic event in which the item is embedded. In other words, an instruction to forget might impair episodic memory directly by limiting the encoding of the F item, and indirectly by altering the subsequent goal-directed behaviour that defines the episode for which the trace is established.

3.2.3 The Present Experiments

There has been one potentially critical oversight in the investigation of the F>R IOR difference that warrants some attention. In a typical cueing paradigm designed to differentiate between the motoric and visual forms of IOR, an important methodological component is the restriction and monitoring of participants' eye movements. Motoric IOR is observed when the oculomotor system is active, and visual IOR is observed when the oculomotor system is suppressed. Critically, Chica et al. (2010b) showed that suppression of the oculomotor system is *necessary* to observe the visual form of IOR. In their experiment, they had participants perform a detection task or a colour discrimination task. IOR was observed in both tasks when the oculomotor system was suppressed by preventing eye movements, suggesting an effect on perceptual processing, consistent with visual IOR. However, when the oculomotor system was activated by having participants make eye movements, IOR was only observed in the detection task. This shows that the visual form of IOR (as measured by IOR in the colour discrimination task) is only observed in RTs when the oculomotor system is suppressed, and suppression can only be guaranteed by monitoring participant’s eye movements. In addition, Hilchey et al. (2012; see also Taylor & Klein, 2000) found that perceptual and motoric effects on RT are not additive in a motoric IOR task by showing equivalent magnitudes of IOR for both central arrow targets (which could only measure a motoric bias) and peripheral targets (which could measure a motoric bias *and* perceptual degradation).

As described above, Taylor and Fawcett (2011) reported no F>R IOR when participants made a perceptual discrimination response to the target. They interpreted this as evidence that memory instruction does not modulate visual IOR effects, and that the interaction was due to an increased bias (like the one responsible for motoric IOR) against responding toward the source of irrelevant information. However, it is likely that participants were moving their eyes to fixate the study words on each trial in order to read them in Taylor and Fawcett (2011). According to Rayner (1998), the human perceptual span ranges from 3-4 letters on the left of fixation to 14-15 letters on the right of fixation. At the viewing distance and font size used by Rayner, this corresponds to about 1 degree of visual angle on the left, and 4-5 degrees on the right. In addition, Rayner noted that the identification span (i.e., the distance at which words can be *identified*) is even smaller, at 7-8 letters to the right, or about 2 degrees of visual angle.

In previous investigations of IOR in directed forgetting, the minimum distance from fixation to the boundaries of the peripheral locations at which words were presented was 4.5 degrees of visual angle (Taylor, 2005; Fawcett & Taylor, 2010; Taylor & Fawcett, 2011; Thompson et al., 2014). Words are typically centered in either the left or right peripheral location, thus the last (if presented to the left) or first (if presented to the right) letter of each word would be no closer than 4.5 degrees of visual angle from fixation. This, in combination with the fact that participants were never instructed to *refrain* from moving their eyes from fixation, means that participants were almost certainly moving their eyes to read the words, even during the perceptual discrimination task in Taylor and Fawcett (2011). Given that activation of the oculomotor system may mask, override, hide, or cancel any visual IOR effects that would otherwise occur if the oculomotor system were suppressed (Chica et al., 2010b), it is unsurprising that the visual IOR effects that Taylor and Fawcett (2011) were testing for might have been masked (the 8 ms overall IOR effect that they observed in their discrimination task was only marginally significant and did not interact with memory instruction). Thus, a more controlled test of the effects of memory instruction on motoric and visual forms of IOR is needed, and our understanding of the nature of this interaction hinges upon such a test.

The present experiments directly assessed whether the F>R IOR difference represents a selective modulation of the motoric form of IOR, as hypothesized by Taylor and Fawcett (2011) and supported by Thompson et al. (2014), or whether the explicit restriction of eye movements will reveal modulation of visual IOR as well. If, under controlled conditions and careful eye movement monitoring, we observe an interaction between memory instruction and visual IOR, it will challenge the previous conclusions about the mechanisms and implications of the F>R IOR difference. Participants completed a DF cueing paradigm similar to that used in previous investigations of IOR in directed forgetting. On each trial, a word was presented to the left or right of a central fixation and was followed by an auditory R or F memory instruction. After a relatively long SOA relative to the word, a target appeared to the left or right. In Experiment 1, participants were required to maintain fixation at centre until making a saccade to the target. In Experiment 2, participants were required to maintain fixation at centre throughout the entire trial, and to make a manual spatially compatible localization response to the target. Participants' eye movements were monitored with an eye tracker in both experiments. This ensured that the participants were adhering to the fixation/saccade requirements of their condition.

Because the oculomotor system should be engaged in Experiment 1, any IOR observed in that experiment should be motoric in nature. IOR in Experiment 2 should be visual in nature since participants are required to suppress the oculomotor system in this experiment (Taylor & Klein, 2000; Hunt & Kingstone, 2003; Chica, et al., 2010b; Hilchey, et al., 2012). Thus, if the interaction of memory instructions and IOR is due to selective modulation of the motoric form of IOR, the F>R IOR pattern should be observed in Experiment 1 only. If, however, memory instructions also interact with the visual form of IOR, the F>R IOR pattern should be observed in Experiment 2 as well.

3.3 Experiment 1

In Experiment 1, participants were presented with study words one at a time to the left or right of central fixation, each followed by an auditory R or F memory instruction, and then by a target in the same or the opposite location as the word. Participants maintained fixation until the target appeared, at which point they moved their eyes to the target. Because the oculomotor system was activated by this requirement to fixate the target, IOR in this experiment should be motoric in nature (Taylor & Klein, 2000; Hunt & Kingstone, 2003; Chica et al., 2010b; Hilchey et al., 2012). To reiterate our predictions: If memory instruction interacts with motoric IOR as it has in previous DF cueing experiments, the F>R IOR pattern should occur in this experiment.

3.3.1 Method

Participants

Twenty-nine participants were recruited from the undergraduate subject pool at Dalhousie University, and received one credit point for participating. All participants reported normal or corrected-to-normal vision and a good understanding of the English language. The experiment was approved by the Human Research Ethics board at Dalhousie University, and thus meets the ethical standards set forth in the Tri-Council Policy Statement.

Materials

The experiment used SR Research Experiment Builder Version 1.10.1 on an Intel Core 2 computer running Microsoft Windows XP Professional Version 2002. Stimuli were presented on a 32” 1366x768 resolution Phillips LCD monitor (Model ID: BDL3231C/00). Participants viewed the monitor from a distance of approximately 55 cm. Eye position was monitored with an EyeLink II (version 2.21) eye tracking system.

A master word list of 320 nouns was selected from the Paivio, Yuille, and Madigan Word Pool using an online generator (http://www.math.yorku.ca/SCS/Online/paivio/). The words had a mean Kucera-Francis word frequency of 47.3 (ranging from 0 – 100, *SD* = 36.7), a mean imagery rating of 5.4 (ranging from 2 – 6.9, *SD* = 1.3), and a mean concreteness rating of 5.4 (ranging from 1.2 – 7, *SD* = 1.8). Words ranged in length from 3 to 6 letters (*M* = 5, *SD* = 0.9). For each participant, Experiment Builder randomized this word list and split it into 4 lists of 20 R words, 4 lists of 20 F words, and a list of 160 Foil words.

Each trial in the study phase began with the presentation of a centrally located fixation stimulus (+; Arial size 18 font) and two circular grey placeholders on a black background. Each placeholder measured 1 degree of visual angle. One placeholder was centered 3.5 degrees to the right of fixation, and the other was centered 3.5 degrees to the left. Words were presented in Arial bold, size 14 font in yellow text, replacing one of the grey placeholders. Yellow circles (of the same size and eccentricity as the grey placeholders) served as targets. In studies that have used a similar paradigm, the cue and target were also both the same colour, but black on a white background instead of yellow on a black background (e.g., Taylor, 2005; Taylor & Fawcett, 2011). Our use of yellow for both the word and target was motivated by the fact that pilot testing showed yellow to be more visible on the background than white – an important consideration when peripheral words must be read while the eyes remain fixed at center. We have no reason to believe that having the word and target both in yellow, rather than both in black, would have any impact on our findings. An inter-trial fixation stimulus was visible in the center of the screen between trials, and was used for drift correction before each trial. This stimulus was a white circle measuring 1 degree with a .4 degree black circle in its centre.

Two auditory tones, one relatively high-pitched (1170 Hz) and one relatively low-pitched (260 Hz), were used as memory instructions. The assignment of memory instruction to tone was counterbalanced such that half of the participants were told that the high-pitched tone was an R instruction and the low-pitched tone was an F instruction, while the other half of the participants were told the opposite (low tone = R, high tone = F).

Procedure

Participants were given verbal instructions detailing the task along with a visual depiction of the trial progression in the study phase. Participants were informed that they were to do their best to follow the memory instruction for each word, and that they were to respond to all targets as quickly and as accurately as possible. Participants were told that the study phase would be followed by a memory test, but they were not told that they would be tested for their memory of F items.

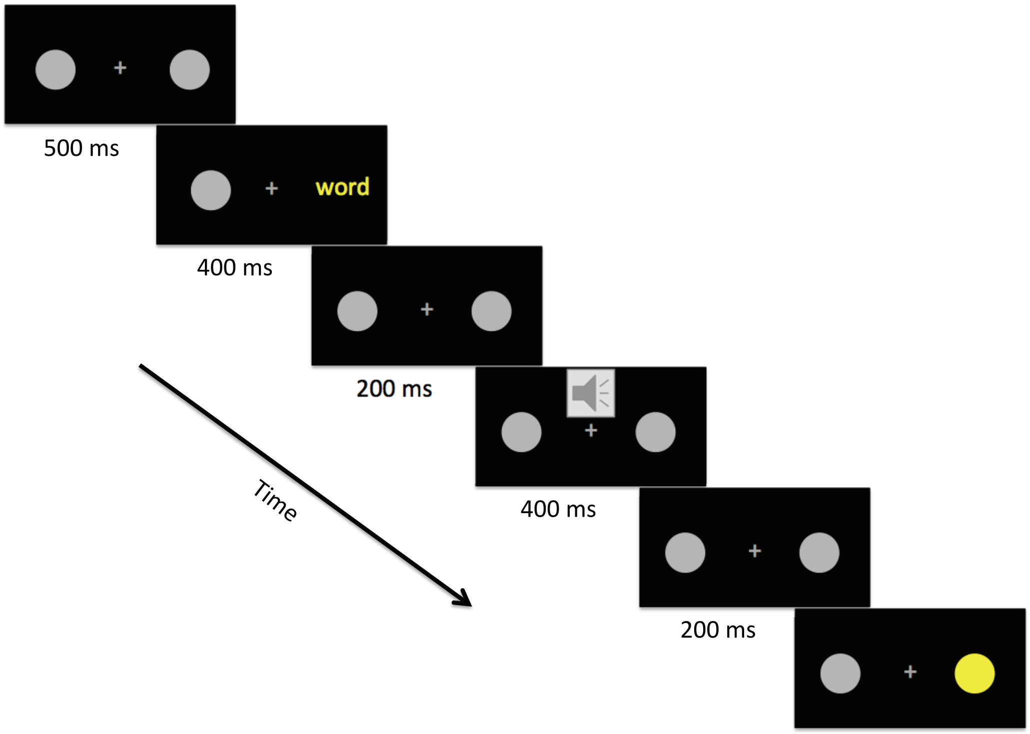


Figure 3.1: Progression of a trial in Experiments 1 and 2.

Study Phase. There were 20 R items and 20 F items for each type of trial for a total of 160 trials in the study phase. A depiction of a trial is presented in Figure 3.1. Each trial was initiated by the participant by depressing the space bar while maintaining fixation on the inter-trial fixation stimulus. This button press initiated a drift correction before each trial, and then initiated the trial once drift correction was complete. Upon initiation of the trial, a fixation cross ("+") replaced the inter-trial fixation stimulus, and two circular grey placeholders (one to the right and one to the left of fixation) appeared. A word replaced one of the placeholders 500 ms after the start of the trial. The word was equally likely to appear in the place of the right or left placeholder, and remained visible for 400 ms. The placeholder reappeared upon word disappearance. An auditory R or F memory instruction (high- or low-pitched tone) was presented 200 ms after the disappearance of the word, and lasted 400 ms. A target (yellow circle) replaced one of the placeholders 200 ms after the end of the memory instruction. The target was equally likely to appear in the place of the right or left placeholder, and remained visible for 1000 ms. Participants were given 2000 ms from the onset of the target to make a response. RT and accuracy were measured. Participants were told to maintain fixation at centre until the target appeared, at which point they should move their eyes from fixation to the target (i.e., make a saccade to the target location) as fast as they could. If any erroneous eye movements (saccades of more than 2.5 degrees away from central fixation[3]) were detected before the target appeared, the trial in progress was aborted. Participants were tested for their memory of words presented on aborted trials, but these words were excluded from the analyses of results.

Recognition Phase. After all study trials had been presented, participants completed a yes/no recognition task. All R and F items from the study phase were presented, along with an equal number of foil items. Thus, 160 study words plus 160 unstudied foil words were presented randomly, making a total of 320 trials in the recognition phase. Words were presented centrally on the computer monitor one at a time. Participants were to indicate whether they recognized the word during the study phase regardless of the memory instruction they received at study. If they recognized the word, they were told to press the ‘y’ button; if they did not, they were told to press the ‘n’ button. After all study and foil words had been presented, participants were debriefed and had any questions answered by the experimenter.

3.3.2 Results

Proportion of Retained Study Trials. Study trials were retained for analysis only if participants refrained from making eye movements before target onset. To determine whether study trials were retained differentially across conditions, a 2 (Word-Target Location: same, different) x 2 (Memory Instruction: R, F) repeated measures Analysis of Variance (ANOVA) was conducted with the proportion of retained trials as the dependent measure. There were no significant main effects or interactions (all *F*s <1). Thus,

---

[3] This eccentricity is similar to what has been used in other studies of inhibition of return (see, e.g., Hilchey et al., 2012).

participants' ability to follow fixation instructions was not influenced by the type of trial that was presented (see Table 3.1 for descriptive statistics).

Table 3.1
Descriptive statistics of the proportion of retained study trials per condition in Experiment 1. Means are reported, with Standard Deviations in parentheses.

	Word-Target Location	
Memory Instruction	**Same**	**Different**
Remember	.59 (.12)	.60 (.14)
Forget	.57 (.14)	.60 (.13)

Recognition accuracy. Although words from aborted study trials were tested during the recognition phase, they were excluded from the calculations of recognition accuracy. The data from the recognition test were analyzed using a one-way repeated measures ANOVA with Word Type (R, F, foil) as the independent variable, and the proportion of 'yes' responses as the dependent variable. There was a significant main effect of Word Type ($F(2, 56) = 62.847$, $MSe = .011$, $p < .001$) such that R items ($M = .51$) were recognized at a higher rate than F items ($M = .37$; $t(28) = 6.475$, $p < .001$). This is the expected DF effect (better memory for R than F items). Both R and F items were recognized at a higher rate than foil words ($M = .20$; $t(28) = 9.167$, $p < .001$, and $t\ (28) = 6.474$, $p < .001$, respectively). These results confirm that participants used the memory instructions as intended at study.

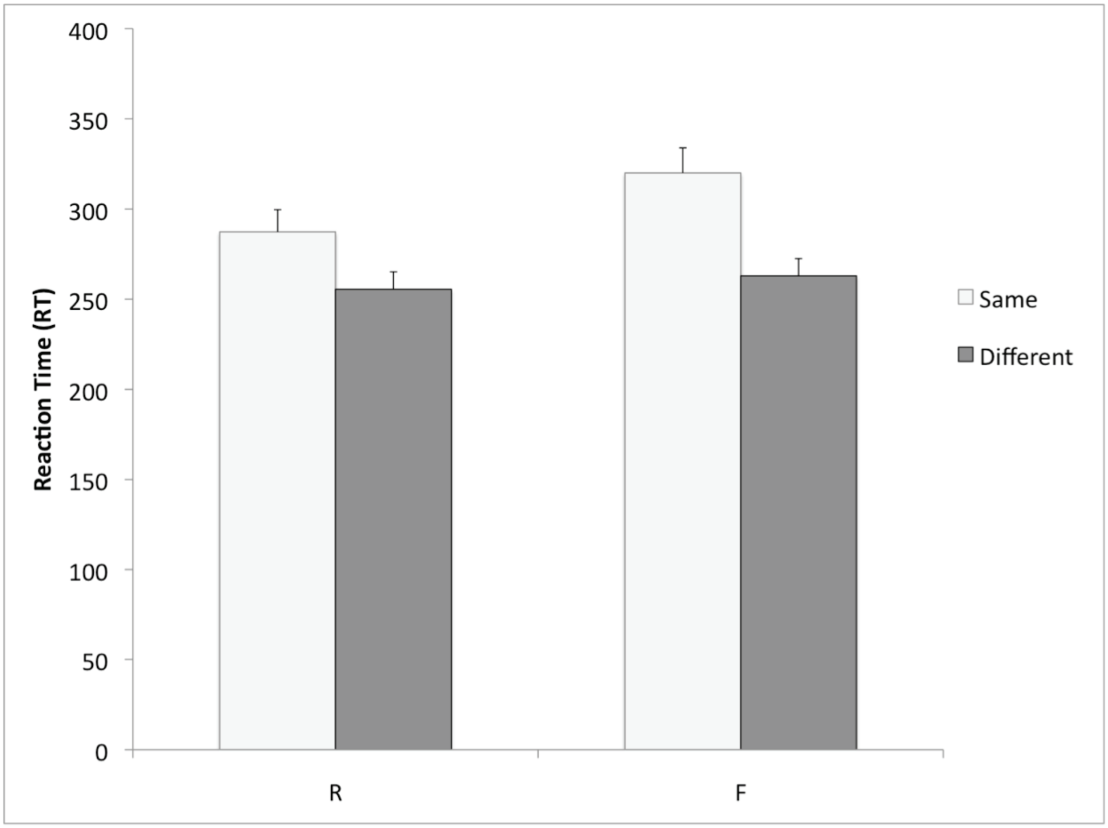


Figure 3.2: Mean RT in ms after R and F memory instructions to targets appearing in the same location as the word compared to those appearing in the different location in Experiment 1. Error bars are standard errors.

Saccadic RTs. Given that participants used the memory instructions as intended, the key question was whether these instructions interacted with the IOR effect measured by saccadic RTs to targets presented at study. See Figure 3.2 for descriptive statistics. A 2 (Word-Target Location: same, different) x 2 (Memory Instruction: R, F) repeated measures ANOVA was conducted on saccadic RTs to the targets. There was a significant main effect of Word-Target Location ($F(1, 28) = 36.590$, $MSe = 1366.332$, $p < .001$) with slower RTs to targets in the same location as the previous word compared to the other location (an IOR effect). There was also a significant main effect of Memory Instruction ($F(1, 28) = 12.157$, $MSe = 760.716$, $p = .002$) with slower RTs after F compared to R instructions. Critically, there was a significant Word-Target Location x Memory Instruction interaction ($F(1, 28) = 4.510$, $MSe = 826.604$, $p = .043$). The interaction was due to the fact that the magnitude of IOR (same RT – different RT) was greater after F ($M = 53$ ms) than R ($M = 30$ ms) instructions.

Analogous analyses on accuracy of the target response yielded no significant effects (all *F*s <1).

3.3.3 Discussion

The data from the yes-no recognition test revealed a directed forgetting effect, indicating compliance with the R and F memory instructions. Given that this was the case, the question of main interest was whether these memory instructions would interact with the motoric form of IOR. Participants responded to a target by making a saccade to its location. We observed the F>R IOR pattern in the saccadic RTs, demonstrating an interaction of memory instruction with the motoric form of IOR. This is consistent with the results of Taylor and Fawcett (2011; see also Thompson et al., 2014), who concluded that memory instruction interacts with the motoric form of IOR.

To fully test Taylor and Fawcett's (2011) conclusions about the F>R IOR difference, it is necessary to explicitly test whether memory instruction also interacts with the visual form of IOR. This was done in Experiment 2.

3.4 Experiment 2

In Experiment 2, participants were presented with study words one at a time to the left or right of central fixation, each followed by an auditory R or F memory instruction, and then by a target in the same or the opposite location as the word. Participants maintained fixation throughout the entire trial, and localized the target with a manual button-press. Because the oculomotor system was suppressed, IOR in this condition should be visual in nature (Taylor & Klein, 2000; Hunt & Kingstone, 2003; Chica et al., 2010b; Hilchey et al., 2012). To reiterate our predictions: If memory instruction selectively interacts with motoric IOR, the F>R IOR pattern should not occur in this experiment since we are not measuring motoric IOR in this task; if memory instruction also interacts with visual IOR, the F>R IOR pattern should occur here since the IOR in this task is visual in nature.

3.4.1 Method

Participants

Twenty-seven[4] participants were recruited from the undergraduate subject pool at Dalhousie University, and received one credit point for participating. All participants reported normal or corrected-to-normal vision and a good understanding of the English language. The experiment was approved by the Human Research Ethics board at Dalhousie University, and thus meets the ethical standards set forth in the Tri-Council Policy Statement.

Materials

The materials were the same as Experiment 1, but included the use of a Universal Serial Bus keyboard to record manual responses.

Procedure

The procedure was identical to Experiment 1, with the exception of the response required to the target. Instead of making a saccade to the target, participants were told to maintain fixation at centre throughout the entire trial. When the target appeared on the left, they pressed the 'f' key, and when it appeared on the right, they pressed the 'j' key. Study trials were aborted if erroneous eye movements were made at any time during the trial.

3.4.2 Results

Proportion of Retained Study Trials. Study trials were retained for analysis only if participants refrained from making eye movements after the start of the trial. To determine whether study trials were retained differentially across conditions a 2 (Word-Target Location: same, different) x 2 (Memory Instruction: R, F) repeated measures ANOVA was conducted with the proportion of retained trials as the dependent measure. There were no significant main effects or interactions (all *F*s <1). Thus, participants'

---

[4] Note that Experiment 2 recruited 2 fewer participants than Experiment 1. This was due to variations in participant volunteer rates between experiments. To ensure that the larger sample size in Experiment 1 (*n*=29) versus Experiment 2 (*n*=27) did not impact our conclusions, we repeated the analysis of Experiment 1 data after excluding the last 2 participants (*n*=27); the pattern of results was unchanged.

ability to follow fixation instructions was not influenced by the type of trial that was presented.

Table 3.2
Descriptive statistics of the proportion of retained study trials per condition in Experiment 2. Means are reported, with Standard Deviations in parentheses.

	Word-Target Location	
Memory Instruction	**Same**	**Different**
Remember	.71 (.14)	.69 (.16)
Forget	.69 (.15)	.70 (.13)

Recognition accuracy. Although words from aborted study trials were tested during the recognition phase, they were excluded from the calculations of recognition accuracy. The data from the recognition test were analyzed using a one-way repeated measures ANOVA with Word Type (R, F, foil) as the independent variable, and the proportion of 'yes' responses as the dependent variable. There was a significant main effect of Word Type ($F(2, 52) = 79.467$, $MSe = .006$, $p < .001$) such that R items ($M = .45$) were recognized at a higher rate than F items ($M = .33$; $t(26) = 6.063$, $p < .001$). This is the expected DF effect (better memory for R than F items). Both R and F items were recognized at a higher rate than foil words ($M = .18$; $t(26) = 10.499$, $p < .001$ and $t\ (26) = 8.120$, $p < .001$, respectively). These results confirm that participants used the memory instructions as intended at study.

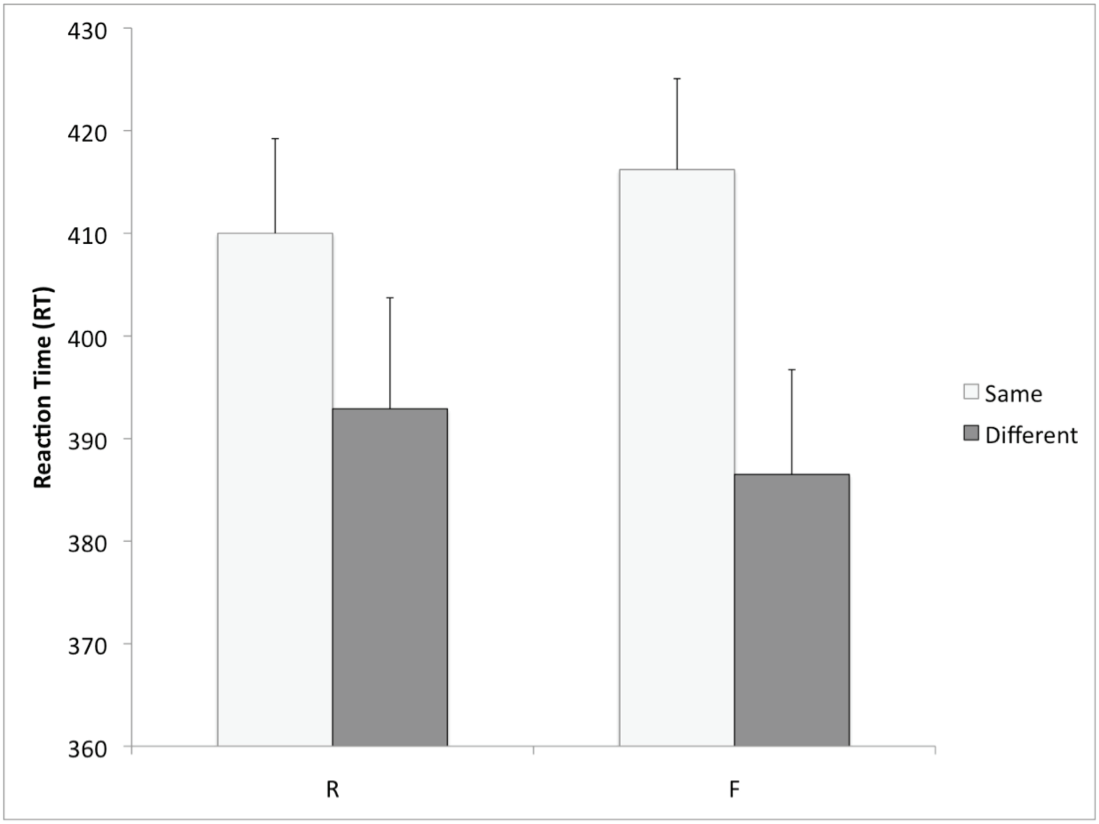


Figure 3.3: Mean RT in ms after R and F memory instructions to targets appearing in the same location as the word compared to those appearing in the different location in Experiment 2. Error bars are standard error.

Manual RTs. Given that participants used the memory instructions as intended, the key question was whether these instructions interacted with the IOR effect measured by manual RTs to targets presented at study. See Figure 3.3 for descriptive statistics. A 2 (Word-Target Location: same, different) x 2 (Memory Instruction: R, F) repeated measures ANOVA was conducted on the manual RTs to the targets. There was a significant main effect of Word-Target Location ($F(1, 26) = 19.537$, $MSe = 655.255$, $p < .001$) with slower RTs to targets in the same location as the previous word compared to the other location (an IOR effect). The main effect of Memory Instruction was not significant ($F < 1$). Finally, there was a significant Word-Target Location x Memory Instruction interaction ($F(1, 26) = 4.744$, $MSe = 263.426$, $p = .039$). The interaction was due to the fact that the magnitude of IOR (same RT – different RT) was greater after F ($M = 29$ ms) than R ($M = 15$ ms) instructions.

Analogous analyses on accuracy of the target response yielded no significant effects (all *F*s <1).

3.4.3 Discussion

The data from the yes-no recognition test revealed a directed forgetting effect, indicating compliance with the R and F memory instructions. Given that this was the case, the question of main interest was whether these memory instructions would interact with the visual form of IOR. We observed the F>R IOR pattern in the analysis of manual RTs to the study trial targets, demonstrating an interaction of memory instruction with the visual form of IOR. This is inconsistent with the results of Taylor and Fawcett (2011; see also Thompson et al., 2014), who concluded that memory instruction interacts selectively with the motoric form of IOR, not the visual form.

While the results of the present experiment are inconsistent with Taylor and Fawcett (2011), this is perhaps not surprising given the potential confound we outlined above. Since participants were likely making saccades to each word in Taylor and Fawcett (2011), the visual form of IOR that might be expected to emerge in their perceptual discrimination task would have been masked (Chica et al., 2010b). However, we thought it prudent to replicate and extend the results of the present experiment by testing for an interaction of memory instruction and visual IOR using the same perceptual discrimination response used by Taylor and Fawcett (2011), while restricting eye movements as in the present experiment. This would give us more confidence in our conclusion that memory instruction interacts with both forms of IOR.

3.5 Experiment 3

The results of Experiment 2 conflict with a previous conclusion from Taylor and Fawcett (2011). In one of their experiments, participants were presented with a word to the left or right, followed by an auditory R or F instruction, then a triangle to the left or right. Participants were required to indicate with a button-press whether the triangle was upright or inverted. Because Taylor and Fawcett (2011) found no significant interaction between memory instruction and IOR for this perceptual discrimination task, they concluded that memory instruction interacts only with the motoric form of IOR, and not with the visual form. However, this conclusion was based on the results of experiments that neither restricted nor monitored eye movements. And, as noted previously, visual IOR does not occur when the eyes are unrestrained (Chica et al., 2010b). This suggests that the lack of eye movement monitoring likely undermined Taylor and Fawcett's (2011) ability to find an interaction of memory instruction with the visual form of IOR. Perhaps an F instruction leads not only to a bias against responding to targets that arise at the location of the previous mis-information but, in the absence of eye movements, also to a perceptual processing deficit for targets presented at that location. If the conclusions of Experiment 2 are correct and memory instructions do interact with visual IOR, then prohibiting and monitoring eye movements in a replication of Taylor and Fawcett's (2011) perceptual discrimination task should produce the F>R IOR pattern that Taylor and Fawcett (2011) could not. To test this, Experiment 3 presented participants with a word to the left or right, followed by an auditory R or F instruction, and then a triangular target to the left or right. Participants were required to discriminate between upright and inverted triangles with a manual button press while maintaining fixation at centre throughout the trial. Eye movement monitoring ensured that participants complied with the instruction to refrain from making movements.

3.5.1 Method

Participants

Thirty-five[5] participants were recruited from the undergraduate subject pool at Dalhousie University, and received one credit point for participating. All participants reported normal or corrected-to-normal vision and a good understanding of the English language. The experiment was approved by the Human Research Ethics board at Dalhousie University, and thus meets the ethical standards set forth in the Tri-Council Policy Statement.

---

[5] Note that the sample size for Experiment 3 was greater than both Experiments 1 and 2. This was motivated by the fact that Experiment 3 was an attempt to replicate Taylor and Fawcett's (2011) discrimination experiment which, for them, consisted of a null result. Given this, we wished to ensure that we had enough power to observe a potentially small effect.

Materials

Materials used were identical to those used in Experiment 1 and 2 with the exception of the targets. Yellow triangles (of the same size and eccentricity as the grey placeholders) served as targets.

Procedure

The procedure used was identical to Experiment 2 with the following exceptions. A triangular target was presented on each trial instead of a circular target. When the target appeared, participants were required to press the ‘f’ key with the index finger of their left hand if the triangle was upright (i.e., pointing upward), or the ‘j’ key with the index finger of their right hand if the triangle was inverted (i.e., pointing downward).

3.5.2 Results

Proportion of Retained Study Trials. Study trials were retained for analysis only if participants refrained from making eye movements after the start of the trial. To determine whether study trials were retained differentially across conditions a 2 (Word-Target Location: same, different) x 2 (Memory Instruction: R, F) repeated measures ANOVA was conducted with the proportion of retained trials as the dependent measure. There was a significant main effect of Word-Target Location ($F(1, 34) = 5.172$, $MSe = .003$, $p = .029$), with a higher proportion of retained trials when the target appeared in the same compared to the different location as the word. No other effects were significant (all Fs < 1).

Table 3.3
Descriptive statistics of the proportion of retained study trials per condition in Experiment 3. Means are reported, with Standard Deviations in parentheses.

	Word-Target Location	
Memory Instruction	**Same**	**Different**
Remember	.79 (.14)	.77 (.12)
Forget	.80 (.10)	.78 (.13)

Recognition accuracy. Although words from aborted study trials were tested during the recognition phase, they were excluded from the calculations of recognition accuracy. The data from the recognition test were analyzed using a one-way repeated measures Analysis of Variance (ANOVA) with Word Type (R, F, foil) as the independent variable, and the proportion of 'yes' responses as the dependent variable. There was a significant main effect of Word Type ($F(2, 68) = 91.668$, $MSe = .010$, $p < .001$) such that R items ($M = .46$) were recognized at a higher rate than F items ($M = .33$; $t(34) = 5.547$, $p < .001$). This is the expected DF effect (better memory for R than F items). Both R and F items were recognized at a higher rate than foil words ($M = .13$; $t(34) = 11.583$, $p < .001$ and $t (34) = 9.492$, $p < .001$, respectively). These results confirm that participants used the memory instructions as intended at study.

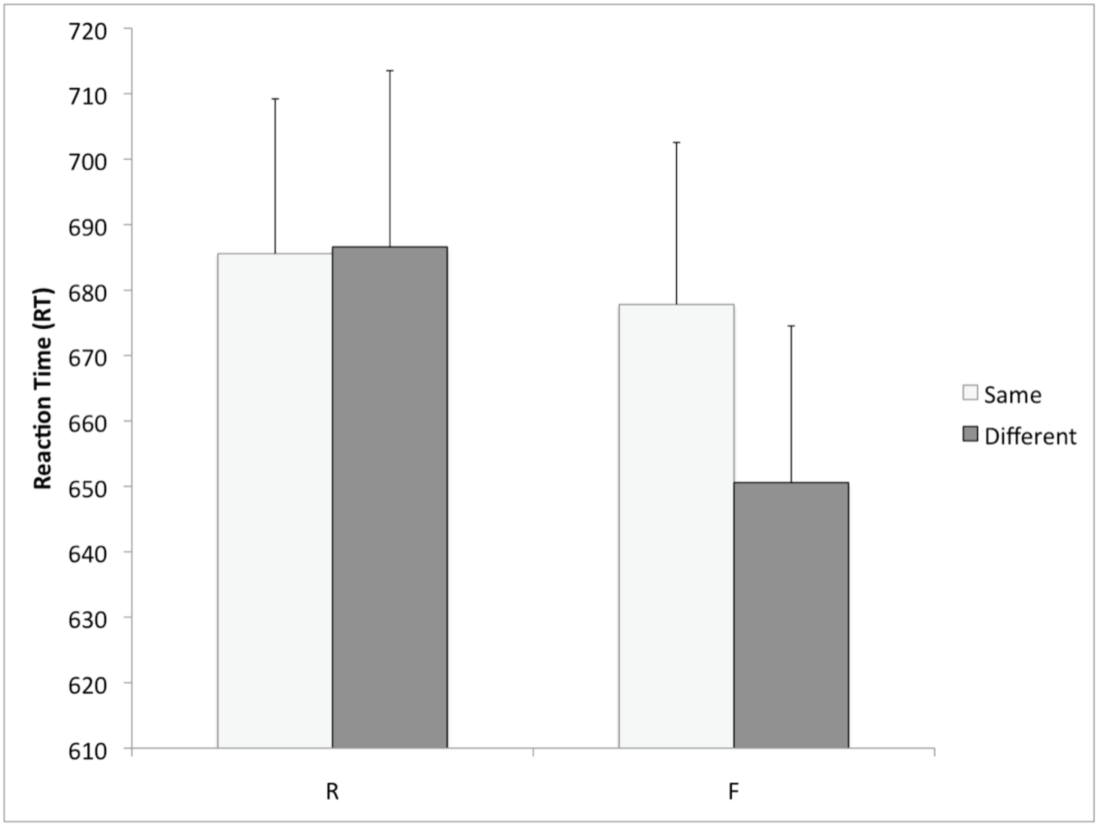


Figure 3.4: Mean RT in ms after R and F memory instructions to targets appearing in the same location as the word compared to those appearing in the different location in Experiment 3. Error bars are standard error.

Discrimination RTs. Given that participants used the memory instructions as intended, the key question was whether these instructions interacted with the IOR effect measured by RTs to discriminate the target arrow on study trials. See Figure 3.4 for descriptive statistics. A 2 (Word-Target Location: same, different) x 2 (Memory

Instruction: R, F) repeated measures ANOVA was conducted on the discrimination RTs. There was a significant main effect of Word-Target Location ($F(1, 34) = 4.921$, $MSe = 1224.310$, $p = .033$) with slower RTs to targets in the same location as the previous word compared to the other location (an IOR effect). There was also a significant main effect of Memory Instruction ($F(1, 34) = 11.157$, $MSe = 1505.005$, $p = .002$) with slower RTs after R compared to F instructions. Finally, there was a significant Word-Target Location x Memory Instruction interaction ($F(1, 34) = 6.792$, $MSe = 1032.661$, $p = .013$). The interaction was due to the fact that the magnitude of IOR (same RT – different RT) was greater after F ($M = 27$ ms) than R ($M = -1$ ms) instructions.

Analogous analyses on accuracy of the target response yielded no significant effects (all Fs <1).

3.5.3 Discussion

The results from the yes-no recognition test confirmed a directed forgetting effect, suggesting that participants complied with the R and F instructions. Given that this was the case, the critical question was whether disallowing eye movements in a replication of Taylor and Fawcett's (2011) perceptual discrimination task would reveal the interaction of memory instruction and visual IOR that Taylor and Fawcett discounted. Indeed, it did. Experiment 3 revealed the F>R IOR pattern for the same perceptual discrimination task as employed by Taylor and Fawcett (2011). In so doing, the results of Experiment 3 bolstered the conclusion drawn from the results of Experiments 1 and 2: Memory instruction interacts not only with the motoric form of IOR but also with the visual form.

Before proceeding to the General Discussion, it is worth noting that in Experiment 3, the larger IOR effect for F than R trials reflected a significant IOR effect for the former and not for the latter condition. This is consistent with previous investigations of IOR and directed forgetting, where the trend is that in some cases the IOR effect is not significant after R instructions, but even in the cases where significant IOR is observed after R instructions, the magnitude of IOR is greater after F compared to R instructions. That is, the increased magnitude of IOR after F instructions is always observed, and this is sometimes accompanied by a non-significant IOR effect after R items (Taylor, 2005; Taylor & Fawcett, 2011; Thompson et al., 2014). This relative increase in magnitude of IOR after F instructions and decrease after R instructions has been examined in comparison to a no-memory control condition (Taylor & Fawcett, 2011). The decreased magnitude of IOR after R instructions may be due to individual differences in study strategies (perhaps explaining its inconsistent appearance), and likely indicates attentional dwelling on R-items to aid in elaborative encoding – this would result in a delay in the appearance of IOR, which is caused by the onset of the word, but is masked by facilitatory effects until attention is withdrawn (Danziger & Kingstone, 1999).

3.6 General Discussion

IOR can be conceived of as a mechanism that facilitates visual search for novelty (Klein & MacInnes, 1999; Klein, 2000; MacInnes & Klein, 2003). After attention is captured by a particular stimulus, re-inspection of that location is prevented in one of two ways depending on the state of the oculomotor system (Taylor & Klein, 2000; Hunt & Kingstone, 2003; Chica et al., 2010b; Hilchey et al., 2012). When the oculomotor system is active, IOR reflects a motoric bias against making responses toward the cued location. When the oculomotor system is inactive or suppressed, IOR reflects a perceptual processing deficit at the stimulus location.

We observed effects of memory instruction on both of these forms of IOR. It seems unlikely that memory instruction has two entirely independent effects, one that interacts only with a motor response bias and one that interacts only with perceptual processing. Instead, it is more parsimonious to assume that despite the fact that motoric and visual IOR represent different behavioural manifestations of the after-effects of peripheral visual stimulation (Taylor & Klein, 2000; Hunt & Kingstone, 2003; Chica et al., 2010b; Hilchey et al., 2012), they must have upstream processing in common, and that it is this common upstream processing that interacts with the memory instruction.

Most research on the two forms of IOR focuses on the mechanisms that differentiate them. However, there may be some commonalities between them. For example, in an rTMS study, Bourgeois et al. (2013) found that disruption of the intra-parietal sulcus (IPS) disrupted both motoric and visual IOR for left-sided targets. Thus, the IPS may represent a neural correlate of both motoric and visual IOR. In attention research, the IPS is known as the seat of a spatial salience map where the salience of environmental stimuli is represented and can be modified based on experience (Silver & Kastner, 2009; van Koningsbruggen, Gabay, Sapir, Henik, & Rafal, 2010). In the inhibition of return framework, it is thought that the salience of a cued location in the IPS is diminished/inhibited to allow orienting to new spatial locations, causing increased RTs to targets presented in cued locations (Sapir, Hayes, Henik, Danziger, & Rafal, 2004; Vivas, Humphreys, & Fuentes, 2006). In accord with the idea that this area could be upstream of both the motoric and visual forms of IOR, the IPS has connections to the superior colliculus (SC; known to be involved in motoric IOR; Robinson, Bowman, & Kurtzman, 1995; Anderson & Rees, 2011; Dorris, Klein, Everling, & Munoz, 2002; Bourgeois et al., 2012; Bourgeois et al., 2013). Not only this, but the dorsal parieto-frontal network that encompasses the IPS is also tightly linked with the ventral parieto-frontal network that encompasses the temporo-parietal junction (TPJ; known to be involved in visual IOR; Asplund, Todd, Snyder, & Marois, 2010; Bourgeois et al., 2012 & 2013). Interestingly, there is research suggesting that the salience map in the IPS has much broader applications than mapping the salience of environmental spatial locations. It is thought to be involved with guiding top-down attention not only spatially, but also with respect to particular target features, semantic associations, and even to retrieval of target memories (Ciaramelli et al., 2008; Cabeza, 2008; Silver & Kastner, 2009). Although highly speculative, this introduces the intriguing possibility that memory instructions interact with motoric and and visual IOR effects by altering representations within the IPS saliency map. Essentially, locations that contained a to-be-forgotten item become relatively less salient than those that contained a to-be-remembered item.

While fMRI research on directed forgetting focuses on frontal and medial temporal lobe activation, there is often parietal activation associated with instantiating an instruction to forget at study (e.g., Wylie et al., 2008; Nowicka et al., 2011; Saletin et al., 2011; Bastin et al. 2012). In addition, electrophysiological investigations of directed forgetting have consistently shown that R instructions are associated with a parietally distributed positivity that is absent after F instructions (Ullsperger, Mecklinger, & Muller, 2000; Hauswald, Schulz, Iordanov, & Kissler, 2011; Paz-Caballero, Menor, & Jimenez, 2004; Hsieh, Hung, Tzeng, Lee, & Cheng, 2009; van Hoof & Ford, 2011; Lin, Kuo, Liu, Han, & Cheng, 2013). This could represent parietal inhibition after F, but not R instructions. When combined with an IOR cueing paradigm, this inhibition after F items may be additive with that observed due to IOR. Finally, parietal areas including the IPS have been found to be associated with the suppression of unwanted memories in other experimental paradigms such as think/no-think (Anderson, Ochsner, Kuhl, Cooper, Robertson, et al., 2004). So, while the present results certainly are not able to directly support the hypothesis that activation in the IPS in particular may be influenced by memory instructions, this is one possibility that is consistent with the existing IOR and directed forgetting literatures.

Collectively, the research on IOR in directed forgetting has taught us much about the cognitive consequences of instantiating an intention to forget. We now have a substantial amount of evidence that attention is more readily withdrawn after F compared to R instructions (Taylor, 2005; Fawcett & Taylor, 2010; Taylor & Fawcett, 2011; Thompson et al., 2014; the present experiments). This differential withdrawal of attention helps direct cognitive resources away from unwanted information and toward relevant information. Withdrawing attention is a cognitively demanding process, which results in reduced availability of cognitive resources following F compared to R instructions (Cheng et al., 2012; Fawcett & Taylor, 2008). While there is conflicting evidence regarding whether the F>R IOR difference is related to the magnitude of the directed forgetting effect (Fawcett & Taylor, 2010; Taylor & Fawcett, 2011; Thompson et al., 2014), we know that successful instantiation of an F instruction *is* related to the availability of cognitive resources. Forgetting is *more* successful under highly demanding task conditions (Lee & Lee, 2011; Lee, 2012). Thus, the differential withdrawal of attention may benefit successful intentional forgetting directly by redirecting attention away from unwanted information. It may also benefit successful intentional forgetting indirectly by occupying cognitive resources.

Not only does an F instruction cause attention to be differentially withdrawn, but it also has lasting and wide-ranging consequences for subsequent information processing. The present experiment has shown that memory instruction interacts with IOR in such a way that it enhances both a bias against responding to the source of the F item, and also perceptual impairments at that source. IOR has been conceptualized as a mechanism that facilitates visual search by encouraging the inspection of novel, un-inspected locations (Klein & MacInnes, 1999; Klein, 2000; MacInnes & Klein, 2003). In this case, a location is inspected, and found to be irrelevant, so processing and responses are directed away from that location to avoid the constant re-inspection of a known irrelevant source. The magnification of this difference by an F instruction is a logical extension. Previous research has suggested that instantiating an F instruction results not only in decreased memory for F items, but also in impoverished encoding of contextual/episodic information presented in close temporal proximity to the F item (Fawcett & Taylor, 2012; Hourihan, Goldberg, & Taylor, 2007).

Fawcett and Taylor (2012) showed decreased memory for probe words presented after F compared to R instructions, suggesting that incidental memory for information presented soon after an F instruction is decreased. Hourihan, Goldberg, and Taylor (2007) showed that presenting items in the same spatial location at study and test benefitted memory performance only for F items, but not R items. This suggests that encoding of contextual characteristics (such as spatial location) was already strong for R items, but the weak encoding of such details for F items lead to a significant improvement on memory performance with the addition of such contextual cues at test.

The notion that an F instruction disrupts episodic encoding of the event is also supported by fMRI studies of item-method directed forgetting, where instantiating an F instruction has been associated with frontal and medial temporal activation (Wylie et al., 2008; Nowicka et al., 2011; Saletin et al., 2011; Bastin et al., 2012) The F>R IOR difference represents a mechanism by which this disruption of episodic encoding occurs. We have shown that an F instruction limits the degree to which contextual elements are able to capture attention by modulating perceptual processing of the event and/or motor output (visual and motoric IOR). This would result in impoverished encoding of the event, and therefore reduced memory strength for F items compared to R items – the DF effect.

To conclude, we have shown that instantiating an instruction to forget increases the magnitude of IOR, leading to both a bias against responding to the F item source and perceptual decrements at the F item location, depending on the state of the oculomotor system. These consequences of instantiating an instruction to forget are adaptive insofar as they promote the encoding of valid and relevant observations about the world, and prevent the encoding of invalid, irrelevant observations.

3.7 Author Note

We would like to thank Dr. David Westwood for the use of his computers and eye tracking equipment, as well as his kind tutelage in their use. I would also like to thank Heath Matheson for help troubleshooting during the programming of the experiment, Matt Hilchey for providing theoretical insight from his wealth of knowledge about IOR, as well as the undergraduate students who volunteered their time to participate in our study.

Chapter 4 Conclusion

The research presented in this dissertation investigated the F>R IOR difference to further clarify the processes that are shared between directed forgetting and IOR with the goal of understanding more about how forgetting is accomplished in the item-method paradigm. Previous research on the F>R IOR difference concluded that memory instruction interacts with motoric IOR, but not visual IOR (Taylor & Fawcett, 2011). This suggested that both IOR and directed forgetting lead to a motoric bias against responding toward irrelevant sources (Taylor & Fawcett, 2011). The experiments in Chapters 2 and 3 empirically tested this conclusion. The results of those investigations are summarized below.

4.1 Summary of Findings

4.1.1 Summary of Chapter 2

Research using the DF cueing paradigm has shown that the magnitude of IOR is greater after an instruction to forget compared to an instruction to remember (Taylor & Fawcett, 2011; Taylor, 2005). Taylor and Fawcett (2011) concluded that this F>R IOR difference appears to be due to a bias against responding toward an unreliable source of information rather than to a perceptual decrement at the source. However, there are a number of alternative ways to interpret the F>R IOR difference. The experiments presented in Chapter 2 tested three such alternatives. In all three experiments, participants were presented with a DF cueing study phase in which a word appeared at one of four peripheral locations, followed by an auditory R or F memory instruction, and then a target appeared in one of the four locations.

Experiment 1 assessed the contribution of attentional momentum (Pratt, Spalek, & Bradshaw, 1999; Snyder, Schmidt, & Kingstone, 2001; and Spalek & Hammad, 2004) to the pattern of results that has been interpreted as an F>R IOR difference. Participants responded to the target by making a spatially compatible localization response. Critically, RT to targets in all three uncued locations did not vary significantly. That is, RT was not speeded at the location directly opposite from the word, compared to the location on the same side or across from the word. Thus, we found no evidence that attentional momentum can account for the pattern of RTs in DF cueing experiments that has previously been interpreted as a F>R IOR difference. Note that an effect of attentional momentum was observed in Experiment 3, but this effect was present after both R and F instructions. In addition, the F>R IOR difference was still significant after accounting for effects of attentional momentum.

Experiment 2 tested the hypothesis that F>R IOR results from the suppression of automatic S-R code activation (Simon, 1969; Kornblum, Hasbroucq, & Osman, 1990; De Jong, Liang, & Lauber, 1994; Metzker & Dreisbach, 2011) after an F instruction. Participants responded to the target by making a spatially neutral localization response. If the F>R IOR difference results from S-R code suppression after an F instruction, the F>R IOR difference should not have emerged here because automatic S-R code activation should not influence the spatially neutral responses used in this experiment. Thus, any influence of the F instruction on S-R code activation could not be measured by the spatially neutral responses. Critically, the F>R IOR difference still emerged with this spatially neutral response, suggesting that the F>R IOR difference is not due to the suppression of automatic S-R code activation by an F instruction.

Experiment 3 determined whether the F>R IOR difference is due to slowed execution of a motoric response by a particular effector after an F instruction. Participants responded to the target by making a directional left/right localization. In this experiment, then, each response corresponded to two locations. If F>R IOR is due to slowed execution of a motoric response associated with a particular effector after an F instruction, we should have seen equally slowed RTs at the location of the previous word *and* at the other location that required a response with the same effector. Instead, we found a significant F>R IOR difference, but RT at the location requiring the same response as word-location targets was not significantly different than RT at the location across from the word. Thus, responding with the particular effector associated with the word location was not slowed.

Ruling out three alternative explanations of the F>R IOR difference lent some indirect support to Taylor and Fawcett's (2011) interpretation of the difference as resulting from a bias against responding to the source of irrelevant information. According to this interpretation, memory instruction interacts with the motoric form of IOR because both are associated with a motoric bias. In motoric IOR, there is a bias against responding toward the cued location, and this bias is thought to be the factor that differentiates motoric IOR from visual IOR (Taylor & Klein, 2000; Hunt & Kingstone, 2003). That memory instruction interacts with the motoric form of IOR suggests that instantiating an instruction to forget also results in a motoric bias against responding toward the source of unwanted information. The motoric biases associated with IOR and intentional forgetting, then, co-occur in the DF cueing paradigm and magnify the IOR effect, resulting in F>R IOR.

4.1.2 Summary of Chapter 3

Interpretation of the F>R IOR difference as a bias against responding to the source of irrelevant information, and *not* as a perceptual decrement for information presented at the source (Taylor & Fawcett, 2011), is based on the assumption that the experiments conducted by Taylor and Fawcett (2011) allowed measurement of both motoric and visual forms of IOR. However, measurement of visual IOR requires suppression of the oculomotor system (Taylor & Klein, 2000; Chica et al., 2010b), and eye movements were not monitored (nor explicitly discouraged) in Taylor and Fawcett (2011). The experiments in Chapter 3 instituted the use of eye tracking technology in the DF cueing paradigm to more conclusively determine whether memory instruction interacts with both motoric and visual IOR in item-method directed forgetting.

In Experiment 1, participants were presented with a typical DF cueing paradigm in which a word was presented to the right or left, followed by an auditory R or F memory instruction, and then a target appeared to the right or left. Participants were required to maintain fixation at centre throughout the trial until the target appeared, when they were to make a saccade to the target location. Motoric IOR is observed any time the oculomotor system is active, and a response is required towards the cued location (Taylor & Klein, 2000; Chica et al., 2010b; Hunt & Kingstone, 2003; Hilchey et al., 2012), as in this experiment. We found a significant F>R IOR difference, confirming that memory instruction interacts with the motoric form of IOR.

In Experiment 2, participants were presented with the same visual stimuli as in Experiment 1. However, participants were required to maintain fixation at centre throughout the trial, and to make a manual localization response to the target. Visual IOR is observed any time the oculomotor system is suppressed, and the target response requires perception of information at the cued location (Taylor & Klein, 2000; Chica et al., 2010b; Hunt & Kingstone, 2003; Hilchey et al., 2012), as in this experiment. We found a significant F>R IOR difference, suggesting that memory instruction interacts with the visual form of IOR.

Experiment 3 was meant to replicate the interaction of memory instruction and visual IOR using the discrimination task utilized by Taylor and Fawcett (2011). Participants were presented with a word to the right or left, followed by an auditory R or F memory instruction, and then a triangular target to the right or left. Participants were required to maintain fixation at centre throughout the trial, and were required to discriminate between upright and inverted triangles. We found a significant F>R IOR difference, confirming that memory instruction interacts with the visual form of IOR.

Observing an interaction between memory instruction and both forms of IOR requires an extension of the interpretation of the F>R IOR difference provided by Taylor and Fawcett (2011). Instantiating an instruction to forget leads to impaired perceptual processing of information associated with F items in addition to the bias against responding toward the source of the F item hypothesized by Taylor and Fawcett. The interaction of memory instruction with both forms of IOR suggests that directed forgetting involves a process that is shared between the motoric and visual forms of IOR. This process could simply be the withdrawal of attention, which is required to observe both motoric and visual IOR, or it could be the modification of the mental salience of information that has captured attention. We will discuss these possibilities below.

4.2 Shared Mechanisms Between IOR and Intentional Forgetting

4.2.1 On the causes and effects of IOR, and where memory instruction could have its influence

To fully understand IOR, it is important to distinguish between the factors that *cause* or *generate* IOR, the subsequent *effects* of IOR on information processing, and the factors that *reveal* or *unmask* IOR in behaviour (Taylor & Klein, 1998; Klein, 2000). As described in Chapter 1, IOR is thought to be *generated* by the onset of the cue, which may result in activation of the oculomotor system (Rafal et al., 1989; although see Chica et al., 2010a) and/or a decrease in the mental salience of the cued location (Henderickx et al., 2012; Sapir, Hayes, Henik, Danziger, & Rafal, 2004; Vivas, Humphreys, & Fuentes, 2006). The generation of IOR has different *effects* on information processing depending on the state of the oculomotor system: When the oculomotor system is active, IOR results in a motoric bias against responding toward the cued location; when the oculomotor system is suppressed, IOR results in impaired or delayed perceptual processing of information at the cued location (Taylor & Klein, 2000; Chica et al., 2010b; Hunt & Kingstone, 2003; Hilchey et al., 2012). In either case, IOR will not be *revealed* in RTs until attention has been withdrawn from the cued location. Attention provides a facilitatory effect where information in the focus of attention is more readily processed, and this facilitation masks IOR until attention is removed (Danziger & Kingstone, 1999).

An interaction between memory instruction and IOR could be interpreted as an influence of memory instruction on the cause (oculomotor activation/decreased mental salience), on the effects (motoric bias or impaired perception), and/or on the unmasking of IOR (withdrawal of attention). When Taylor and Fawcett (2011) found that memory instruction appeared to interact selectively with the motoric form of IOR, and *not* with the visual form, they suggested that the more ready withdrawal of attention from the F than from the R item location reveals a bias against responding toward information that arises subsequently from the F item location; they argued that the F>R IOR difference arises from the interaction of this bias with the bias that underlies the motoric (but not the visual) form of IOR. In other words, they presumed that the specificity of the F>R IOR effect for the motoric form of IOR meant that memory instruction interacts with the *effects* of IOR (i.e., on subsequent information processing).

In this dissertation, I have shown that memory instruction does, in fact, interact with both motoric *and* visual IOR, which opens up the possibility that memory instruction interacts with IOR earlier – during the *generation* of IOR and/or during its *unmasking*. Technically, it is also possible that the influence of memory instruction is on *both* the motoric bias associated with motoric IOR *and* the perceptual impairment associated with visual IOR (i.e., an interaction with two dissociable *effects*). However, it is more parsimonious to assume that memory instruction influences earlier processes that are shared by the two forms of IOR. In addition, while it is unclear why memory instruction might have these two different consequences (a motoric bias and impaired perception), there is converging evidence that supports the conclusion that memory instruction might be associated with either the differential withdrawal of attention after F and R instructions (i.e., memory instruction influences the unmasking of IOR) and/or modifications of the salience of mental representations of F and R items (i.e., memory instruction influences the factors that generate IOR). These two possibilities will be discussed below.

4.2.2 Differential withdrawal of attention

This dissertation set out to understand how the F>R IOR difference can inform us about the processes involved in intentionally forgetting information in the item-method directed forgetting paradigm. The presence of an F>R IOR difference suggests that attention is more readily withdrawn after F compared to R instructions (Taylor, 2005), and this differential withdrawal of attention may be the cognitively demanding process that is associated with instantiating an instruction to forget (Fawcett & Taylor, 2008). Active withdrawal of attention after an instruction to forget may be the mechanism by which F item rehearsal is stopped (Taylor, 2005; Taylor & Fawcett, 2011; Fawcett & Taylor, 2010), a key component of the Selective Rehearsal account of the item-method directed forgetting effect (Bjork & Woodward, 1973; Woodward, Bjork, & Jongeward, 1973; MacLeod, 1975). While Taylor and Fawcett (2011) supported a role for differential attentional withdrawal from F and R items and agreed with the postulated role in preventing unwanted rehearsal of F items, they believed that the F>R IOR pattern emerged only for the motoric form of IOR. Under this view, differential withdrawal of attention was deemed *necessary* to reveal the F>R IOR pattern, but not *sufficient*. However, in light of the current findings which show an F>R IOR pattern for both the motoric and visual forms of IOR, it follows that differential attentional withdrawal may, in fact, be both necessary *and* sufficient.

While the majority of research that investigates motoric and visual IOR is aimed at differentiating the two forms from one another, there are potentially some shared processes between the two. An obvious similarity between them is the necessity for the withdrawal of attention before observing IOR in behaviour. Typically, IOR emerges at cue-target SOAs greater than ~300 ms, but Danziger and Kingstone (1999) demonstrated that IOR could be observed at earlier SOAs if attention was withdrawn prematurely from the cued location. They compared performance in two conditions: one in which the peripheral cue was non-predictive of target location (the typical procedure used in studies of IOR), and one in which the cue indicated that the target was likely to appear one location clockwise from the cued location. In the non-predictive cue condition, they observed the typical bi-phasic pattern in RTs: at an early SOA (50 ms) RT was faster for targets appearing at the cued location compared to uncued locations (facilitation), but at a late SOA (950 ms) RT was faster for uncued compared to cued targets (IOR). In the predictive condition, RT was compared between the cued location (the location where the cue appeared), the predicted location (the location where the target was likely to appear – one location clockwise from the cued location), and uncued locations (where no cue appeared, and targets were unlikely to appear). At the early SOA, RT was fastest for targets appearing at the predicted location (facilitation), followed by those appearing at uncued locations, and slowest at the cued location (IOR). This pattern was the same at the late SOA. This pattern of results could suggest that IOR begins as soon as attention is withdrawn from the cued location, or that IOR and facilitation are both initiated at cue onset, and it is the summation of these effects that we observe in RT (Berlucci, Chelazzi, & Tassinari, 2000; Dorris, Klein, Everling, & Munoz, 2002; Klein, 2000; Tian, Klein, Satel, Xu, & Yao, 2011; Danziger & Kingstone, 1999). According to the latter characterization, at early SOAs, the influence of attentional facilitation is greater than

IOR, and so RTs are faster at the cued compared to uncued locations. However, facilitation dissipates over time as attention is withdrawn from the cued location. IOR, which is fairly consistent in magnitude for two to three seconds (Samuel & Kat; 2003), then begins to overpower the diminishing facilitatory effect, such that RTs are slowed at the cued compared to the uncued locations.

A change in the magnitude of IOR as a function of memory instruction could be accomplished by varying the withdrawal of attention in a number of ways. First, it could be that attention is removed earlier after an F compared to an R instruction. This would result in an earlier unmasking of the IOR effect in RTs. However, Taylor and Fawcett (2011) investigated the time course of the F>R IOR difference, and did not observe any differences in the SOA at which IOR appeared between R and F trials. Instead, across a wide range of SOAs, the magnitude of IOR was greater after F compared to R instructions. This argued against a different time course for the revelation of IOR following F and R instructions. Second, it could be that attention is removed more fully after an F compared to an R instruction, leaving less facilitation to mask IOR after F instructions. This differential removal could reflect spatial differences in the allocation of attentional resources, with a greater tendency for the focus of attention to be withdrawn from the periphery on F compared to R trials. Finally, the probability that attention is withdrawn may be different after F compared to R instructions. It may be that attention is more likely to be withdrawn from the word location after an F compared to an R instruction. When averaging across trials, there is a higher proportion of trials on which IOR is unmasked after F compared to R instructions, resulting in F>R IOR. This notion is consistent with the observation that the magnitude of IOR that is observed after F instructions is fairly stable (around 35 ms), whereas the magnitude of IOR after R instructions is quite variable. In some cases IOR after R instructions is significant, in some cases not. This could be due to a relatively weaker likelihood that attention is withdrawn after R instructions, leaving the mask of facilitation in place more often than after an F instruction.

If the F>R IOR difference is due to an interaction of memory instruction with the withdrawal of attention per se, then we might expect to see interactions between memory instruction and other processes that are more definitively associated with attentional orienting. Taylor and Fawcett (2011) conducted 3 experiments to assess whether the F>R IOR difference results from differential withdrawal of exogenous or endogenous attentional resources. Remember from Chapter 1 that exogenous attention is captured reflexively via sudden visual onsets in the periphery, whereas endogenous attention is guided top-down based on current task goals (Klein, 2004; Posner, 1980; Wright & Ward, 2008). Taylor and Fawcett (2011) presented a visual cue-back to center in two experiments (in one case, the cue-back was a centrally presented memory instruction, in the other it was an uninformative onset at center between cue and target). This manipulation served to equate the withdrawal of exogenous attention from the word location by capturing attention at center with a visual onset. In a third experiment, instead of presenting targets only at peripheral locations, targets could appear at the central location as well, and, in fact, were most likely to appear centrally. This manipulation served to equate the withdrawal of endogenous attention from the word location by motivating participants to return attention to center, where targets were most likely to appear.

When the withdrawal of exogenous attention was equated after R and F instructions, there was no F>R IOR difference. Conversely, when the withdrawal of endogenous attention was equated after R and F instructions, the F>R IOR difference was still observed. Because F>R IOR did not appear when exogenous attention was occupied by an onset at centre, Taylor and Fawcett (2011) interpreted these results as suggesting that the F>R IOR difference results from the differential withdrawal of exogenous attention from F compared to R item locations. That is, exogenous attention must be free to withdraw differentially after the memory instruction for the F>R IOR difference to emerge, which could not occur when it was captured equally after F and R instructions with a central onset. Thus, what this investigation suggests is that differential withdrawal of exogenous attention may play a role in F>R IOR.

4.2.3 Decreased mental salience of F items

While differential attentional withdrawal is a candidate explanation of the source of the F>R IOR difference, I have considered other processes common to both motoric and visual IOR that could be involved in intentional forgetting. Initially it was thought that both motoric and visual IOR were generated by the activation of the oculomotor system by the cue. This oculomotor activation could be accomplished by presenting a peripheral cue, which was thought to result in the automatic programming of a saccade, or by central arrow cues to which participants would voluntarily program a saccade. Rafal et al. (1989) tested this hypothesis explicitly. Participants in this experiment were required to program saccades in response to either central or peripheral cues, but on some trials these saccades were cancelled. Critically, Rafal et al. (1989) observed IOR in response to centrally presented cues not only when a prepared saccade was executed, but also when a saccade was prepared and then cancelled. If no saccade was prepared, IOR was not observed in response to these central arrows. Thus, they concluded that preparation of a saccade was necessary and sufficient to produce IOR, regardless of whether a saccade was actually executed. This could explain the emergence of IOR in both motoric and visual forms of IOR, as long as we assume that a peripheral cue automatically results in saccade preparation regardless of whether this oculomotor response is executed (motoric IOR) or suppressed (visual IOR). However, the notion that oculomotor activation is responsible for the generation of IOR has not stood the test of time.

Chica et al. (2010a) attempted to extend the influential Rafal et al. (1989) findings, but failed to replicate the critical IOR effect following the cancellation of prepared saccades in response to central arrow cues. Chica et al. (2010a) concluded that perhaps preparing a saccade does not activate the oculomotor system in the same way as executing a saccade does, in which case their inability to replicate Rafal et al. (1989) would not contradict the oculomotor activation hypothesis of IOR. Alternatively, they concluded, perhaps the motoric and visual forms of IOR do not have a common cause. A third possibility is that motoric and visual IOR do share processing, but that this shared processing is something other than oculomotor activation.

One candidate process is that the representation of the cue location is reduced in a mental salience/activation map (e.g., Wolfe, 2007) after the presentation of the cue causes attention to be drawn to the location (Henderickx et al., 2012; Sapir, Hayes, Henik, Danziger, & Rafal, 2004; Vivas, Humphreys, & Fuentes, 2006). This reduction in salience would decrease the likelihood of attention being drawn back to previously inspected locations, increase the likelihood of attention being drawn to new aspects of the visual scene, and bias responses away from previously inspected locations, a description that is very much in line with typical explanations of the utility of the IOR effect (e.g., as a mechanism that encourages visual search for novelty; Klein & MacInnes, 1999; Klein, 2000; McInnes & Klein, 2003).

Henderickx et al. (2012) developed a clever method to show that a reduction in low-level visual salience of the cued location could result in IOR, even without direct stimulation of the location by either a peripheral onset or a saccade. They presented a coloured central fixation stimulus that was followed by the simultaneous onset of coloured cue stimuli at two peripheral locations. Thus, stimulation of the two peripheral locations was the same on each trial. However, only one of these peripheral cues matched the fixation stimulus in colour, and participants were instructed to covertly attend to the matching cue. Participants made a manual localization response to a subsequent target that could appear in the matching cue location (cued) or the other location (uncued). IOR was observed in RTs at a 500 ms cue-target SOA. Critically, this was only the case in conditions where participants were given time to process the central fixation colour before the cue appeared. That is, no IOR was observed if the peripheral cues appeared simultaneously with the coloured fixation, nor when the coloured fixation appeared after the peripheral cues. This suggests that participants successfully used top-down expectations about the peripheral cue colour to direct endogenous attention to the matching cue, and this resulted in a decrease in the salience of the cued location in a mental salience map, leading to slowed responding toward that location – IOR. Instantiating an instruction to forget may be able to modulate mental salience of information in a very similar, top-down manner.

A potential neural correlate of the mental saliency map that is implicated in the generation of IOR could be activation in the IPS (Henderickx et al., 2012; Sapir, Hayes, Henik, Danziger, & Rafal, 2004; Vivas, Humphreys, & Fuentes, 2006). Research on attention has suggested that the IPS houses a mental representation of the visual environment in which the salience of particular locations or objects can be modified based on experience (Silver & Kastner, 2009; van Koningsbruggen, Gabay, Sapir, Henik, & Rafal, 2010). In addition, while motoric and visual forms of IOR have been associated with at least partially dissociable neural modules, the IPS has connections to both of these networks. In particular, the IPS is functionally connected to the superior colliculus (SC). The SC has been strongly associated with the motoric form of IOR (Robinson, Bowman, & Kurtzman, 1995; Anderson & Rees, 2011; Dorris, Klein, Everling, & Munoz, 2002; Bourgeois et al., 2012; Bourgeois et al., 2013). Visual IOR has been associated with the temporo-parietal junction (TPJ; Asplund, Todd, Snyder, & Marois, 2010; Bourgeois et al., 2012 & 2013), which is encompassed by the ventral parieto-frontal attention network. This network is strongly linked with the dorsal parieto-frontal attention network, which encompasses the IPS (Corbetta & Shulman, 2002).

The notion that instantiating an instruction to forget could result in a modulation of the mental salience of information associated with the instruction may seem tenuous if the IPS is understood to represent primarily the salience of visual spatial information in the immediate environment. However, theorists are beginning to acknowledge that the function of the IPS has much broader applications than mapping the mental salience of visual information. Indeed, the IPS is now thought to be involved in guiding attention top-down toward both goal-relevant stimulus features and semantic associations in memory, and is also thought to guide the retrieval of target memories (Ciaramelli et al., 2008; Cabeza, 2008; Silver & Kastner, 2009).

Although this is speculative, I would like to put forward the hypothesis that intentional forgetting could involve modifications of the mental salience of contextual and cognitive representations associated with F items. When combined with an IOR cueing paradigm, the suppression of mental salience following an F instruction would be additive with the suppression of mental salience of the cued location that results in IOR. This summation of two inhibitory effects does not occur following an R instruction. The summation after F but not R instructions, then, leads to F>R IOR. In fMRI investigations of directed forgetting, there is often parietal activation associated with the instantiation of an F instruction (e.g., Wylie et al., 2008; Nowicka et al., 2011; Saletin et al., 2011; Bastin et al. 2012). In ERP research on directed forgetting, there is a parietally distributed positivity after R instructions that is absent after F instructions (Ullsperger, Mecklinger, & Muller, 2000; Hauswald, Schulz, Iordanov, & Kissler, 2011; Paz-Caballero, Menor, & Jimenez, 2004; Hsieh, Hung, Tzeng, Lee, & Cheng, 2009; van Hoof & Ford, 2011; Lin, Kuo, Liu, Han, & Cheng, 2013). The parietal activation in fMRI research, and the absence of a parietal component after F instructions in ERP research, could be indicative of inhibition or suppression in the IPS following instructions to forget.

Future research may shed some light on the specific shared process that results in F>R IOR by testing the hypotheses that F>R IOR is due to the differential withdrawal of attention after F and R memory instructions and/or that F>R IOR is due to modifications of the mental saliency of F and R item representations.

4.3 How Might F>R IOR be Related to Successful Forgetting?

As described in Chapter 1, the most prominent theory explaining the item-method directed forgetting effect is the Selective Rehearsal hypothesis (Bjork & Woodward, 1973; Woodward et al., 1973; MacLeod, 1975). This hypothesis states that better memory for R compared to F items results from differential elaborative rehearsal of R items over F items. That is, after an item is presented, participants use maintenance rehearsal to keep the item in working memory until the memory instruction is given. When an R instruction is given, participants elaboratively rehearse the R item to maximize the likelihood that the item will be encoded and remembered later. However, when an F instruction is given, participants do not elaboratively rehearse the F item. This cessation of rehearsal of F items has been described in a way that suggests the discarding of F items is a passive process. However, as we have seen, this removal of F items from the focus of working memory is initially even more cognitively demanding than remembering (Fawcett & Taylor, 2008), and instantiating an instruction to forget has a wide ranging impact on subsequent information processing (Taylor, 2005; Taylor & Fawcett, 2011; the current experiments). While it is clear that elaborative rehearsal of R items over F items contributes greatly to improved memory for R over F items, the effort involved in forgetting, and the cognitive consequences of forgetting, should be included in a full account of intentional forgetting.

The cognitive consequences of instantiating an instruction to forget appear to be comprised of the redirection of attention away from to-be-forgotten information toward to-be-remembered information, and/or a decrease in the mental salience of the to-be-forgotten information, the source of the information, and/or contextual details associated with the information (including other information appearing in close spatial or temporal proximity). These processes are cognitively demanding and resource intensive, explaining the slowed responding after F compared to R instructions in a probe detection task (Fawcett & Taylor, 2008). The cognitively demanding processes associated with intentional forgetting are likely directly involved in successful forgetting by ensuring that F items are no longer rehearsed, decreasing the likelihood that they will be remembered.

In addition, it may be that the decreased salience of contextual/episodic details associated with F items results in impaired encoding of these details. That is, not only is rehearsal of F items stopped by the redirection of attention, but the linking of episodic and contextual details to form a recollective experience is impaired by the decreased mental salience of information related to the F item, as well. This fits with research suggesting impoverished episodic representations of F items compared to R items (Basden, 1996; Gardiner et al., 1994; Paller, 1990; Basden et al., 1993; Fawcett et al., 2013; Hourihan et al., 2007). As described in Chapter 1, investigations of item-method directed forgetting using a Remember/Know memory test have shown a DF effect for Remembered items, which are those associated with strong episodic memories, but not for Known items, which are associated only with a sense of familiarity with the item (Basden, 1996; Gardiner et al., 1994). Similarly, the DF effect only emerges on direct tests of memory like recall or recognition, but not on indirect tests like word-stem completion (Paller, 1990; Basden et al., 1993). The impoverished memory for contextual details associated with F items (Fawcett et al., 2013; Hourihan et al., 2007), then, may be a result of decreased mental salience of these details after F instructions.

Previous investigations of IOR in directed forgetting have analyzed whether the magnitude of IOR is related to the magnitude of the directed forgetting effect. Fawcett and Taylor (2010) found that the F>R IOR difference was driven by trials on which the intention to forget was successful. However, Taylor and Fawcett (2011) found no significant relation between the magnitude of the directed forgetting effect and the magnitude of IOR. In Chapter 2, we found a significant relation between the magnitude of directed forgetting and the magnitude of IOR, but also found that the magnitude of IOR did not vary as a function of whether the study item was later recognized for R or F items. Since the relation between F>R IOR and the magnitude of the directed forgetting effect is not consistent, the degree to which the F>R IOR difference reflects processes that have a direct impact on the magnitude of the directed forgetting effect is somewhat uncertain. That is, F>R IOR may not directly influence memory for study items. Even if there is no direct relation, the cognitive consequences of intentional forgetting may be indirectly associated with successful forgetting by virtue of the fact that they are cognitively demanding. Lee's Cognitive Load hypothesis (Lee & Lee, 2011; Lee, 2012) states that the ability to intentionally forget depends on the occupation of processing resources. That is, the likelihood of successfully instantiating an F instruction is inversely related to the availability of cognitive resources. For example, Lee and Lee (2011) found that participants were more successful at forgetting F items when they performed a secondary counting task after the memory instruction compared to when they were not required to divide their attention in this way. If engaging cognitive resources for any purpose impedes the automatic processing of F items, the cognitively demanding processes that lead to F>R IOR (attentional withdrawal and/or decreased mental salience) could benefit our ability to intentionally forget indirectly.

In summary, the F>R IOR difference suggests that intentional forgetting involves cognitively demanding processing associated with attentional withdrawal and/or modifications of the mental salience. The processing that occurs when instantiating an instruction to forget at least partially accounts for the directed forgetting effect by ensuring the cessation of rehearsal of F items, and impeding the formation of episodically rich memories of those F items that do become encoded.

4.4 Interactions Between Attention and Memory

Popular conceptions of the cognitive organization of attention and memory have considered them as separate from one another. For example, Baddeley's (2001) model of working memory consists of a number of storage buffers (the visuo-spatial sketchpad, the episodic buffer, and the phonological loop) that have limited capacity and duration, but that interface with long-term memory stores. The model also includes a central executive, which coordinates the activity and contents of the storage buffers, and regulates rehearsal of information in the buffers to allow the maintenance of information there. Critically, the only mention of the involvement of attention is with respect to the central executive, which is thought to coordinate the allocation of attention to determine what information enters working memory.

Modern conceptualizations of working memory, however, provide a much more central role for attention in working memory as the mechanism through which rehearsal is accomplished (Awh & Jonides, 2001; Jonides, Lacey, & Nee, 2005; Jonides, Lewis, Nee, Lustig, Berman, & Moore, 2008). Jonides et al. (2005) proposed that the very attentional mechanisms that process perceptual information are also responsible for maintaining activation of mental representations in working memory. This connection between spatial/sensory attentional processing and working memory is made more intuitive by evidence that these mental representations are, in fact, essentially re-activations of the same brain structures that are involved in perception.

Similar arguments have been made about the relation between attention and long-term memory (Ciaramelli et al., 2008; Cabeza, 2008; Silver & Kastner, 2009). Ciaramelli et al. (2008) propose the AtoM (Attention to Memory) hypothesis, which implicates the dorsal and ventral parieto-frontal attention networks that have been shown to be associated with endogenous and exogenous orienting of spatial attention, respectively (Corbetta & Shulman, 2002) in episodic memory retrieval. Here, again, attentional processes that have predominantly been investigated with respect to their involvement with spatial attention are thought to be involved in directing attention to memory, retrieving and activating a target long-term memory within working memory.

According to these theories, the lines are becoming blurred between the notions of memory and attention, and the research presented in this dissertation fits nicely with these new conceptualizations of a flexible attention system that enhances the processing of goal relevant information, regardless of whether that information is a visual target or an item that needs to be encoded. Here I have shown another parallel between the workings of spatial attention and attention to memory in the F>R IOR difference. IOR represents a mechanism that promotes efficient visual search of the environment by biasing attention away from known irrelevant locations and toward novel locations. The research presented here shows that a similar mechanism might also promote the encoding of relevant information about the world by biasing attention away from irrelevant information and toward relevant information. Insofar as the focusing of attention on a mental representation reflects rehearsal (as suggested by Jonides et al., 2005), such focus leads to the encoding of new memories. It follows, then, that redirection of attention away from unwanted information, and a resulting suppression of the salience of that information, could lead to forgetting.

4.5 Conclusion

Regardless of whether the F>R IOR difference is directly related to the magnitude of the item-method directed forgetting effect, the research presented in this dissertation has improved our understanding not only of the F>R IOR difference itself, but of its relevance to theories of directed forgetting. I have shown that memory instruction interacts with both visual and motoric forms of IOR, suggesting that the shared process between instantiating a memory instrucion and IOR is unlikely to be a late-stage *effect* of IOR such as a motoric bias against responding to the source of irrelevant information. Instead, the shared process is likely to be one that is common to these two forms of IOR. Thus, I have provided evidence for a memory-related process that may function in a way similar to how IOR functions in visual search. IOR serves to promote inspection of novel locations and to discourage re-inspection of recently attended locations. My research has shown that a similar process may exist to promote the encoding of relevant, desired information, and to discourage the encoding of irrelevant, undesired information.

While selective rehearsal of R items certainly plays a large role in the emergence of the directed forgetting effect, a complete account of this effect must include consideration of the cognitive consequences of instantiating an instruction to forget. Rather than simply the absence of rehearsal, we have consistently shown that forgetting is associated with active attentional processes, and these cognitive consequences of intentional forgetting likely aid our ability to selectively remember and forget. We must not forget the importance of these processes in explanations of intentional forgetting.

References

Abrams, R.A., & Dobkin, R.S. (1994). The gap effect and inhibition of return: Interactive effects on eye movement latencies. *Experimental Brain Research, 98*, 483-487.

Anderson, E.J., & Rees, G. (2011). Neural correlates of spatial orienting in the human superior colliculus. *Journal of Neurophysiology, 106*, 2273-2284.

Anderson, M.C., & Bjork, R.A. (1994). Mechanisms of inhibition in long-term memory: A new taxonomy. In D. Dagenbach & T. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 265-325). San Diego: Academic Press.

Anderson, M.C., Bjork, R.A., & Bjork, E.L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 1063-1087.

Anderson, M.C., & Green, C. (2001). Suppressing unwanted memories by executive control. *Nature, 410*, 366-369.

Anderson, M.C., & Levy, B.J. (2009). Suppressing unwanted memories. *Current Directions in Psychological Science, 18*(4), 189-194.

Anderson, M.C., Ochsner, K.N., Kuhl, B., Cooper, J., Robertson, E., Gabrieli, S.W., Glover, G.H., & Gabrieli, J.D.E. (2004). Neural systems underlying the suppression of unwanted memories. *Science, 303*(5655), 232-235.

Anderson, M.C., & Spellman, B.A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102*(1), 68-100.

Asplund, C.L., Todd, J.J., Snyder, A.P., & Marois, R. (2010). A central role for the lateral prefrontal cortex in goal-directed and stimulus driven attention. *Nature Neuroscience, 13*, 507-512.

Atkinson, R.C., & Shiffrin, R.M. (1968). Human memory: A proposed system and its control processes. *Psychology of Learning and Motivation, 2*, 89-195.

Awh, E., & Jonides, J. (2001). Overlapping mechanisms of attention and spatial working memory. *Trends in Cognitive Science, 5*(3), 119-126.

Baddeley, A.D. (2001). Is working memory still working? *American Psychologist, 56*, 851-864.

Basden, B.H. (1996). Directed forgetting: Further comparisons of the item and list methods. *Memory, 4*(6), 633-654.

Basden, B.H., & Basden, D.R. (1998). Directed forgetting: A contrast of methods and interpretations. In J.M. Golding & C.M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 139 – 172). Mahwah, NJ: Lawrence Erlbaum Associates.

Basden, B.H., Basden, D.R., & Gargano, G.J. (1993). Directed forgetting in implicit and explicit memory tests: A comparison of methods. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(3), 603-616.

Bastin, C., Feyers, D., Majerus, S., Balteau, E., Degueldre, C., Luxen, A., Maquet, P., Salmon, E., & Collette, F. (2012). The neural substrates of memory suppression: A fMRI exploration of directed forgetting. *PLoS ONE, 7*(1): e29905. doi:10.1371/journal.pone.0029905

Berlucci, G., Chelazzi, L., & Tassinari, G. (2000). Volitional covert orienting to a peripheral cue does not suppress cue-induced inhibition of return. *Journal of Cognitive Neuroscience, 12*, 648-663.

Bjork, R.A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H.L. Roedigger, & F.M. Craik (Eds.), *Varieties of Memory & Consciousness: Essays in Honour of Endel Tulving* (pp. 309-330). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bjork, R. A., & Geiselman, R. E. (1978). Constituent processes in the differentiation of items in memory. *Journal of Experimental Psychology: Human Learning and Memory, 4*, 347–361.

Bjork, R.A., & Woodward, A.E. (1973). Directed forgetting of individual words in free recall. *Journal of Experimental Psychology, 99*(1), 22-27.

Bourgeois, A., Chica, A.B., Migliaccio, R., Thiebaut de Schotten, M., & Bartolomeo, P. (2012). Cortical control of inhibition of return: Evidence from patients with inferior parietal damage and visual neglect. *Neuropsychologia, 50*(5), 800-809.

Bourgeois, A., Chica, A.B., Valero-Cabre, A., & Bartolomeo, P. (2013). Cortical control of inhibition of return: Causal evidence for task-dependent modulations by dorsal and ventral parietal regions. *Cortex, 49*(8), 2229-2238.

Broadbent, D.E. (1958). *Perception and Communication*. London: Pergamon Press.

Cabeza, R. (2008). Role of parietal regions in episodic memory retrieval: The dual attentional processes hypothesis. *Neuropsychologia, 46*(7), 1813-1827.

Cheng, S.K., Liu, I., Lee, J.R., Hung, D.L., & Tzeng, O.J.L. (2012). Intentional forgetting might be more effortful than remembering: An ERP study of item-method directed forgetting. *Biological Psychology, 89*(2), 283-292.

Chica, A.B., Klein, R.M., Rafal, R.D., & Hopfinger, J.B. (2010a). Endogenous saccade preparation does not produce inhibition of return: Failure to replicate Rafal, Calabresi, Brennan, & Sciolto (1989). *Journal of Experimental Psychology: Human Perception and Performance, 36*(5), 1193-1206.

Chica, A.B., Taylor, T.L., Lupiáñez, J., & Klein, R.M., (2010b). Two mechanisms underlying inhibition of return. *Experimental Brain Research, 201*, 25-35.

Ciaramelli, E., Grady, C.L., Moscovitch, M. (2008). Top-down and bottom-up attention to memory: A hypothesis (AtoM) on the role of the posterior parietal cortex in memory retrieval. *Neuropsychologia, 46*(7), 1828-1851.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159. doi:10.1037/0033-2909.112.1.155

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers, 25*, 257–271. doi:10.3758/BF03204507

Corbetta, M., & Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201-215.

Danziger, S. & Kingstone, A. (1999). Unmasking the inhibition of return phenomenon. *Perception & Psychophysics, 61*(6), 1024-1037.

De Jong, R., Liang, C.-C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus–response correspondence. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 731–750. doi:10.1037/0096-1523.20.4.731

Dorris, M.C., Klein, R.M., Everling, S., & Munoz, D.P. (2002). Contribution of the primate superior colliculus to inhibition of return. *Journal of Cognitive Neuroscience, 14*(8), 1256-1263.

Duncan, J., & Humphreys, G.W. (1989). Visual search and stimulus similarity. *Psychological Review, 96*(3), 433-458.

Ebbinghaus, H. (1885). In H. A. Ruger & C. E. Bussenius (Eds.), *Memory: A contribution to experimental psychology*. New York: Columbia University, Teachers College.

Eich, J.E. (1980). The cue-dependent nature of state-dependent retrieval. *Memory & Cognition, 8*(2), 157-173.

Eriksen, C.W., & Hoffman, J.E. (1972). Some characteristics of selective attention in visual perception determined by vocal reaction time. *Perception & Psychophysics, 11*, 169-171.

Fawcett, J.M., & Taylor, T.L. (2008). Forgetting is effortful: Evidence from reaction time probes in an item-method directed forgetting task. *Memory & Cognition, 36*(6), 1168-1181.

Fawcett, J.M., & Taylor, T.L. (2010). Directed forgetting shares mechanisms with attentional withdrawal but not with stop-signal inhibition. *Memory & Cognition, 38*(6), 797-808.

Fawcett, J.M., & Taylor, T.L. (2012). The control of working memory resources in intentional forgetting: Evidence from incidental probe word recognition. *Acta Psychologica, 139*(1), 84-90.

Fawcett, J. M., Taylor, T. L., & Nadel, L. (2013). Intentional forgetting diminishes memory for continuous events. *Memory, 21*, 675–694. doi:10.1080/09658211.2012.748078

Gallager, S. (2000). Philosophical conceptions of the self: Implications for cognitive science. *Trends in Cognitive Sciences, 4*(1), 14-21.

Gardiner, J.M. (1988). Functional aspects of recollective experience. *Memory & Cognition, 16*(4), 309-313.

Gardiner, J.M., Gawlik, B., & Richardson-Klavehn, A. (1994). Maintenance rehearsal affects knowing, not remembering; elaborative rehearsal affects remembering, not knowing. *Psychonomic Bulletin & Review, 1*(1), 107-110.

Geiselman, R.E., Bjork, R.A., & Fishman, D.L. (1983). Disrupted retrieval in directed forgetting: A link with posthypnotic amnesia. *Journal of Experimental Psychology: General, 112*(1), 58-72.

Goernert, P. N., Widner, R. L., & Otani, H. (2007). Classification accuracy across multiple tests following item method directed forgetting. *Quarterly Journal of Experimental Psychology, 60*, 1178–1186.

Hauswald, A., Schulz, H., Iordanov, T., & Kissler, J. (2011). ERP dynamics underlying successful directed forgetting of neutral but not negative pictures. *Social Cognitive and Affective Neuroscience, 6*(4), 450-459.

Henderickx, D., Maetens, K., & Soetens, E. (2012). The involvement of bottom-up saliency processing in endogenous inhibition of return. *Attention, Perception, & Psychophysics, 74*(2), 285-299.

Hilchey, M.D., Klein, R.M., & Ivanoff, J. (2012). Perceptual and motor inhibition of return: Components or flavors? *Attention, Perception, & Psychophysics, 74*(7), 1416-1429.

Hilchey, M.D., Klein, R.M., & Satel, J. (2014). Returning to "Inhibition of Return" by dissociating long-term oculomotor IOR from short-term sensory adaptation and other nonoculomotor "inhibitory" cueing effects. *Journal of Experimental Psychology: Human Perception and Performance, 40*(4), 1603-1616.

Hommel, B., Proctor, R. W., & Vu, K.-P. L. (2004). A feature-integration account of sequential effects in the Simon task. *Psychological Research, 68*, 1–17. doi:10.1007/s00426-003-0132-y

Hourihan, K.L., Goldberg, S., & Taylor, T.L. (2007). The role of spatial location in remembering and forgetting peripheral words. *Canadian Journal of Experimental Psychology, 61*(2), 91-101.

Hourihan, K.L., Ozubko, J.D., & MacLeod, C.M. (2009). Directed forgetting of visual symbols: Evidence for nonverbal selective rehearsal. *Memory & Cognition, 37*(8), 1059-1068.

Hourihan, K. L., & Taylor, T. L. (2006). Cease remembering: Control processes in directed forgetting. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 1354–1365.

Hsieh, L.-T., Hung, D.L., Tzeng, O.J.-L., Lee, J.R., & Cheng, S.-K. (2009). An event-related potential investigation of the processing of remember/forget cues and item encoding in item-method directed forgetting. *Brain Research, 1250*(23), 190-201.

Hunt, A.R., & Kingstone, A. (2003). Inhibition of return: Dissociating attentional and oculomotor components. *Journal of Experimental Psychology: Human Perception and Performance, 29*(5), 1068-1074.

Ivanoff, J., Klein, R. M., & Lupiáñez, J. (2002). Inhibition of return interacts with the Simon effect: An omnibus analysis and its implications. *Perception & Psychophysics, 64*, 318–327. doi:10.3758/BF03195794

Jacoby, L.L., & Hollingshead, A. (1990). Toward a generate/recognize model of performance on direct and indirect tests of memory. *Journal of Memory and Language, 29*, 433-454.

Jonides, J., Lacey, S.C., & Nee, D.E. (2005). Processes of working memory in mind and brain. *Current Directions in Psychological Science, 14*, 2-5.

Jonides, J., Lewis, R.L., Nee, D.E., Lustig, C.A., Berman, M.G., & Moore, K.S. (2008). The mind and brain of short-term memory. *Annual Review of Psychology, 59*, 193-224.

Klein, R.M. (2000). Inhibition of return. *Trends in Cognitive Sciences, 4*(4), 138-147.

Klein, R.M. (2004). On the control of visual orienting. In M.I. Posner (Ed.), *Cognitive neuroscience of attention* (pp. 29-44). New York, NY: Guillford Press.

Klein, R.M. & Hilchey, M.D. (2011). Oculomotor inhibition of return. In S. Liversedge, I. Gilchrist & S. Everling (Eds.), *The Oxford handbook of eye movements* (pp. 471 – 492). Oxford: Oxford University Press.

Klein, R. M., & Ivanoff, J. (2011). The components of visual attention and the ubiquitous Simon effect. *Acta Psychologica, 136*, 225–234.

Klein, R.M., & MacInnes, W.J. (1999). Inhibition of return is a foraging facilitator in visual search. *Psychological Science, 10*(4), 346-352.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus–response compatibility—A model and taxonomy. *Psychological Review, 97*, 253–270. doi:10.1037/0033-295X.97.2.253

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present day American English*. Providence: Brown University Press.

Lee, Y.-S. (2012). Cognitive load hypothesis of item-method directed forgetting. *The Quarterly Journal of Experimental Psychology, 65*(6), 1110-1122.

Lee, Y.-S., & Lee, H.-M. (2011). Divided attention facilitated intentional forgetting: Evidence from item-method directed forgetting. *Consciousness and Cognition, 20*(3), 618-626.

Lehman, M., & Malmberg, K.J. (2009). A global theory of remembering and forgetting from multiple lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(4), 970-988.

Lin, W.-J., Kuo, Y.-C., Liu, T.-L., Han, Y.-J., & Cheng, S.-K. (2013). Intentional forgetting reduces the semantic processing of to-be-forgotten items: An ERP study of item-method directed forgetting. *Psychophysiology, 50*, 1120-1132.

Ludowig, E., Möller, J., Bien, C. G., Münte, T. F., Elger, C. E., & Rosburg, T. (2010). Active suppression in the mediotemporal lobe during directed forgetting. *Neurobiology of Learning and Memory, 93*, 352–361.

MacInnes, W.J., & Klein, R.M. (2003). Inhibition of return biases orienting during the search of complex scenes. *The Scientific World Journal, 3*, 75-86.

MacLeod, C.M. (1975). Long-term recognition and recall following directed forgetting. *Journal of Experimental Psychology: Human Learning and Memory, 104*(3), 271-279.

MacLeod, C.M. (1989). Directed forgetting affects both direct and indirect tests of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(1), 13-21.

MacLeod, C.M. (1998). Directed forgetting. In J.M. Golding & C.M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 1 – 57). Mahwah, NJ: Lawrence Erlbaum Associates.

MacLeod, C.M. (1999). The item and list methods of directed forgetting: Test differences and the role of demand characteristics. *Psychonomic Bulletin & Review, 6*(1), 123-129.

MacLeod, C. M., & Daniels, K. A. (2000). Direct versus indirect tests of memory: Directed forgetting meets the generation effect. *Psychonomic Bulletin & Review, 7*, 354–359.

Metzker, M., & Dreisbach, G. (2011). Priming processes in the Simon task: More evidence from the lexical decision task for a third route in the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 892–902.

Noreen, S., & MacLeod, M.D. (2013). It's all in the detail: Intentional forgetting of autobiographical memories using the autobiographical think/no-think task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*(2), 375-393.

Nowicka, A., Marchewka, A., Jednorog, K., Tacikowski, P., & Brechmann, A. (2011). Forgetting of emotional information is hard: An fMRI study of directed forgetting. *Cerebral Cortex, 21*, 539-549.

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology, 76*(1), 1–25. doi:10.1037/h0025327

Paller, K.A. (1990). Recall and stem-completion priming have different electrophysiological correlates and are modified differentially by directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(6), 1021-1032.

Paller, K.A., Bozic, V.S., Ranganath, C., Grabowecky, M., & Yamada, S. (1999). Brain waves following remembered faces index conscious recollection. *Cognitive Brain Research, 7*, 519-531.

Paz-Caballero, M. D., & Menor, J. (1999). ERP correlates of directed forgetting effects in direct and indirect memory tests. *European Journal of Cognitive Psychology, 11*, 239–261.

Paz-Caballero, M.D., Menor, J., & Jiménez, J.M. (2004). Predictive validity of event-related potentials (ERPs) in relation to the directed forgetting effects. *Clinical Neurophysiology, 115*(2), 369-377.

Posner, M.I. (1978). *Chronometric explorations of mind*. Lawrence Erlbaum.

Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Posner, M.I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. Bouwhuis (Eds.), *Attention and Performance X* (pp. 531-556). Hove, UK: Lawrence Erlbaum Associates.

Posner, M.I., & Petersen, S.E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25-42.

Posner, M.I., Rafal, R.D., Choate, L.S., & Vaughan, J (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology, 2*(3), 221-228.

Posner, M.I., Snyder, C.R., & Davidson, B.J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 109*(2), 160-174.

Postman, L. & Underwood, B.J. (1973). Critical issues in interference theory. *Memory & Cognition, 1*, 19-40.

Pratt, J., Spalek, T. M., & Bradshaw, F. (1999). The time to detect targets at inhibited and noninhibited locations: Preliminary evidence for attentional momentum. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 730–746. doi:10.1037/0096-1523.25.3.730

Quinlan, C.K., Taylor, T.L., & Fawcett, J.M. (2010). Directed forgetting: Comparing pictures and words. *Canadian Journal of Experimental Psychology, 64*(1), 41-46.

Racsmány, M., & Conway, M. A. (2006). Episodic inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*, 44–57. doi:10.1037/0278-7393.32.1.44

Rafal, R.D., Calabresi, P.A., Brennan, C.W., & Sciolto, T.K. (1989). Saccade preparation inhibits reorienting to recently attended locations. *Journal of Experimental Psychology: Human Perception and Performance, 15*(4), 673-685.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372-422.

Reuter-Lorenz, P.A., Jha, A.P., & Rosenquist, J.N. (1996). What is inhibited in inhibition of return? *Journal of Experimental Psychology: Human Perception and Performance, 22*(2), 367-378.

Robinson, D.L., Bowman, E.M., & Kertzman, C. (1995). Covert orienting of attention in macaques. II. Contributions of parietal cortex. *Journal of Neurophysiology, 74*, 698-712.

Sahakyan, L., & Goodmon, L.B. (2007). The influence of directional associations on directed forgetting and interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(6), 1035-1049.

Sahakyan, L., & Kelley, C.M. (2002). A contextual change account of the directed forgetting effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(6), 1064-1072.

Saletin, J.M., Goldstein, A.N., & Walker, M.P. (2011). The role of sleep in directed forgetting and remembering of human memories. *Cerebral Cortex, 21*, 2534-2541.

Samuel, A.G., & Kat, D. (2003). Inhibition of return: A graphical meta-analysis of its time course and an empirical test of its temporal and spatial properties. *Psychonomic Bulletin & Review, 10*(4), 897-906.

Sapir, A., Hayes, A., Henik, A., Danziger, S., & Rafal, R. (2004). Parietal lobe lesions disrupt saccadic remapping of inhibitory location tagging. *Journal of Cognitive Neuroscience, 16*(4), 503-509.

Saslow, M.G. (1967). Effects of components of displacement-step stimuli upon latency of saccadic eye movement. *Journal of the Optical Society of America, 57*, 1024-1029.

Sheard, E.D., & MacLeod, C.M. (2005). List method directed forgetting: Return of the selective rehearsal account. In N. Ohta, C.M. MacLeod, & Utti, B. (Eds.), *Dynamic Cognitive Processes* (pp. 219-248). Tokyo: Springer Tokyo.

Silver, M.A., & Kastner, S. (2009). Topographic maps in human frontal and parietal cortex. *Trends in Cognitive Sciences, 13*(11), 488-495.

Simon, J. R. (1969). Reactions toward the source of stimulation. *Journal of Experimental Psychology, 81*, 174–176. doi:10.1037/h0027448

Snyder, J. J., Schmidt, W. C., & Kingstone, A. (2001). Attentional momentum does not underlie the inhibition of return effect. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 1420–1432. doi:10.1037/0096-1523.27.6.1420

Spalek, T. M., & Hammad, S. (2004). Supporting the attentional momentum view of IOR: Is attention biased to go right? *Perception & Psychophysics, 66*, 219–233.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs , 74*, Series 498.

Stoffels, E. J. (1996). On stage robustness and response selection: Further evidence. *Acta Psychologica, 91*, 67–88.

Stürmer, B., Leuthold, H., Soetens, E., Schröter, H., & Sommer, W. (2002). Control over location-based response activation in the Simon task: Behavioural and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 28*, 1345–1363. doi:10.1037/0096-1523.28.6.1345

Taylor, T.L. (2005). Inhibition of return following instructions to remember and forget. *The Quarterly Journal of Experimental Psychology, 58*(4), 613-629.

Taylor, T.L., & Fawcett, J.M. (2011). Larger IOR effects following forget than following remember instructions depend on endogenous attentional withdrawal and target localization. *Attention, Perception, and Psychophysics, 73*, 1790-1814. doi:10.3758/s13414-011-0146-2

Taylor, T.L., & Fawcett, J.M. (2012). Does an instruction to forget enhance memory for other presented items? *Consciousness and Cognition, 21*, 1186-1197.

Taylor, T.L., & Klein, R.M. (1998). On the causes and effects of inhibition of return. *Psychonomic Bulletin & Review, 5*(4), 625-643.

Taylor, T.L., & Klein, R.M. (2000). Visual and motor effects in inhibition of return. *Journal of Experimental Psychology: Human Perception and Performance, 26*(5), 1639-1656.

Thompson, K.M., Fawcett, J.M, & Taylor, T.L. (2011). Tag, you're it: Tagging as an alternative to yes/no recognition in item method directed forgetting. *Acta Psychologica, 138*(1), 171-175.

Thompson, K.M., Hamm, J.P., & Taylor, T.L. (2014). Effects of memory instruction on attention and information processing: Further investigation of inhibition of return in item-method directed forgetting. *Attention, Perception, & Psychophysics, 76*(2), 322-344.

Tian, Y., Klein, R. M., Satel, J., Xu, P., & Yao, D. (2011). Electrophysiological explorations of the cause and effect of inhibition of return in a cue–target paradigm. *Brain Topography, 24*, 164–182. doi:10.1007/s10548-011-0172-3

Tulving, E. (1976). Ecphoric processes in recall and recognition. In J. Brown (Ed.), *Recall and Recognition*. Oxford, England: John Wiley & Sons.

Tulving, E. (1985). Memory and Consciousness. *Canadian Psychology, 26*, 1-12.

Ullsperger, M., Mecklinger, A., & Müller, U. (2000). An electrophysiological test of directed forgetting: The role of retrieval inhibition. *Journal of Cognitive Neuroscience, 12*(6), 924-940.

Van Hooff, J.C., & Ford, R.M. (2011). Remember to forget: ERP evidence for inhibition in an item-method directed forgetting paradigm. *Brain Research, 1392*, 80-92.

Van Hooff, J. C., Whitaker, T. A., & Ford, R. M. (2009). Directed forgetting in direct and indirect tests of memory: Seeking evidence of retrieval inhibition using electrophysiological measures. *Brain and Cognition, 71*, 153–164. doi:10.1016/j.bandc.2009.05.001

Van Koningsbruggen, M.G., Gabay, S., Sapir, A., Henik, A., & Rafal, R.D. (2010). Hemispheric asymmetry in the remapping and maintenance of visual saliency maps: A TMS study. *Journal of Cognitive Neuroscience, 22*(8), 1730-1738.

Vivas, A.B., Humphreys, G.W., & Fuentes, L.J. (2006). Abnormal inhibition of return: A review and new data on patients with parietal lobe damage. *Cognitive Neuropsychology, 23*(7), 1049-1064.

Wang, Z., & Klein, R.M. (2010). Searching for inhibition of return in visual search: A review. *Vision Research, 50*(2), 220-228.

Woodward, A.E., Bjork, R.A., & Jongeward, R.H. (1973). Recall and recognition as a function of primary rehearsal. *Journal of Verbal Learning and Verbal Behaviour, 12*, 608-617.

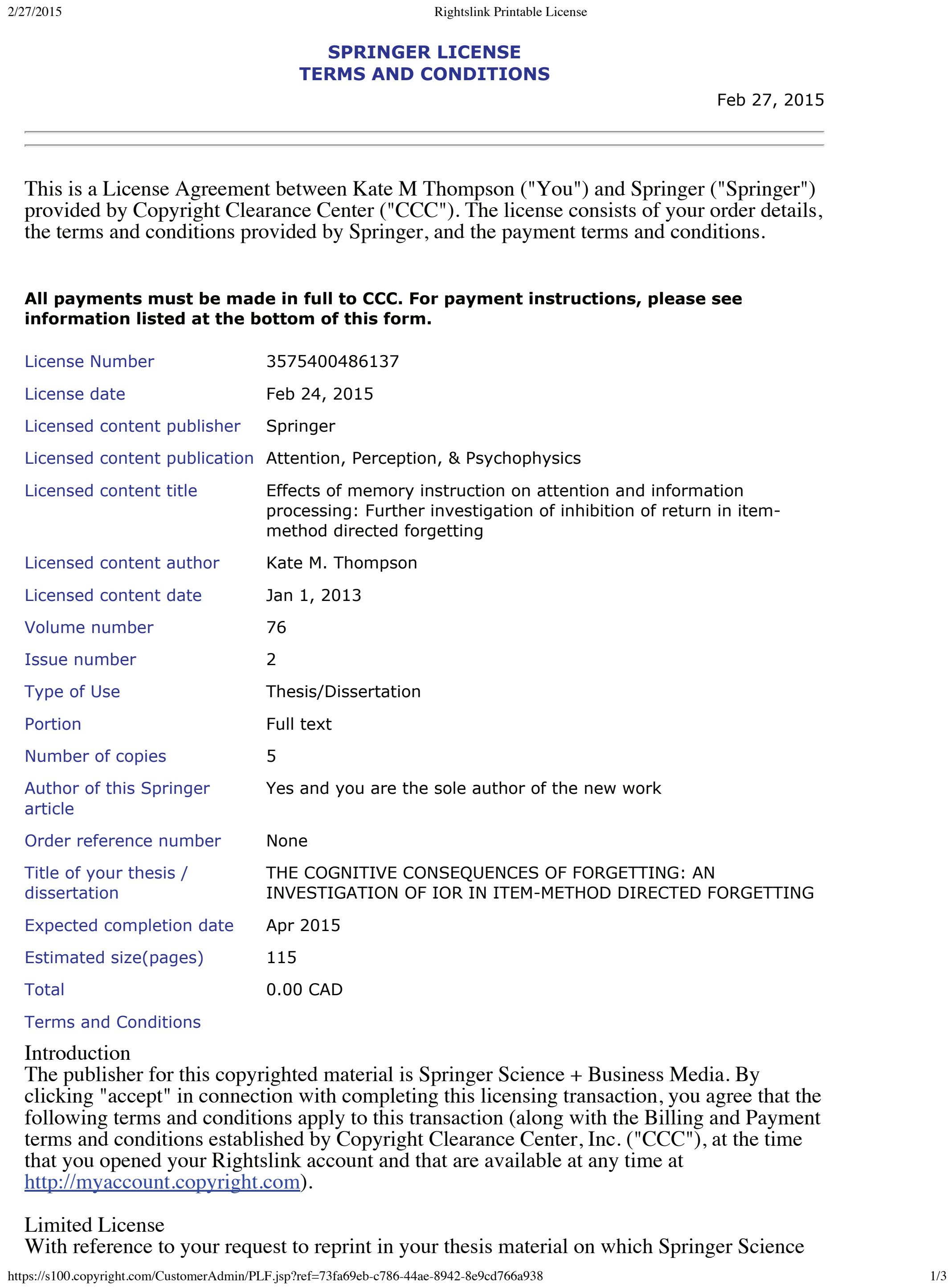
Wright, R.D., & Ward, L.M. (2008). *Orienting of attention.* New York: Oxford University Press.

Wylie, G.R., Foxe, J.J., & Taylor, T.L. (2008). Forgetting as an active process: an FMRI investigation of item-method-directed forgetting. *Cerebral Cortex, 18*(3), 670-682.

Zacks, R.T., Radvansky, G., & Hasher, L. (1996). Studies of directed forgetting in older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(1), 143-156.

Appendix A

Copyright Liscence Agreements for Reproduction of Manuscripts



SPRINGER LICENSE
TERMS AND CONDITIONS

Feb 27, 2015

This is a License Agreement between Kate M Thompson ("You") and Springer ("Springer") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by Springer, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

License Number	3575400486137
License date	Feb 24, 2015
Licensed content publisher	Springer
Licensed content publication	Attention, Perception, & Psychophysics
Licensed content title	Effects of memory instruction on attention and information processing: Further investigation of inhibition of return in item-method directed forgetting
Licensed content author	Kate M. Thompson
Licensed content date	Jan 1, 2013
Volume number	76
Issue number	2
Type of Use	Thesis/Dissertation
Portion	Full text
Number of copies	5
Author of this Springer article	Yes and you are the sole author of the new work
Order reference number	None
Title of your thesis / dissertation	THE COGNITIVE CONSEQUENCES OF FORGETTING: AN INVESTIGATION OF IOR IN ITEM-METHOD DIRECTED FORGETTING
Expected completion date	Apr 2015
Estimated size(pages)	115
Total	0.00 CAD

Terms and Conditions

Introduction
The publisher for this copyrighted material is Springer Science + Business Media. By clicking "accept" in connection with completing this licensing transaction, you agree that the following terms and conditions apply to this transaction (along with the Billing and Payment terms and conditions established by Copyright Clearance Center, Inc. ("CCC"), at the time that you opened your Rightslink account and that are available at any time at http://myaccount.copyright.com).

Limited License
With reference to your request to reprint in your thesis material on which Springer Science

and Business Media control the copyright, permission is granted, free of charge, for the use indicated in your enquiry.

Licenses are for one-time use only with a maximum distribution equal to the number that you identified in the licensing process.

This License includes use in an electronic form, provided its password protected or on the university's intranet or repository, including UMI (according to the definition at the Sherpa website: http://www.sherpa.ac.uk/romeo/). For any other electronic use, please contact Springer at (permissions.dordrecht@springer.com or permissions.heidelberg@springer.com).

The material can only be used for the purpose of defending your thesis limited to university-use only. If the thesis is going to be published, permission needs to be re-obtained (selecting "book/textbook" as the type of use).

Although Springer holds copyright to the material and is entitled to negotiate on rights, this license is only valid, subject to a courtesy information to the author (address is given with the article/chapter) and provided it concerns original material which does not carry references to other sources (if material in question appears with credit to another source, authorization from that source is required as well).

Permission free of charge on this occasion does not prejudice any rights we might have to charge for reproduction of our copyrighted material in the future.

Altering/Modifying Material: Not Permitted
You may not alter or modify the material in any manner. Abbreviations, additions, deletions and/or any other alterations shall be made only with prior written authorization of the author(s) and/or Springer Science + Business Media. (Please contact Springer at (permissions.dordrecht@springer.com or permissions.heidelberg@springer.com)

Reservation of Rights
Springer Science + Business Media reserves all rights not specifically granted in the combination of (i) the license details provided by you and accepted in the course of this licensing transaction, (ii) these terms and conditions and (iii) CCC's Billing and Payment terms and conditions.

Copyright Notice:Disclaimer
You must include the following copyright and permission notice in connection with any reproduction of the licensed material: "Springer and the original publisher /journal title, volume, year of publication, page, chapter/article title, name(s) of author(s), figure number(s), original copyright notice) is given to the publication in which the material was originally published, by adding; with kind permission from Springer Science and Business Media"

Warranties: None

Example 1: Springer Science + Business Media makes no representations or warranties with respect to the licensed material.

Example 2: Springer Science + Business Media makes no representations or warranties with respect to the licensed material and adopts on its own behalf the limitations and disclaimers established by CCC on its behalf in its Billing and Payment terms and conditions for this licensing transaction.

Indemnity
You hereby indemnify and agree to hold harmless Springer Science + Business Media and

CCC, and their respective officers, directors, employees and agents, from and against any and all claims arising out of your use of the licensed material other than as specifically authorized pursuant to this license.

No Transfer of License
This license is personal to you and may not be sublicensed, assigned, or transferred by you to any other person without Springer Science + Business Media's written permission.

No Amendment Except in Writing
This license may not be amended except in a writing signed by both parties (or, in the case of Springer Science + Business Media, by CCC on Springer Science + Business Media's behalf).

Objection to Contrary Terms
Springer Science + Business Media hereby objects to any terms contained in any purchase order, acknowledgment, check endorsement or other writing prepared by you, which terms are inconsistent with these terms and conditions or CCC's Billing and Payment terms and conditions. These terms and conditions, together with CCC's Billing and Payment terms and conditions (which are incorporated herein), comprise the entire agreement between you and Springer Science + Business Media (and CCC) concerning this licensing transaction. In the event of any conflict between your obligations established by these terms and conditions and those established by CCC's Billing and Payment terms and conditions, these terms and conditions shall control.

Jurisdiction
All disputes that may arise in connection with this present License, or the breach thereof, shall be settled exclusively by arbitration, to be held in The Netherlands, in accordance with Dutch law, and to be conducted under the Rules of the 'Netherlands Arbitrage Instituut' (Netherlands Institute of Arbitration).***OR:***

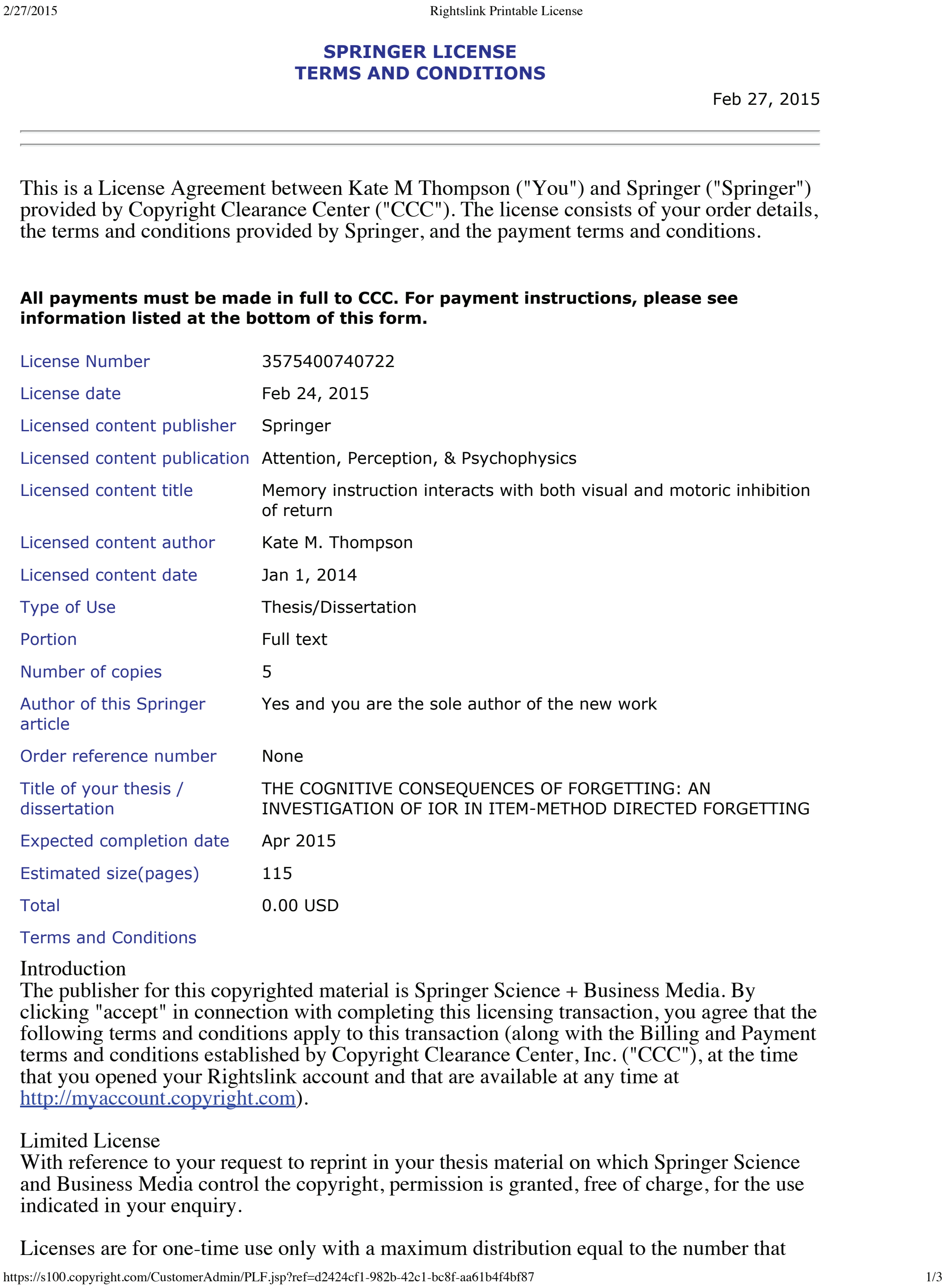
All disputes that may arise in connection with this present License, or the breach thereof, shall be settled exclusively by arbitration, to be held in the Federal Republic of Germany, in accordance with German law.

Other terms and conditions:

v1.3

Questions? customercare@copyright.com or +1-855-239-3415 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing $0 in the Total field) are free. Please retain this printable license for your reference. No payment is required.



SPRINGER LICENSE
TERMS AND CONDITIONS

Feb 27, 2015

This is a License Agreement between Kate M Thompson ("You") and Springer ("Springer") provided by Copyright Clearance Center ("CCC"). The license consists of your order details, the terms and conditions provided by Springer, and the payment terms and conditions.

All payments must be made in full to CCC. For payment instructions, please see information listed at the bottom of this form.

License Number	3575400740722
License date	Feb 24, 2015
Licensed content publisher	Springer
Licensed content publication	Attention, Perception, & Psychophysics
Licensed content title	Memory instruction interacts with both visual and motoric inhibition of return
Licensed content author	Kate M. Thompson
Licensed content date	Jan 1, 2014
Type of Use	Thesis/Dissertation
Portion	Full text
Number of copies	5
Author of this Springer article	Yes and you are the sole author of the new work
Order reference number	None
Title of your thesis / dissertation	THE COGNITIVE CONSEQUENCES OF FORGETTING: AN INVESTIGATION OF IOR IN ITEM-METHOD DIRECTED FORGETTING
Expected completion date	Apr 2015
Estimated size(pages)	115
Total	0.00 USD
Terms and Conditions	

Introduction
The publisher for this copyrighted material is Springer Science + Business Media. By clicking "accept" in connection with completing this licensing transaction, you agree that the following terms and conditions apply to this transaction (along with the Billing and Payment terms and conditions established by Copyright Clearance Center, Inc. ("CCC"), at the time that you opened your Rightslink account and that are available at any time at http://myaccount.copyright.com).

Limited License
With reference to your request to reprint in your thesis material on which Springer Science and Business Media control the copyright, permission is granted, free of charge, for the use indicated in your enquiry.

Licenses are for one-time use only with a maximum distribution equal to the number that you identified in the licensing process.

This License includes use in an electronic form, provided its password protected or on the university's intranet or repository, including UMI (according to the definition at the Sherpa website: http://www.sherpa.ac.uk/romeo/). For any other electronic use, please contact Springer at (permissions.dordrecht@springer.com or permissions.heidelberg@springer.com).

The material can only be used for the purpose of defending your thesis limited to university-use only. If the thesis is going to be published, permission needs to be re-obtained (selecting "book/textbook" as the type of use).

Although Springer holds copyright to the material and is entitled to negotiate on rights, this license is only valid, subject to a courtesy information to the author (address is given with the article/chapter) and provided it concerns original material which does not carry references to other sources (if material in question appears with credit to another source, authorization from that source is required as well).

Permission free of charge on this occasion does not prejudice any rights we might have to charge for reproduction of our copyrighted material in the future.

Altering/Modifying Material: Not Permitted
You may not alter or modify the material in any manner. Abbreviations, additions, deletions and/or any other alterations shall be made only with prior written authorization of the author(s) and/or Springer Science + Business Media. (Please contact Springer at (permissions.dordrecht@springer.com or permissions.heidelberg@springer.com)

Reservation of Rights
Springer Science + Business Media reserves all rights not specifically granted in the combination of (i) the license details provided by you and accepted in the course of this licensing transaction, (ii) these terms and conditions and (iii) CCC's Billing and Payment terms and conditions.

Copyright Notice:Disclaimer
You must include the following copyright and permission notice in connection with any reproduction of the licensed material: "Springer and the original publisher /journal title, volume, year of publication, page, chapter/article title, name(s) of author(s), figure number(s), original copyright notice) is given to the publication in which the material was originally published, by adding; with kind permission from Springer Science and Business Media"

Warranties: None

Example 1: Springer Science + Business Media makes no representations or warranties with respect to the licensed material.

Example 2: Springer Science + Business Media makes no representations or warranties with respect to the licensed material and adopts on its own behalf the limitations and disclaimers established by CCC on its behalf in its Billing and Payment terms and conditions for this licensing transaction.

Indemnity
You hereby indemnify and agree to hold harmless Springer Science + Business Media and CCC, and their respective officers, directors, employees and agents, from and against any and all claims arising out of your use of the licensed material other than as specifically authorized pursuant to this license.

No Transfer of License
This license is personal to you and may not be sublicensed, assigned, or transferred by you to any other person without Springer Science + Business Media's written permission.

No Amendment Except in Writing
This license may not be amended except in a writing signed by both parties (or, in the case of Springer Science + Business Media, by CCC on Springer Science + Business Media's behalf).

Objection to Contrary Terms
Springer Science + Business Media hereby objects to any terms contained in any purchase order, acknowledgment, check endorsement or other writing prepared by you, which terms are inconsistent with these terms and conditions or CCC's Billing and Payment terms and conditions. These terms and conditions, together with CCC's Billing and Payment terms and conditions (which are incorporated herein), comprise the entire agreement between you and Springer Science + Business Media (and CCC) concerning this licensing transaction. In the event of any conflict between your obligations established by these terms and conditions and those established by CCC's Billing and Payment terms and conditions, these terms and conditions shall control.

Jurisdiction
All disputes that may arise in connection with this present License, or the breach thereof, shall be settled exclusively by arbitration, to be held in The Netherlands, in accordance with Dutch law, and to be conducted under the Rules of the 'Netherlands Arbitrage Instituut' (Netherlands Institute of Arbitration).***OR:***

All disputes that may arise in connection with this present License, or the breach thereof, shall be settled exclusively by arbitration, to be held in the Federal Republic of Germany, in accordance with German law.

Other terms and conditions:

v1.3

Questions? customercare@copyright.com or +1-855-239-3415 (toll free in the US) or +1-978-646-2777.

Gratis licenses (referencing $0 in the Total field) are free. Please retain this printable license for your reference. No payment is required.