THE ROLE OF FACES IN ITEM-METHOD DIRECTED FORGETTING

by

Chelsea K. Quinlan

Submitted in partial fulfillment of the requirements
for the degree of Master of Science

at

Dalhousie University
Halifax, Nova Scotia
May 2011

DALHOUSIE UNIVERSITY

DEPARTMENT OF PSYCHOLOGY

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "THE ROLE OF FACES IN ITEM-METHOD DIRECTED FORGETTING" by Chelsea K. Quinlan in partial fulfilment of the requirements for the degree of Master of Science.

Dated: May 31st, 2011

Supervisor: __________________________________

Readers: __________________________________

____

Departmental Representative: ______________________________

DALHOUSIE UNIVERSITY

DATE: May 31st, 2011

AUTHOR: Chelsea K. Quinlan

TITLE: THE ROLE OF FACES IN ITEM-METHOD DIRECTED FORGETTING

DEPARTMENT OR SCHOOL: Department of Psychology

DEGREE: MSc CONVOCATION: October YEAR: 2011

Signature of Author

DEDICATION PAGE

We journey to the end, but in the end, it's the journey that matters…

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The current thesis explored the intentional forgetting of different types of facial expression (*Angry, Neutral, Happy)* within the item-method directed forgetting paradigm (Experiments 1-4). Also, as a manipulation check, Experiment 5 obtained the subjective ratings of valence and arousal for the different types of facial expression used in the previous four Experiments. In summary, a significant directed forgetting effect occurred for *Neutral* facial expressions; however, a significant directed forgetting effect did not consistently occur for emotional facial expressions (e.g., there was no directed forgetting effect for *Angry* facial expressions in Experiments 2 and 3, or *Happy* facial expressions in Experiment 3). These findings are discussed in terms of encoding time as well as valence and arousal, and how these two factors modulate the effect of emotional facial expression on the ability to intentionally forget.

LIST OF ABBREVIATIONS USED

ANOVA	Analysis of variance
BOLD	Blood oxygen level dependent
EEG	Electroencephalography
ERP	Event-related potential
fMRI	Functional magnetic resonance imaging
IAPS	International affective picture system
M	Mean
ms	milliseconds
PET	Positron emission tomography
PTSD	Post-traumatic stress disorder
RT	Reaction time
SAM	Self-assessment manikin
SCR	Skin conductance response
SD	Standard deviation

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Dr. Tracy Taylor-Helmick for all of her advice and support throughout these past two years. Tracy has been an incredible supervisor and an amazing friend who I value and admire very much. Whether it be a celebratory hug or words of wisdom during a hard time, Tracy has always been there for me. If it wasn’t for her kind words of encouragement, this thesis certainly wouldn’t be what it is today. I would also like to thank my committee members, Drs. Ray Klein and Shannon Johnson for all of their wonderful feedback and advice throughout the past two years. I would like to extend an enormous thank-you to Carl Helmick who helped me with programming and statistical analyses as well as Laura Goodman who helped me learn to use the electrophysiological equipment. Finally, I would like to thank my lab members (Jon Fawcett and Kate Thompson), friends, and family for their continuous love, support, and encouragement.

CHAPTER 1 INTRODUCTION

1.1 FACES

As humans, we are consistently given experience with faces from the day we are born until the day we die. On a day-to-day basis, we are exposed to numerous faces, some of which may be familiar (e.g., the face of a family member, a close friend, or a co-worker) and others of which may be unfamiliar (e.g., the face of the person who sat next to us on the bus today). Compared to non-face stimuli, faces are very important for social functioning. Although it is not always necessary, it is important for us to recognize both familiar and unfamiliar faces. Imagine a situation where you fail to recognize a good friend at the supermarket and how embarrassed it would make you feel. Similarly, failing to recognize a face that you have only encountered once could also be embarrassing. Imagine a situation where you fail to recognize the face of an important researcher (who you have meet once before) at an academic conference. This would likely result in a very awkward encounter. As such, both the recognition of familiar as well as unfamiliar faces can be very critical in our everyday lives.

Fortunately, we come into this world with a bias for processing faces (Johnson & Morton, 1991). This results in us being highly expert face perceivers, such that we can recognize faces both accurately and quickly (Carey, 1992; Diamond & Carey, 1986). Faces are special compared to many other non-face stimuli in our environment. For example, take a moment to compare a number of faces with one another (e.g., your partner, your best friend, a co-worker) and a number of fruits (e.g., an apple, a banana, a pineapple) with one another. After making this comparison, one important distinction should be evident and that is that faces are all very similar to one another (e.g., all faces have two eyes, a nose, and a mouth), whereas fruits can be quite different from one another (e.g., an apple is round, a banana is long and curved, and a pineapple is cylindrical and prickly). Because it is crucial that we are able to identify *individual* faces, we cannot place them in a single generic category labeled ‘faces’. To properly distinguish between faces, we must use the various small details contained within a face (e.g., shape of the nose, eye colour). Again, this is in contrast with many other stimuli. For instance, if we see a type of fruit, it is not crucial or even necessary that we are able to label that specific fruit (e.g., apple, banana). In fact, often it is sufficient to know that it belongs to the category of fruits. In other words, the recognition of individual faces and the recognition of non-face stimuli occur at different levels of categorization. In particular, the recognition of individual faces occurs at a subordinate level (i.e., specific), whereas the recognition of many non-face stimuli occurs at a basic or even, superordinate level (i.e., general). Also, in contrast to non-face stimuli, face stimuli are subject to configural processing, which involves processing the relations among individual features (e.g., nose, mouth, eyes; see Maurer, Le Grande, & Mondloch, 2002). Although there are a number of different types of configural processing, one important type is holistic processing. It involves organizing the relations among individual features into an organized whole (Maurer et al., 2002). This type of processing is not necessary for the recognition of non-face stimuli, but it is often used for the recognition of face stimuli.

Additionally, compared to objects, the processing of faces may depend on neural processing modules that are dedicated to face processing or that are at least sensitive to the expertise that humans have in perceiving other human faces. For instance, single unit recordings from monkeys have shown that cells in the inferotemporal cortex respond to both monkey and human faces, but not other complex stimuli such as animals and food (Bruce, Desimone, & Gross, 1981; Rolls & Baylis, 1986; Saito, Yukie, Tanaka, Hikosoka, Fukada, & Iwai, 1986; Young & Yasmane, 1992). Event-related potentials (ERPs) in humans have revealed a positive P150 component (Botzel & Grusser, 1989) and a negative N170 component (Bentin, Allison, Puce, Perez, & McCarthy, 1996) that have been linked to the unique encoding of faces.

The N170 component is a posterior negative deflection following the visual presentation of a picture of a face, peaking at occipito-temporal sites at approximately 170 ms (Bentin et al.,1996). Early studies that investigated the N170 response for faces and objects (e.g., flowers, cars) found that the N170 response was absent for non-face stimuli. In contrast, more recent studies (e.g., de Haan, Pascalis, & Johnson, 2002; Tanaka & Curran, 2001; Taylor, McCarthy, Saliba, & Degiovanni, 1999) have found that the N170 response can occur for both face as well as non-face stimuli (e.g., houses, chairs, cars, animals). Although the N170 response can sometimes occur for non-face stimuli, when it does, its amplitude tends to be much smaller than for face stimuli.

Two main theoretical views have been proposed to account for the differential N170 response for face and non-face stimuli: the subordinate level expertise account (Rossion, Curran, & Gauthier, 2002) and the domain specific account (Camel & Bentin, 2002). The subordinate level expertise account suggests that the N170 response is not specific to faces, but that it occurs in response to stimuli for which an individual has visual expertise or experience. This means that an individual who has expertise and extensive experience with cars would show a similar N170 response for cars and faces, and this N170 response for cars and faces would be greater than that for non-car and non-face stimuli. In contrast, the domain specific account proposes that it is the domain specificity of the visual mechanism implicated in the processing of faces that is important. As such, unlike the subordinate level expertise account, the domain specificity account suggests that the N170 response to faces should not be influenced by either task or expertise —that is, it is *domain specific* to faces and not *task* or *expertise specific*. This means that even if individuals have expertise and extensive experience with cars, they should only show an N170 response for face stimuli (or at least the N170 response should be greater for face stimuli compared to cars and other non-face stimuli). Indeed, Scott, Tanaka, Sheinberg, and Curran (2008) found that even individuals who were trained at car recognition continued to show a greater N170 response for faces compared to cars. Moreover, Camel and Bentin (2002) challenged the subordinate-level expertise account by demonstrating that the N170 response was not affected by task or level of expertise for faces. In their first experiment, Camel and Bentin (2002) included two tasks. The first task presented participants with pictures from four equally probable categories (birds, cars, faces, and furniture) and participants were required to detect only cars. The second task included pictures of the same four categories, but in this task, participants were required to categorize each picture as either animate or inanimate. In both tasks, faces elicited a greater N170 response compared to cars, birds, and furniture (Camel & Bentin, 2002), which suggests that not only is the N170 response greater for faces than other categories, but also that the N170 response for faces was not affected by manipulations of task. Indeed, the N170 response for faces was greater than that for cars, *even when participants were required to detect only the cars*.

Although Camel and Bentin (2002) argued that the N170 response to faces was unaffected by manipulations in task/attention (i.e., no differences in N170 amplitude despite different demands across the two tasks), these researchers did not include an explicit measure of attention. Nevertheless, a study conducted by Eimer (2000; also see Holmes, Vuilleumier, & Eimer, 2003) found that when participants were required to attend to faces, the amplitude of the N170 response was enhanced relative to when participants were not required to attend to faces; this enhancement did not occur for non-face stimuli (e.g., Eimer, 2000; also see Holmes, et al. 2003).

Similar to the above studies that measured neural activity, studies using both positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have found that the bilateral fusiform gyrus is activated by faces (Clark, Keil, Maisog, Courtney, Ungerleider, & Haxby, 1996; Halgren, Dale, Sereno, Tootell, Marinkovic, & Rosen, 1999; Haxby, Grady, Horwitz, Ungerleider, Mishkin, Carson, Herscovitch, Schapiro, & Rapoport, 1991; Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997; Puce, Allison, Gore, McCarthy, 1995; Sergent, Ohta, & MacDonald, 1992). Furthermore, electroencephalography (EEG) recordings have shown that activity in the fusiform gyrus (part of the temporal lobe in Brodman Area 37 and also known as the occipitotemporal gyrus) is evoked by faces at approximately 165 ms following the presentation of face stimuli (Allison, McCarthy, Nobre, Puce, & Belger, 1994). This mirrors the time course of the N170 response to face stimuli. Indeed, combined fMRI and ERP recordings have shown significant correlations between the amplitude of the N170 response and blood oxygen level dependent (BOLD) signal in the bilateral fusiform gyrus suggesting that activity in the bilateral fusiform gyrus may contribute to the N170 response (Horovitz, Rossion, Skudlarski, & Gore, 2004; Iidaka, Matsumoto, Haneda, Okada, & Sadato, 2006). Altogether, it seems as though ERP waveform components, such as the N170 as well as brain areas, such as the fusiform gyrus show an increased response to face stimuli at approximately 170 ms following the onset of that stimulus. This enhanced response to face stimuli has been suggested to be indicative of enhanced processing and encoding of face stimuli compared to non-face stimuli (Bentin, et al., 1996)

1.2 FACES AND MEMORY

As humans, we appear to have a specialized system used to process faces (e.g., Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al., 2003). An important component of this specialized system is the N170 component, which is enhanced for faces compared to objects. Because the N170 response is reflective of early attention and cognitive processing, it is important to investigate whether the early and enhanced processing of faces have a benefit on memory. For instance, does this specialized system for faces do more than simply enhance the early processing of faces? Does the early processing carried out by this specialized face system confer benefits to higher-up cognitive processes, such as memory?

To address this issue, Sommer, Schweinberger, and Matt (1991) conducted a study that compared ERP activity during the encoding of face stimuli that were subsequently recognized versus not recognized. Compared to unrecognized faces, for recognized faces, there was a greater positive ERP in the frontal region and a greater negative ERP in the parietal and temporal regions. Although ERP differences were predictive of subsequent memory performance for faces, because *only* face stimuli were used (as opposed to both face and non-face stimuli), these findings do not suggest that memory performance is better for face stimuli compared to non-face stimuli. In fact, there has been very little research that has directly tested memory for faces, and the research that has tested memory for faces has typically used *visual memory* techniques. These include presenting participants with two faces simultaneously (usually from different viewpoints) and asking them to indicate whether the two faces are the same or different (Johnston & Edmonds, 2009) as well as asking participants to indicate if they think a particular face has previously been presented in a series of faces (Johnston & Edmonds, 2009). Also, clinical neuropsychology research has investigated patients who have brain lesions that have led to prosopagnosia, which is a disorder for which the ability to recognize a face is impaired, but the ability to recognize a non-face is intact (see Farah, 2004 for review). These studies aid in understanding the processing and recognition of faces in both normal and clinical populations, but they do not necessarily aid in understanding *memory* for faces.

Despite a relative paucity of research on memory for faces, two things are known: 1) the specialized system for faces functions to enhance the processing and encoding of face stimuli (see section 1.1 Faces for review; Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al. 2003; Sommer et al., 1991) and 2) enhanced processing and encoding are related to enhanced memory (e.g., Backman & Nilsson, 1985; Cohen, 1981; Craik & Lockhart, 1972; Crutcher & Healy, 1989; MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010; McNamara & Healy, 2000; Nelson, 1979; Paivio, 1991). Indeed, there are a number of known memory effects that are produced by enhanced processing and/or encoding of stimuli. For instance, the picture superiority effect is the finding that memory is better for pictures than words. There have been a number of explanations proposed to account for the picture superiority effect, such as the dual coding theory (Paivio, 1991), the sensory-semantic theory (Nelson, 1979), and the levels of processing approach (Craik & Lockhart, 1972). The dual coding theory suggests that pictures are remembered better than words because pictures receive a verbal code as well as a visual code, whereas words receive a verbal code only (Paivio, 1991). The sensory-semantic theory proposes that pictures have more salient sensory characteristics than words, which facilitates their processing, resulting in better memory for pictures than words (Nelson, 1979). Finally, the levels of processing approach suggests that pictures are remembered better than words because they are processed on a deeper, more elaborative level than words (Craik & Lockhart, 1972). While these theoretical views are slightly different, they all share a common component, which is that pictures are remembered better than words because they are processed and encoded to a greater extent.

Similar to the picture-superiority effect, the generation effect refers to the finding that memory is better for words that are generated as opposed to words that are simply read (Jacoby, 1978). For example, generating the word ‘banana’ from the word fragment b_n_n_ would produce better subsequent memory than simply reading the word, ‘banana’. Analogous to the theories for the picture superiority effect (e.g., Craik & Lockhart, 1972; Nelson, 1979; Paivio, 1991), the theoretical views for the generation effect (Crutcher & Healy, 1989; McNamara & Healy, 2000) suggest that semantic association and elaboration enhance the encoding of generated versus read words (Crutcher & Healy, 1989; McNamara & Healy, 2000). Other effects that benefit memory include the production effect (MacLeod et al., 2010) and subject-performed tasks (Backman & Nilsson, 1985; Cohen, 1981). The production effect refers to the finding that reading a word aloud produces better memory than reading a word silently, whereas subject-performed tasks tend to produce better memory for phrases that are enacted (e.g., touch your nose) rather than simply read (e.g., “touch your nose”). Differences in processing and encoding have been suggested to account for the memory benefits generated by both the production effect as well as subject-performed tasks. That is, stimuli that are processed and encoded more elaborately will be remembered better.

Given that there is a specialized system for the processing, encoding, and recognition of faces (e.g., Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al. 2003; Sommer et al., 1991), and enhanced processing and encoding has been shown to be related to enhanced memory (e.g., Craik & Lockhart, 1972; Crutcher & Healy, 1989; McNamara & Healy, 2000; Nelson, 1979; Paivio, 1991), it follows that memory should be enhanced for face compared to non-face stimuli. To this end, Dobson and Rust (1994) found that both mentally retarded and non-mentally retarded adult participants showed better memory for faces compared to objects, with no significant memory loss for faces over a two-month time period. Thus, not only is memory better for faces compared to non-faces, but it is durable and long lasting.

1.3 DIRECTED FORGETTING

As indicated by William James (1890, pp. 680), the ability to remember is not the only important memory process: “If we remembered everything, we should on most occasions be as ill off as if we remembered nothing.” Although counterintuitive, the ability to forget can be as equally important as the ability to remember. Instead of thinking of the implications of never forgetting, we often think of the negative and embarrassing consequences of forgetting. Nevertheless, there are many things in our daily lives that we wish to forget including where we parked our car last week, a friend’s old telephone number, or the incorrect directions that someone gave us to the airport. If we did not *intentionally* forget these things described above, then our memory would not function efficiently. Not only does intentional forgetting allow for the successful removal of outdated and irrelevant information, it contributes to the ability to intentionally remember by allowing new information to be stored. In regard to faces, while it is typically functional to remember familiar faces, this is not necessarily true for unfamiliar faces. For instance, similar to the examples above, if we remembered every unfamiliar face that we encountered, our memory would not function efficiently, which may interfere with our ability to remember familiar faces (see MacLeod, 1998 for review; also see Muther, 1965).

Because we have a specialized system for processing, encoding, and recognizing faces, which likely produces (and in one case was shown to produce; Dobson & Rust, 1994) enhanced memory for faces compared to non-faces, does this mean that it is more difficult to intentionally forget faces? Not necessarily. Intentional remembering and intentional forgetting are two separate memory processes; if a stimulus produces an increased ability to remember, it does not necessarily produce a decreased ability to intentionally forget. In fact, Wylie, Fox, and Taylor (2008) revealed that intentional forgetting produces unique neural activations that are distinct from those produced during intentional remembering, including in the the right insula/inferior frontal gyrus. These findings suggest that intentional remembering and intentional forgetting are different memory processes, which involve the activation of some independent brain areas and thus it follows that these two memory processes are not necessarily affected in the same manner by a given manipulation.

Intentional forgetting can be studied in the laboratory using the directed forgetting paradigm. Although there are variants of the directed forgetting paradigm (see Golding & MacLeod, 1998 for a review), the item-method directed forgetting paradigm is one of the most widely used. In the item-method paradigm, participants are presented with a series of study items, one at a time, each followed by either an instruction to *Remember* the preceding item or an instruction to *Forget* the preceding item. The order of the memory instructions (*Remember, Forget*) is random with the constraint that each occurs equally often. Following the presentation of all study items, participants are tested for their memory of all items, using either recall or recognition. Intentional forgetting is calculated as the proportion of *Remember*-cued items correctly recalled/recognized minus the proportion of *Forget*-cued items correctly recalled/recognized. If memory performance is greater for *Remember*-cued items compared to *Forget*-cued items, then it is defined as a directed forgetting effect. Even when participants are offered monetary compensation for each additional *Forget*-cued item that they can recall, a significant directed forgetting continues to occur. Therefore, this effect is not due to demand characteristics (MacLeod, 1998).

Generally, explanations for the directed forgetting effect in the item-method paradigm have focused on encoding mechanisms. A passive view of item method directed forgetting suggests that a directed forgetting effect occurs because of differences in the rehearsal of *Remember*-cued and *Forget*-cued items as well as the passive decay of

Forget-cued items. Prior to receiving a memory instruction, each item is stored in working memory through maintenance rehearsal (e.g., repeating the item over and over, either subvocally or aloud). If a *Remember* memory instruction is received then participants engage in some type of elaborate rehearsal (e.g., forming an image of an item or making semantic associations between an item and other items; see Craik & Lockhart, 1972 for a review) to commit that item to memory; however, if a *Forget* memory instruction is received, then participants simply let the item passively decay from working memory. Similar to a passive view of item method directed forgetting, an active view of item method directed forgetting suggests that upon the receipt of a *Remember* memory instruction, participants engage in elaborate rehearsal to commit that item to memory; however, in contrast to a passive view, an active view suggests that upon the receipt of a *Forget* memory instruction, participants engage some type of attentional mechanism (e.g., withdrawal of attention; see Fawcett & Taylor, 2008; Zacks, Radvansky, & Hasher, 1996) to expunge that item from working memory. Although these two theoretical views propose that different mechanisms are used to intentionally forget, both views suggest that the mechanisms that produce a directed forgetting effect operate at encoding. As such, it follows that the directed forgetting effect should be affected by manipulations designed to enhance the encoding of items.

MacLeod and Daniels (2000) examined the influence of word generation on the directed forgetting effect (for overview of the generation effect, see section 1.2 Faces and Memory). Participants were required to generate 10 *Remember* items and 10 *Forget* items from a definition (e.g., “a large, triangular structure in Egypt-p?”) and to read silently 10 *Remember* items and 10 *Forget* items (e.g., “pyramid”). While there was a directed forgetting effect when participants read the *Remember* and *Forget* items, there was no significant directed forgetting effect when participants generated the *Remember* and *Forget* items (MacLeod & Daniels, 2000). Similarly, Hourihan and MacLeod (2008) examined the influence of the production effect on the directed forgetting effect (see section 1.2 Faces and Memory for overview; MacLeod, et al., 2010). Participants were required to read aloud 20 *Remember* items and 20 *Forget* items and to read silently 20 *Remember* items and 20 *Forget* items. Consistent with the findings of MacLeod and Daniels (2000), a directed forgetting effect occurred when participants read the *Remember* and *Forget* items silently, but no significant directed forgetting effect occurred when the participants read the *Remember* and *Forget* items aloud. Moreover, Earles and Kersten (2002) examined the effect of subject-performed tasks on the directed forgetting effect. They asked participants to perform the action of 20 verb-noun pairs (e.g., "break-toothpick") or read silently the 20 verb-noun pairs without performing the action. Each verb-noun pair was followed by a *Remember* or *Forget* memory instruction. A directed forgetting effect occurred when participants read the verb-noun pairs, but no directed forgetting effect occurred when participants performed the action of the verb-noun pairs. Sahakyan and Foster (2009) have since replicated this finding.

Quinlan, Taylor, and Fawcett (2010) explored the influence of the picture superiority effect on the directed forgetting effect by presenting participants with words or corresponding line-drawings (e.g., the word "worm" or a line-drawing picture of a worm), each followed by a *Remember* or *Forget* memory instruction. Although a significant directed forgetting effect occurred for words as well as line-drawings, the magnitude of the directed forgetting effect was smaller for line-drawings compared to words. Similarly, Hauswald and Kissler (2008) used complex pictures from the International Affective Picture System (IAPS; Lang, et al. 2005) database in a standard item-method directed forgetting paradigm and found that the magnitude of the directed forgetting effect was smaller for complex IAPS pictures compared to line-drawings (e.g., Lehman, McKinley-Pace, Leonard, Thompson, & Johns, 2001). Together, these findings suggest that as the visual complexity of a stimulus increases, the magnitude of the directed forgetting effect decreases.

In an fMRI investigation, Reber, Siwiec, Gitleman, Parrish, Mesulam, and Paller (2002) used both word and face stimuli in the item-method directed forgetting paradigm and found a significant directed forgetting effect in behaviour for word stimuli, but no significant directed forgetting effect for face stimuli. However, a high false alarm rate for faces may have compromised the ability to detect a reliable difference in memory performance for *Remember*-cued and *Forget*-cued faces. As well, a failure to observe a significant difference in activation in the fusiform gyrus for faces compared to words suggests that the face stimuli may have been of poor image quality. Indeed, these face stimuli were scanned black and white photos from a 1997 yearbook. So, although Reber et al. (2002) found no significant directed forgetting effect for faces, the data are not compelling.

1.4 CURRENT EXPERIMENTS

Compared to non-face stimuli, face stimuli are processed, encoded, and recognized by a specialized system (e.g., Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al. 2003; Sommer et al., 1991); however, the role that this system plays in memory processes, and in particular, the ability to intentionally forget has not been investigated thoroughly. The goal of this thesis was to investigate two important memory processes, the ability to remember and the ability to intentionally forget unfamiliar faces in the item-method directed forgetting paradigm. Each experiment included a standard item-method directed forgetting task that consisted of a study phase followed by a test phase. In the study phase, items were presented one at a time, each followed with equal probability by a *Remember* or *Forget* memory instruction. Upon completion of the study phase, a yes/no recognition test was presented. Experiment 1 explored whether or not there would be a significant directed forgetting effect for *Neutral* facial expressions. Experiments 2 and 3 further investigated the relationship between faces and memory processes by using emotional facial expressions (*Angry, Happy*) in the item-method paradigm. In addition to a measure of yes/no recognition performance (or the directed forgetting effect), Experiment 3 included a measure of galvanic skin conductance response (SCR) to investigate the influence of valence and physiological arousal of facial expressions on the subsequent ability to intentionally forget. The goal of Experiment 4 was to replicate Experiment 2; however, the stimulus presentation duration was decreased to investigate the role of stimulus presentation duration and encoding time on the ability to intentionally forget different types of facial expression. Finally, Experiment 5 served as a manipulation check to determine whether the facial expressions differed in valence and/or arousal (these facial expression had not been previously rated, but were ‘sorted’ into categories based on the emotionality of their expression).

CHAPTER 2 EXPERIMENT 1

In Experiment 1, participants were presented with a series of faces displaying a *Neutral* facial expression, one at a time, each followed by an instruction to *Remember* or an instruction to *Forget*. Following the presentation of all study items, participants completed a yes/no recognition test that presented *Remember* and *Forget*-cued items as well as an equal number of *foil* items (items not presented at study). Performance on the yes/no recognition task was used to measure the directed forgetting effect for *Neutral* facial expressions (i.e., the proportion of *Remember*-cued items correctly recognized minus the proportion of *Forget*-cued items correctly recognized).

Given that: 1) we have a well-established system for processing, encoding, and recognizing faces (e.g., Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al. 2003; Sommer et al., 1991); 2) enhanced (or specialized) processing and encoding of stimuli tends to produce better memory for those stimuli (e.g., Craik & Lockhart, 1972; Crutcher & Healy, 1989; McNamara & Healy, 2000; Nelson, 1979; Paivio, 1991); and 3) the directed forgetting effect tends to be eliminated (e.g., Earles & Kersten, 2002; Hourihan & MacLeod, 2008; MacLeod & Daniels, 2000; Sahakyan & Foster, 2009) or reduced by manipulations designed to enhance encoding (e.g., Hauswald & Kissler, 2008; Quinlan et al., 2010), it was predicted that the specialized system for faces would function to elaborately encode faces and override instructions to *Forget.* As such, it was predicted that there would be no significant directed forgetting effect.

Method

Participants

Participants were 30 undergraduate students (9 males, 21 females) who volunteered in exchange for credit towards their grade in an eligible Psychology class at Dalhousie University. The experiment was run in one session lasting approximately 30 minutes. All participants reported normal or corrected-to-normal vision and a good understanding of the English language.

Stimuli and Apparatus

A 24" iMac computer (Mac OSX Leopard, version 10.5), running PsyScope 5.1.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) was used to run the experiment. Responses were collected from standard Macintosh Universal Serial Bus keyboard. A fixation stimulus ("+") measuring 8° x 7° (horizontal x vertical, respectively) visual degrees was presented prior to the presentation of the face in each trial. Faces displayed during both the study and recognition phases were presented within a region measuring 8° x 7° visual degrees, and that was centered on the display monitor. Face stimuli were presented in 32-bit RGV 256 grayscale with a resolution of 72 x 72 dpi, and were selected from the AR face database (Martinez & Benavente, 1998). Because there are more male faces than female faces in the AR face database, 72 men and 48 women were selected. The faces were displayed from the shoulders up and in a frontal view. Although hair was not occluded, faces that included highly distinctive features (in particular, those with glasses or facial hair) were excluded. For each participant, custom software randomly distributed the stimuli from each face collection (*Men, Women*) into *Remember* (n=30), *Forget* (n=30), and recognition *foil* (n=60) collections; each participant therefore had a unique combination of *Remember*, *Forget*, and *foil* items.

Memory instructions were presented via Sony MDR-XD100 stereo headphones and consisted of high- and low-frequency tones (260Hz and 1170 Hz, respectively). During recognition, participants input their responses on the keyboard (‘y’ or ‘n’) and their responses were displayed in the bottom-center of the screen within in a black 6-point rectangle measuring 3° x 2° visual degrees.

Procedure

Prior to beginning the experiment, participants were instructed that they would be presented with a series of faces, one at a time, each followed with equal probability by an instruction to *Remember* or an instruction to *Forget.* They were told that the memory instruction would be in the form of high and low frequency tones. Half of the participants were told to *Remember* the items associated with a high-frequency tone and to *Forget* the items associated with a low-frequency tone, whereas the other half of participants were told to *Remember* the items associated with a low-frequency tone and to *Forget* the items associated with a high-frequency tone. Following the presentation of all study items, participants were told that they would be asked to complete a recognition task and that when it was time to do so, instructions would appear at the top of the computer screen. There was no indication that both *Remember* and *Forget*-cued items would be tested.

Familiarization phase. Before beginning the study phase, participants were presented with 10 trials to familiarize them with the tones used as memory instructions. These trials consisted of five high-frequency tones and five low-frequency tones, which were randomly intermixed. On each familiarization trial, at centre, participants were presented the verbal descriptor of the memory instruction (e.g., ‘High tone – Remember’) for 3000 ms. The corresponding tone was played through the headphones 2000 ms following the onset of the verbal descriptor and lasted for 400 ms.

Study phase. Immediately following the last trial in the familiarization phase, participants began the study phase trials. There were a grand total of 60 trials in the study phase: 30 *Remember*-cued trials and 30 *Forget*-cued trials, with each face presented only once (i.e., the faces were not repeated in the study phase).

As shown in Figure 1, each trial in the study phase began with the fixation point ('+') in the centre of the computer screen for 1500 ms followed by the presentation of a face for 1000 ms. This face was chosen randomly from the *Remember* or *Forget* face collection. After an inter-stimulus interval of 200 ms during which a blank screen was presented, either a high or low-frequency tone (representing a *Remember* or *Forget* memory instruction) was played through the headphones for 400 ms. Following the presentation of the memory instruction, each trial ended with an inter-trial interval of 2000 ms, which consisted of a blank screen. The total duration of each trial in the study phase was 5100 ms, from the beginning of the fixation point to the end of the 2000 ms inter-trial interval.

Recognition phase. Upon completion of the study phase trials, participants immediately began the recognition phase, which consisted of a yes/no recognition test. Instructions for the yes/no recognition test appeared at the top of the computer screen and remained on the screen throughout the duration of the recognition phase. The recognition phase consisted of 120 trials: the 30 *Remember*-cued trials and 30 *Forget*-cued trials from the study phase as well as 60 *foil* trials (36 of which were *Men* faces and 24 of which were *Women* faces). These trials were randomly intermixed.

For each trial in the recognition phase, participants were presented with a face in the centre of the computer screen. They were told to press the ‘y’ key if they recognized the face from *any* of the study phase trials —regardless of whether it was followed by a *Remember* or *Forget* memory instruction, and to press the ‘n’ key if they did not recognize the face from the study phase trials (i.e., a *foil* face). Each face remained on the computer screen until participants input a response. If they were satisfied with their response, they could press the space bar to submit it and begin the next trial in the recognition phase; otherwise, they could press the backspace key to change their response, which remained visible on the monitor until submitted. Upon completion of all recognition phase trials, participants were debriefed.

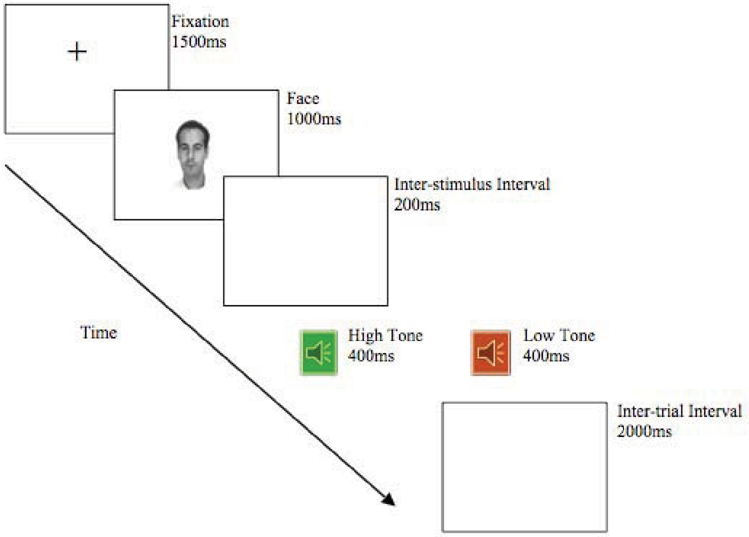

Figure 1 Experiment 1: Schematic of a single study phase trial. Stimulus duration is shown below each trial event.

Results

To correct for guessing (see Baddeley, 2004), the *foil* false alarm rate (*M*=.205, *SD*=.145) was subtracted from the corresponding uncorrected hit rate for each memory instruction (*Remember: M*=.530, *SD*=.214; *Forget: M*=.471, *SD*=.194) on a subject-by-subject basis. The corrected hit rates were analyzed in a one-way ANOVA, as a function of memory instruction (*Remember, Forget*). As shown in Figure 2, this analysis revealed a significant main effect of memory instruction, *F*(1, 29)=5.191, *MSe*=.010, *p*=.030, (η=.152), which revealed better recognition of *Remember* faces (*M*=.325, *SD*=.181) than *Forget* faces (*M*=.266, *SD*=.139).

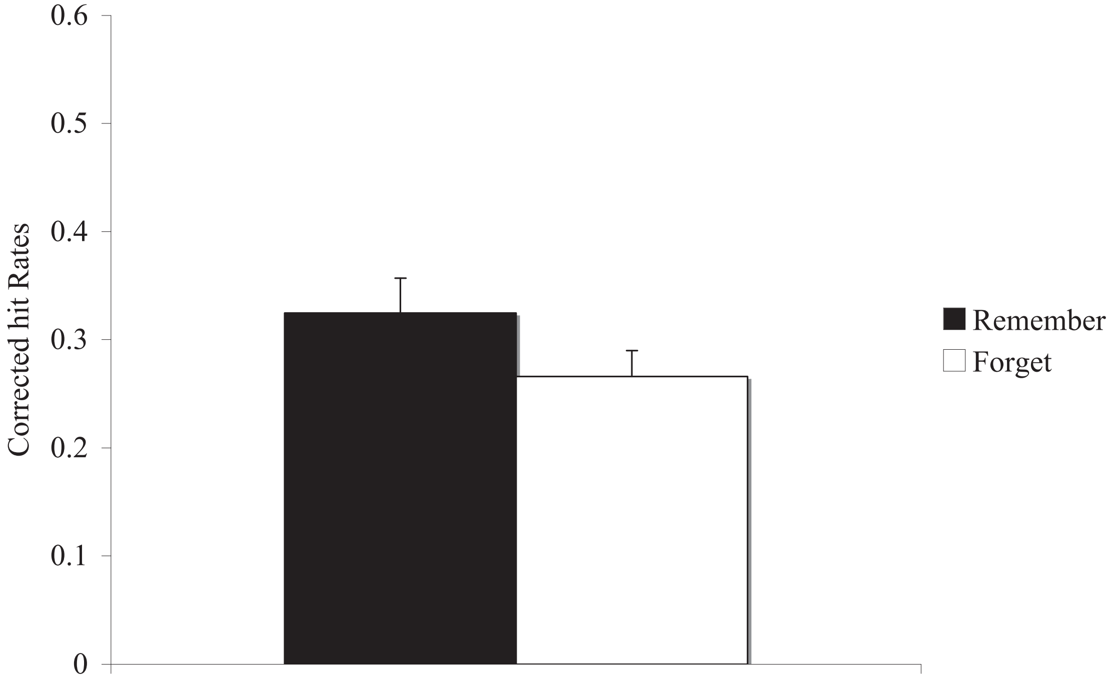

Figure 2 Experiment 1: The corrected hit rates on the recognition test as a function of memory instruction (*Remember, Forget*); error bars represent one standard error.

Discussion

The purpose of Experiment 1 was to examine the effect of *Neutral* facial expressions on the ability to intentionally forget. Participants were presented with a series of *Neutral* facial expressions each followed by a *Remember* or *Forget* memory instruction. After the presentation of all study items, memory performance was tested using a yes/no recognition test. In contrast to the prediction of no directed forgetting effect for faces (see also Reber et al., 2002), the current Experiment revealed a significant directed forgetting effect for faces displaying a *Neutral* facial expression. More specifically, memory performance was significantly greater for *Remember*-cued items relative to *Forget*-cued items. At a glance, this finding contradicts past research that has suggested that compared to non-face stimuli, face stimuli are special (e.g., Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al. 2003; Sommer et al., 1991) and that our remarkable ability to recognize faces may make them resistant to forgetting (e.g., Bruce & Young, 1986). However, consistent with the notion that face stimuli are more elaborately encoded than non-face stimuli, the magnitude of the directed forgetting effect was only 6%. When compared to Quinlan et al. (2010) who investigated the directed forgetting effect for words and line-drawings, the magnitude of directed forgetting for *Neutral* facial expressions in the current Experiment was significantly smaller than that for words (*M*=20%; t(29)=3.594, p<.01), and marginally smaller than that for line-drawings, (*M*=12%; t(29)=1.733, p=.092). Indeed, the magnitude of the directed forgetting effect for *Neutral* facial expressions was almost one-fourth that for words and one-half that for line-drawings. Although these findings suggest that *Neutral* facial expressions can be intentionally forgotten as instructed, this ability is reduced compared to non-face stimuli, such as words and line-drawings. Because the current Experiment found a significant directed forgetting effect for faces, whereas Reber et al. (2002) found no significant directed forgetting effect for faces, this supports the notion that the non-significant directed forgetting effect in Reber et al. (2002) was driven by the high foil false alarm rate and/or poor image quality.

The functional model for face recognition makes a distinction between the recognition of familiar and unfamiliar faces (Bruce & Young, 1986). It suggests that there are two routes for face recognition, one of which functions to recognize familiar faces and the other which temporarily stores unfamiliar faces in working memory (Bruce & Young, 1986). The model also proposes that unfamiliar faces are stored in a pictorial code and only once those faces have become familiar are they stored in an identity-specific semantic code. This is supported by clinical neuropsychology research, which has identified prosopagnosic patients who show no deficit in matching unfamiliar faces, but a severe deficit in matching familiar faces (Malone, Morris, Kay, & Levin, 1982). Therefore, the specialized face system may not function the same for familiar and unfamiliar faces, which could explain why this system did not override the ability to intentionally forget. Because unfamiliar faces may be encoded in a pictorial code and familiar faces may be encoded in identity-specific semantic code, unfamiliar faces may be processed and encoded using more simple strategies than familiar faces. That is, the unfamiliar faces used in this experiment may still have been processed and encoded to a greater extent than non-face stimuli, such as words and pictures (as indicated by the reduced directed forgetting effect for faces compared to words and pictures; Quinlan et al., 2010), but perhaps to a lesser extent than if familiar faces were used.

In any case, the reduced directed forgetting effect for *Neutral* facial expressions compared to words and line-drawings (Quinlan et al., 2010) does suggest that the faces used in the current experiment were processed and encoded in a way that functioned to increase elaborative rehearsal and thus, decrease the ability to selectively encode *Remember* and *Forget*-cued items. And, while these findings do not necessarily speak to the passive and active views of item method directed forgetting, they do suggest that some type of active process must be engaged to intentionally forget (cf. Hourihan & Taylor, 2006; Wylie, et al., 2008; see also, Fawcett & Taylor, 2010). If intentional forgetting was entirely a passive process, then it should have been very easy for the elaborative encoding of faces (Dobson & Rust, 1994) to override the *Forget* memory instruction and thereby produce a non-significant directed forgetting effect. Instead, these findings imply that some type of active executive process (e.g., attentional withdrawal, Hourihan & Taylor, 2006; Fawcett & Taylor, 2008; 2010; Taylor, 2005) must occur to enable the successful intentional forgetting of faces.

To further explore any potential effects that faces may have on the ability to intentionally forget, I replicated and extended these findings in Experiment 2 by incorporating emotional facial expressions (*Angry, Neutral, Happy*) into a standard item-method directed forgetting paradigm.

CHAPTER 3 EXPERIMENT 2

While there was a significant directed forgetting effect for *Neutral* facial expressions in Experiment 1, in our everyday lives we often encounter emotional facial expressions, such as *Angry* and *Happy* facial expressions. As such, the purpose of Experiment 2 was to explore whether or not emotional facial expressions (e.g., *Angry* and *Happy* facial expressions) modulate the ability to intentionally forget.

3.1 EMOTION AND MEMORY

Emotional material is typically better remembered than neutral material. This has not only been found to apply to words (Kensinger, 2004), stories (Arntz, de Groot, & Kindt, 2005) and pictures (Dolcos, LaBar, & Cabeza, 2004), but also to faces (Fischer, Sandblom, Nyberg, Herlitz, & Backman, 2007). Especially important to item method directed forgetting, enhanced memory for emotional stimuli has been suggested to occur by enhancing various processes at encoding, such as attention, elaboration and rehearsal, and neural activation (see Reisberg & Heuer, 1992 for review).

3.1.1 Attention

The attention mediation hypothesis (Cahill & McGaugh, 1998) is a critical account for the memory enhancement of emotional stimuli. It suggests that compared to neutral stimuli, negative stimuli tend to attract attention and it is this greater allocation of attention that produces enhanced memory for negative stimuli. Indeed, an attentional bias has been found for negative facial expressions at early time intervals (e.g., 100 ms) indicating that participants are faster to respond to a dot probe following the presentation of a negative facial expression compared to a neutral or happy facial expression (e.g., Cooper & Langton, 2006). In addition to the finding that negative facial expressions attract attention at early time intervals (e.g., Cooper & Langton, 2006), negative facial expressions have also been found to maintain attention. In an inhibition of return (IOR) task, participants are presented with a series of reaction time (RT) trials. Each trial begins with three boxes across the horizontal axis (left box, middle box, and right box) of the computer screen. A fixation point occurs in the middle box, followed by a visual onset cue in either the left or right peripheral box, and then a visual onset target in either the left or right peripheral box to which a speeded response is required. This task yields valid trials in which the cue and target occur in the same peripheral location and invalid trials in which the cue and target occur in different peripheral locations. If the time between the onset of the cue and the onset of the target is between ~300 to 1000 ms, an IOR effect occurs, which is defined by slower RTs on valid than invalid trials (Posner & Cohen, 1984). By biasing our attention towards novel spatial locations, IOR functions as a foraging facilitator and allows for the detection of more meaningful stimuli in our environment (Klein & MacInnes, 1999). Fox, Russo, and Dutton (2002; Experiment 2) used faces depicting angry, neutral, and happy expressions as cues in an IOR task and found that the magnitude of the IOR effect was significantly smaller following angry versus neutral and happy cues. The authors argued that compared to neutral and happy facial expressions, angry facial expressions maintained attention, resulting in participants being slower to disengage attention from the peripheral location of the angry facial expression. This interpretation is consistent with a number of studies that have shown negative facial expressions capture attention more efficiently (or quickly) compared to positive facial expressions when presented in a visual search task (Eastwood, Smilek, & Merikle, 2001; Frischen, Eastwood, & Smilek, 2008).

3.1.2 Rehearsal and Elaboration

Generally, emotional pictures and faces not only give more social and affective information, but also more perceptual information (i.e., more detailed and complex visual information) than neutral stimuli. This additional information results in more elaborate processing and rehearsal of these stimuli. Supporting this idea, Bohannon (1988) found that the additional rehearsal given to emotional stimuli (compared to neutral stimuli) was not only sufficient to maintain emotional flashbulb memories over a short period of time, but also over a long period of time. Furthermore, Safer, Christianson, Autry, and Osterlund (1998) as well as Heuer and Reisberg (1990) found that participants remembered emotionally arousing events in a more personal way than neutral events. For example, Heuer and Reisberg (1990) found that when participants made errors in recalling the details of an emotional story, it was because they projected their own emotions into their memories and could no longer distinguish the actual stimulus input from the information that was suggested by their own emotional elaboration.

3.1.3 Distinctiveness and Neural Structures

In addition to emotional stimuli receiving increased attention as well as increased rehearsal and elaboration compared to neutral stimuli, emotional stimuli, in particular negative stimuli also tend to be more distinctive compared to neutral stimuli. In fact, different neural substrates may represent different facial expressions (Calder, Lawrence, & Young, 2001). Compared to facial expressions displaying a neutral or positive affect (e.g., happy, surprise), facial expressions displaying a negative affect (e.g., fear, disgust, anger) seem to involve specialized brain structures —most notably, the amygdala (Morris, Frith, Perrett, Rowland, Young, Calder, & Dolan, 1996). Fischer et al. (2007) conducted an fMRI study using fearful and neutral facial expressions at encoding and then presented participants with a surprise recognition test and a subjective rating task. Overall, fearful facial expressions were better recognized than neutral facial expressions, with greater overall recognition of those faces rated most fearful. Additionally, there was a positive correlation between activity in the right limbic system (of which the amygdala is a part) and the recognition of fearful facial expressions such that greater activation in the limbic system was linked to greater recognition of fearful facial expressions. Therefore, some feature or aspect of negative facial expressions causes them to be remembered better and this has been supported by both subjective ratings as well as neural activity (e.g., Fischer et al., 2007).

Whalen, Rauch, Etcoff, McInerney, Lee, and Jenike (1998) used fMRI during a backward masking task using fearful, happy, or neutral facial expressions. In a series of trials, fearful and happy facial expressions were displayed for 33 ms, and then masked with the neutral facial expression for 167 ms. Because of the short stimulus presentation, it was unlikely that the participants noticed the emotional facial expressions. Even though participants did not report seeing the masked fearful and happy facial expressions, there was more activation in the amygdala in response to the presentation of fearful facial expressions compared to the presentation of happy facial expressions (Whalen et al., 1998). These findings suggest that not only is the amygdala more active in response to explicit negative emotional stimuli, it also shows activation in response to negative emotional stimuli (Whalen et al., 1998) that are perceived subliminally.

Further support for the role of the amygdala in the perception and expression of emotion comes from a study conducted by Keyser and Gazzola (2006). Participants who had bilateral amygdala damage as well as control participants were asked to rate facial expressions displaying various emotions, such as anger, fear, and happiness. Half of the patients who had bilateral amygdala damage (12 out of 24) rated facial expressions displaying fear and anger as less fearful and angry than a control group, which supports the importance of the amygdala in recognizing negative emotional stimuli. Halgren, Walter, Cherlow, and Crandall (1978) administered electrical stimulation to the amygdala of human participants and found that it resulted in an emotional facial expression of fear (Halgren et al., 1978). This further supports the importance of the amygdala in the perception and expression of negative emotional stimuli and in particular, negative facial expressions, such as fear and anger.

This special role of the amygdala in the recognition of faces displaying negative emotions has typically been interpreted from an evolutionary perspective (Ekman, 1992). Because negative emotions, such as anger and fear signal danger and the potential for immediate harm, the role of the amygdala in the recognition of negative facial expressions is an adaptive reaction that enhances our fitness to survive. The amygdala allows for quick cognitive appraisal, decision-making, and response or choice of behaviour.

Although the above studies (e.g., Morris et al., 1996; Whalen et al., 1998) clearly indicate that the amygdala plays an important role in the recognition and processing of negative emotion (although see Kensinger, 2004, and Section 4.1 Valence and Arousal for further discussion of the role of the amygdala in the processing of both negative as well as positive stimuli), one may wonder how this activation of the amygdala by emotional stimuli is related to enhanced memory for these stimuli. The modulation model (see Hamann, 2001; McGaugh, 2004 for reviews) suggests that the enhanced memory for negative stimuli is a result of the projections from the amygdala to the hippocampus. More specifically, compared to neutral and positive stimuli, negative stimuli are generally rated high in arousal. It is this arousing nature of negative stimuli that triggers the amygdala to release epinephrine and glucocorticoids (two adrenal hormones), which bind to adrenergic receptors in the amygdala and send a response via projections to the hippocampus (McGaugh & Roozendaal, 2002). It is thought that the link (and communication; i.e., the release of adrenal hormones) between the amygdala and hippocampus functions to increase memory consolidation and consequently enhance memory for negative stimuli.

3.1.4 Directed Forgetting

Although common nouns are often used in the item-method directed forgetting paradigm (e.g., Bjork 1970; MacLeod, 1975; MacLeod, 1989; Muther, 1965; Woodward & Bjork, 1971), there have been a few studies that have used emotional words. Many of the studies that have used emotional words have done so to study clinical populations (see Korfine & Hooley, 2000; McNally, Metzger, Lasko, Clancy, & Pitman, 1998; McNally, Otto, Yap, Pollack, & Hornig, 1999**;** Moulds & Byrant, 2002; Tolin, Hamlin, & Foa, 2002; Wilhelm, McNally, Baer, & Florin, 1996), such as individuals with obsessive compulsive disorder (OCD; Tolin et al., 2002) or post-traumatic stress disorder (PTSD; McNally et al., 1999). As a result, the negative stimuli that are used in these studies are typically specific to the clinical population of interest. For example, the goal of McNally et al. (1999) was to explore the ability to intentionally forget trauma-related words, such as “molested” in adult women who have PTSD due to childhood sexual abuse.

A recent study conducted by Quinlan and Taylor (under revision) used emotional words (negative, neutral, positive) in the context of an item-method directed forgetting paradigm that employed a non-clinical sample. This study found a significant directed forgetting effect for neutral and positive words, but no significant directed forgetting effect for negative words. The non-significant directed forgetting effect for negative items was due to both a significant increase in the *Forget*-cued items recognized as well as a significant decrease in the *Remember*-cued items recognized relative to neutral and positive words. This pattern was somewhat surprising because it suggested that negative words were not overall more memorable than neutral and positive items. Instead, the pattern of results suggested that the negative valence interfered with the processes used to both intentionally remember as well as intentionally forget the study items. Quinlan (unpublished Honour’s thesis) extended these findings to pictures from the IAPS database (Lang et al., 2005). Again, there was a significant directed forgetting effect for neutral and positive IAPS pictures, but no significant directed forgetting effect for negative IAPS pictures. In contrast to Quinlan and Taylor (under revision), in Quinlan (unpublished Honour’s thesis), the non-significant directed forgetting effect for negative pictures was driven entirely by a significant increase in the number of *Forget*-cued items recognized. Regardless of this slight discrepancy between the two studies, these findings suggest that emotional stimuli (words and pictures) can interfere with the differential encoding of *Remember* and *Forget*-cued items and thereby override the directed forgetting effect —either via a increased memory for *Forget*-cued items (Quinlan, unpublished Honour's thesis) or increased memory for *Forget*-cued items and decreased memory for *Remember*-cued items (Quinlan & Taylor, under revision).

3.2 CURRENT EXPERIMENT

The purpose of Experiment 2 was to replicate and extend the findings of Experiment 1 by incorporating emotional facial expressions (*Angry, Neutral, Happy*) into a standard item-method directed forgetting paradigm. Participants were presented with a series of faces displaying an *Angry, Neutral,* or *Happy* facial expression, one at a time, each followed by an instruction to *Remember* or an instruction to *Forget*. Following the presentation of all study items, participants completed a yes/no recognition test, which presented both *Remember* and *Forget*-cued items as well as an equal number of *foil* items; performance on the yes/no recognition task was used to measure the directed forgetting effect.

Although a directed forgetting effect was found for *Neutral* facial expressions in Experiment 1, because negative emotion enhances attention, elaboration, rehearsal, and neural activation (see Reisberg & Heuer, 1992 for review) and negative emotion has been shown to override the ability to intentionally forget (Quinlan, unpublished Honour's thesis; Quinlan & Taylor, under revision), it was predicted that the specialized face system in combination with the memory-enhancing benefits of negative emotion would override the mechanisms used to intentionally forget *Angry* facial expressions. More specifically, it was predicted that there would be a significant directed forgetting effect for *Neutral* and *Happy* facial expressions, but no significant directed forgetting effect for *Angry* facial expressions.

Method

Participants

Participants were 56 undergraduate students (12 males, 44 females) who volunteered in exchange for credit towards their grade in an eligible Psychology class at Dalhousie University. The experiment was run in one session lasting less than one hour. All participants reported normal or corrected-to-normal vision and a good understanding of the English language.

Stimuli and Apparatus

The stimuli and apparatus were identical to Experiment 1, with the exception that this study manipulated facial expression, such that there were *Angry*, *Neutral*, and *Happy* facial expressions. Different faces were used for each type of facial expression (e.g., the faces displaying *Angry* facial expressions were different faces from those displaying *Neutral* facial expressions). Again, because there are more male faces than female faces in the AR face database, the faces of 72 men and 48 women were selected. Within the set of male faces as well as the set of female faces, 1/3 of the faces displayed an *Angry* facial expression, 1/3 of the faces displayed a *Neutral* facial expression, and 1/3 of the faces displayed a *Happy* facial expression. For instance, of the 72 male faces, 24 displayed an *Angry* facial expression, 24 displayed a *Neutral* facial expression, and 24 displayed a *Happy* facial expression.

As in Experiment 1, for each participant, customized software was used to randomly distribute the items from the face collections (*Angry Men, Angry Women, Neutral Men, Neutral Women, Happy Men, Happy Women)* equally into *Remember* (n=30), *Forget* (n=30), and recognition *foil* (n=60) collections; each participant therefore had a unique combination of *Remember*, *Forget*, and *foil* items.

Procedure

The general procedure was identical to Experiment 1, except that participants were presented with an intermixed presentation of different faces displaying an *Angry*, *Neutral*, or *Happy* facial expression.

There were a total of 60 trials in the study phase: 30 *Remember*-cued trials and 30 *Forget*-cued trials (36 trials consisted of faces that were *Men* and 24 trials consisted of faces that were *Women*; 20 trials consisted of *Angry* facial expressions, 20 trials consisted of *Neutral* facial expressions, and 20 trials consisted of *Happy* facial expressions).

The yes/no recognition phase consisted of the same 60 trials from the study phase as well as 60 *foil* trials (72 trials consisted of faces that were *Men* and 48 trials consisted of faces that were *Women*; 40 trials consisted of *Angry* facial expressions, 40 trials consisted of *Neutral* facial expressions, and 40 trials consisted of *Happy* facial expressions).

Results

Mean uncorrected ‘y’ responses as a function of item type (*Remember*, *Forget, foil*) and type of facial expression (*Angry, Neutral, Happy*) are shown in Table 1. The proportions of false alarms made to unstudied foils on the recognition test were analyzed in a one-way ANOVA, with type of facial expression (*Angry, Neutral, Happy*) as a within-subjects factor. This analysis revealed a significant difference in the false alarm rate as a function of type of facial expression, *F*(2,110)=6.993, *MSe*=.007, *p*=.001 (η=.113). Planned contrasts revealed that significantly more ‘y’ responses were made to unstudied *Angry foils* (*M*=.254, *SD*=.164) than unstudied *Neutral foils* (*M=.198*, *SD*=.155; *t*(55)=3.937, *p*<.001), and to unstudied *Happy foils* (*M*=.244, *SD*=.169) than unstudied *Neutral foils*, *t*(55)=2.723, *p*=.009; however, there was no significant difference for the number of 'y' responses made to unstudied *Angry foils* and unstudied *Happy foils, t*(55)=.619, *p*=.538.

As described in Experiment 1, hit rates were corrected for their respective false alarm rates (see Baddeley, 2004) within type of facial expression, on a subject-by-subject basis. The corrected hit rates were analyzed in a 3 x 2 repeated measures ANOVA with memory instruction (*Remember*, *Forget*) and type of facial expression (*Angry, Neutral, Happy*) as within-subjects factors. As shown in Figure 3, this analysis revealed a significant main effect of memory instruction, *F*(1,55)=20.826, *MSe*=.018, *p*<.001 (η=.275), which confirms a directed forgetting effect with overall greater recognition of *Remember* items (*M*=.365, *SE*=.018) than *Forget* items (*M*=.299, *SE*=.023). There was no significant main effect for type of facial expression, *F*(2, 110)=2.256, *MSe*=.038, *p*=.110 (η=.039). Also, the two-way interaction of memory instruction and type of facial expression was not significant, *F*(2,110)=1.267, *MSe*=.016, *p*=.286 (η=.023), indicating that the magnitude of the directed forgetting effect was not significantly different across the three types of facial expression (*Angry, Neutral, Happy*). Nevertheless, planned contrasts were conducted to examine the directed forgetting effect for each type of facial expression (*Angry, Neutral, Happy*). These planned contrasts revealed a significant directed forgetting effect for both the *Happy* facial expressions, (*Remember*: *M*=.366, *SD*=.21; *Forget*: *M*=.286, *SD*=.209; *t*(55)= 3.310, *p*=.002), and *Neutral* facial expressions, (*Remember*: *M*=.404, *SD*=.226; *Forget*: *M*=.32, *SD*=.17; *t*(55)= 3.459, *p*=.001); however, there was no significant directed forgetting effect for *Angry* facial expressions, (*Remember*: *M*=.326, *SD*=.213; *Forget*: *M*=.29, *SD*=.18; *t*(55)= 1.489, *p*=.142).

Table 1 Experiment 2: Means (and standard deviations) for uncorrected hit rates as a function of word type (*Remember, Forget, foil*) and type of facial expression (*Angry, Neutral, Happy*).

	Remember	Forget	Foil
Angry	.58 (.215)	.544 (.200)	.254 (.164)
Neutral	.602 (.203)	.518 (.191)	.198 (.155)
Happy	.61 (.200)	.53 (.193)	.244 (.169)

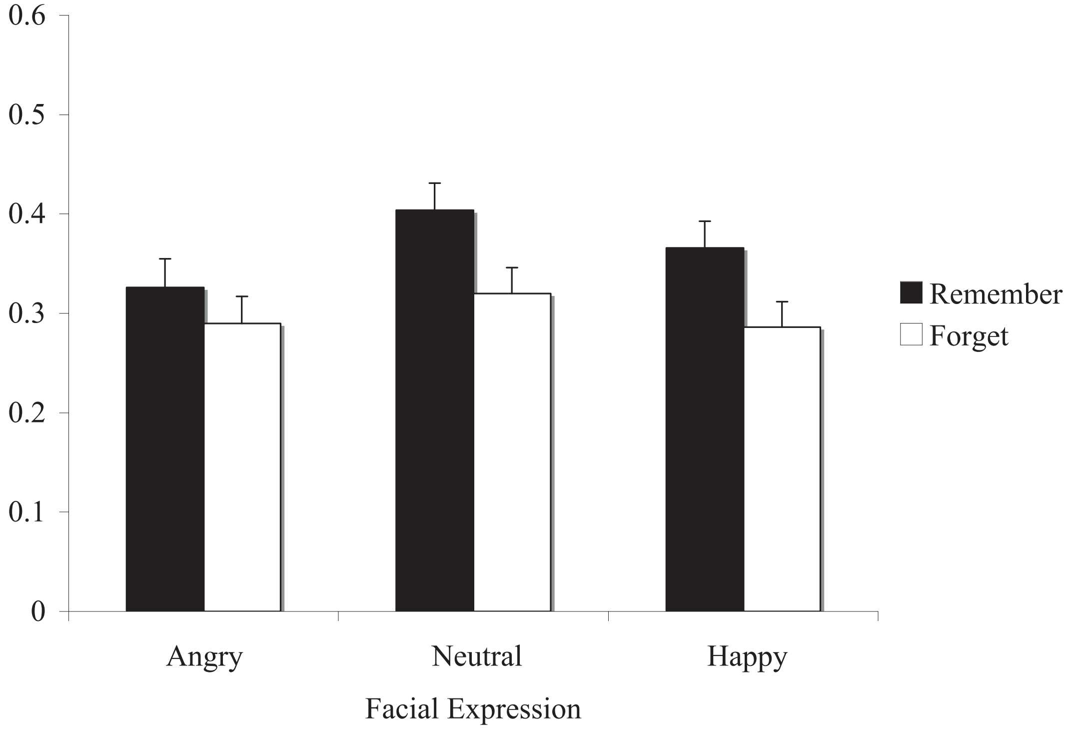

Figure 3 Experiment 2: The corrected hit rates on the recognition test as a function of memory instruction (*Remember, Forget*) and type of facial expression (*Angry, Neutral, Happy*); error bars represent one standard error.

Discussion

Experiment 2 explored the effect of emotional facial expression (*Angry, Neutral, Happy*) on the ability to intentionally forget. Participants were presented with an intermixed series of *Angry, Neutral,* and *Happy* facial expressions each followed by a *Remember* or *Forget* memory instruction. After the presentation of all study items, memory performance was tested using a yes/no recognition test. Because negative emotion enhances various cognitive processes, such as attention and elaboration (see Reisberg & Heuer, 1992 for review) and negative emotion can override the ability to intentionally forget (Quinlan, unpublished Honour's thesis; Quinlan & Taylor, under revision), it was predicted that there would be no significant directed forgetting effect for *Angry* facial expressions, but there would be a significant directed forgetting effect for *Neutral* and *Happy* facial expressions.

The two-way interaction of memory instruction (*Remember, Forget*) and type of facial expression (*Angry, Neutral, Happy*) failed to reach significance in the omnibus ANOVA of the present experiment. Because the magnitude of the directed forgetting effect was relatively small for all three types of facial expression, it is not surprising that these small differences did not emerge in the two-way interaction. Nevertheless, consistent with the above hypothesis, the planned contrasts used to examine the directed forgetting effect for each type of facial expression (*Angry, Neutral, Happy*) indicated that there was a significant directed forgetting effect for *Neutral* and *Happy* facial expressions, but not for *Angry* facial expressions. These findings replicated those of Quinlan and Taylor (under revision) and Quinlan (unpublished Honour's Thesis) who found a significant directed forgetting effect for neutral and positive words and pictures, but no significant directed forgetting effect for negative words and pictures.

Foil items are included in the yes/no recognition test to ensure that participants are responding accurately and not just pressing ‘y’ or ‘n’ meaninglessly (e.g., responding ‘y’ to all items or responding ‘n’ to all items). In this experiment, *Angry* facial expressions as well as *Happy* facial expressions produced a significantly greater number of *foil* false alarms than *Neutral* facial expressions. At a glance, this finding suggests that participants may be more liberal in responding ‘y’ on the yes/no recognition test to *Angry* and *Happy* facial expressions than to *Neutral* facial expressions. Because emotional facial expressions are of evolutionary importance (e.g., they signal danger or safety), this finding makes sense. Also, it is consistent with the findings of previous studies that have found a bias for participants to respond ‘y’ (i.e., that they recognize the item from the study phase) to emotional stimuli compared to neutral stimuli (e.g., Kapucu, Rotello, Ready, & Seidl, 2008). If the greater proportion of *foil* false alarms was due to a more liberal response bias, then participants should have been more likely to respond ‘y’ to emotional facial expressions than *Neutral* facial expressions, regardless of whether it was old (*Remember, Forget*) or new (*foil*); however, this was not the case. Collapsing across all item types (*Remember, Forget, foil*), a series of contrasts were conducted comparing the proportion of uncorrected ‘y’ responses across the types of facial expression (*Angry, Neutral, Happy*); there were no significant differences, all p’s>.181. Therefore, it does not appear as though participants are more liberal in responding to emotional facial expressions (*Angry, Happy*) compared to *Neutral* facial expressions, but rather they mistake *foil* emotional facial expressions as being old or previously presented more often than *foil Neutral* facial expressions. This may be because faces displaying an emotional facial expression are very similar to one another (e.g., all *Angry* facial expressions have eyebrows pointed inward and down), whereas there is more variety among the faces displaying a *Neutral* facial expression.

In the current Experiment, the corrected hit rates to *Remember*-cued items were significantly lower for *Angry* facial expressions compared to *Neutral* facial expressions, $t(55)= 2.377$, $p=.021$, but not *Happy* facial expressions, $t(55)= 1.412$, $p=.164$ (also there was no significant difference for the corrected hit rates to *Remember*-cued items for *Neutral* facial expressions compared to *Happy* facial expressions, $t(55)= 1.178$ $p=.244$). Interestingly, there were no differences in corrected hit rates to *Forget*-cued items as a function of type of facial expression, all *p*'s>.265. Therefore, the non-significant directed forgetting effect for *Angry* facial expressions was not due to overall enhanced memory, but rather to a reduced ability to remember *Angry* facial expressions. Although this reduced ability to remember *Angry* facial expressions (compared to *Neutral* and *Happy* facial expressions) is inconsistent with the findings that negative facial expressions (e.g., anger, fear, sad) are more likely to be processed and encoded elaborately (see Reisberg & Heuer, 1992 for review), this finding is consistent with Quinlan and Taylor (under revision) who found a relatively decreased ability to remember negative words.

Regardless of the source of the non-significant directed forgetting effect for *Angry* facial expressions, the fact is that memory for these stimuli is different than for happy and neutral stimuli. What is it about an *Angry* facial expression that reduces the magnitude of the directed forgetting effect? Is it the expression of anger (i.e., valence) or it is the arousing nature (i.e., the excitement) of an *Angry* facial expression? There is a debate in the emotion literature as to whether it is the valence of negative stimuli that influences memory (e.g., Kensinger & Corkin, 2004) or whether it is the arousal of the negative stimuli that influences memory (Hamann, 2001; Kensinger & Corkin, 2004; McGaugh, 2004; McGaugh & Roozendaal, 2002). As such, the goal of Experiment 3 was to dissociate the effects of valence and arousal on the directed forgetting effect for faces. In doing so, Experiment 3 incorporated an electrophysiological measure of arousal, the galvanic SCR.

CHAPTER 4 EXPERIMENT 3

In Experiment 2, there was no significant directed forgetting effect for *Angry* facial expressions. It is important to determine whether this was due to the valence (negativity) of the *Angry* facial expression and/or the arousal (intensity/excitement) of the *Angry* facial expression. This will aid in understanding the mechanisms that allow for the successful, as well as unsuccessful, remembering and forgetting of information.

4.1 VALENCE AND AROUSAL

Emotion can be divided into two independent dimensions: Valence and arousal. Valence refers to the pleasantness of the stimulus (unpleasant/negative, pleasant/positive), whereas arousal refers to the intensity of the stimulus (exciting/arousing, calming/non-arousing; Lang, Greenwald, Bradley, & Hamm, 1993). Both valence (e.g., Adolphs, Russell, & Tranel, 1999; Tranel, Gullickson, Koch, & Adolphs, 2006) and arousal (e.g., Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004) have been shown to enhance memory.

To account for memory enhancement by emotional stimuli, recent research has focused on the amygdala and its interaction with other neural structures, such as the hippocampus. While some studies have suggested that the amygdala is involved in the recognition of negative and positive valence (e.g., Adolphs et al., 1999; Tranel et al., 2006), other research has emphasized the importance of arousal and has found that the amygdala responds to arousing stimuli —regardless of valence (e.g., Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004). Furthermore, some studies have found that arousal affects the activation of the amygdala, but that this activation is dependent upon the valence of the stimulus. For instance, Garavan, Pendergrass, Ross, Stein, and Risinger (2001) found that arousal modulated amygdala activity for negative stimuli, but not for positive stimuli. Additionally, Steinmetz, Addis, and Kensinger (2010) presented participants with pictures that varied in valence (negative, positive) and arousal (high, low) while measuring brain activity using fMRI. Similar to Garavan et al. (2001), these researchers found that for negative stimuli, the level of arousal (i.e., high arousal) increased the strength of connections between the amygdala and the inferior frontal gyrus as well as the strength of connection between the amygdala and the middle occipital gyrus (both of these brain areas have been shown to be involved in memory; Kensinger & Corkin, 2003; Zald, Donndelinger, & Pardo, 1998). In contrast, for positive stimuli, the level of arousal decreased the connections between the amygdala and these two brain areas (i.e., the inferior frontal gyrus and the middle occipital gyrus; Steinmetz et al., 2010).

Morris et al. (1996) used PET to measure activation in the amygdala while participants viewed pictures of fearful and happy facial expressions, which varied in terms of their arousal (intensity of facial expression). Compared to happy facial expressions, there was greater activation in the amygdala in response to fearful facial expressions. Furthermore, the activation in the amygdala varied as a function of intensity such that the more intense the fearful facial expression, the greater the activation. In contrast, the more intense the happy facial expression, the lower the activation in the amygdala.

Taken together, these neuroimaging studies (Garavan et al., 2001; Morris et al., 1996; Steinmetz et al., 2010) imply that arousal is a key factor in producing increased activation in the amygdala, which has been suggested to result in enhanced memory for emotional stimuli (e.g., the modulation hypothesis; see Hamann, 2001; McGaugh, 2004 for reviews). However, it is important to note that to an extent, it seems as though the effect of arousal is dependent upon valence such that arousal enhances memory for negative stimuli, but it does not enhance memory for positive stimuli (see Morris et al., 1996).

The amygdala is associated with activation of the autonomic nervous system (e.g., sweating, heart rate, blood pressure). Galvanic SCR is a method of measuring autonomic nervous system arousal via small changes in activity in the sweat ducts in the skin and the opening and collapse of the sweat duct near the pores (Edelberg, 1993). Although measures of autonomic nervous system arousal can often be unreliable, SCR is thought to provide a reliable index of emotional processing (Bauer, 1998; Lang et al., 1993). Indeed, highlighting the fact that amygdala activation is associated with increases in autonomic nervous system arousal, the findings of a study conducted by Phelps, O'Connor, Gatenby, Gore, Grillon, & Davis (2001) demonstrated that the magnitude of the amygdala response to emotional stimuli was correlated with the magnitude of SCRs. More specifically, when participants were presented with a stimulus that they were told might be linked to a negative event, the stimulus resulted in activation of the amygdala, with the level of activation positively correlated with SCR ($r=.649$). Extending this finding, Glascher and Adolphs (2003) found that compared to normal control participants, participants with right amygdala damage and bilateral amygdala damage showed a decrease in SCRs to emotionally arousing stimuli. These researchers also found a positive association between SCRs and normative ratings of arousal in normal control participants (but not participants with amygdala damage; Glascher & Adolphs, 2003). Furthermore, Anders, Lotze, Erb, Grodd, and Birbaumer (2004) found that subjective ratings of arousal were positively correlated with SCR (r=.75). The fact that SCR is positively correlated with other measures of arousal, such as neural activation of the amygdala (Phelps et al., 2001) and subjective ratings of arousal (Anders et al., 2004) highlights the reasons for regarding SCR as the most useful laboratory test for measuring autonomic nervous system activation (Damasio, 1994).

4.2 CURRENT EXPERIMENT

Many studies that have examined the effect of emotion on memory have used words or pictures from the IAPS database (e.g., Quinlan & Taylor, under revision; Quinlan, unpublished Honour's thesis). Typically, these word and picture stimuli have separate ratings of valence and arousal so that one dimension can be controlled while the other dimension is manipulated (e.g., control for the arousal of the stimulus while manipulating the valence of the stimulus). In contrast to these studies, the faces from the AR face database, which were used in both Experiment 1 and Experiment 2, did not have separate ratings of valence and arousal; these face stimuli were simply organized into categories based on the type of facial expression they displayed (e.g., *Angry, Neutral, Happy*). The purpose of Experiment 3 was to extend the findings of Experiment 2 using galvanic SCR to dissociate valence and arousal within the context of item-method directed forgetting of faces. Experiment 3 used faces drawn from the AR Face Database (Martinez & Benavente, 1998) that displayed *Angry*, *Neutral*, and *Happy* expressions. Each face was presented one at a time. Following the disappearance of each face, participants received a tone that instructed them to *Remember* or *Forget* the preceding face. Critically, during each study trial, galvanic SCR was measured and recorded. The galvanic SCR was used to assess the change in SCR (arousal) as a function of the type of facial expression (*Angry, Neutral,* and *Happy*). Following the presentation of all study trials, participants performed a yes-no recognition task. Performance in this task was used to assess the magnitude of the directed forgetting effect as a function of type of facial expression (*Angry, Neutral,* and *Happy*).

Method

Participants

Participants were 13 undergraduate students who volunteered in exchange for credit towards their grade in an eligible Psychology class at Dalhousie University. The experiment was run in one session lasting approximately 30 minutes. All participants reported normal or corrected-to-normal vision and a good understanding of the English language. Because electrodes were used to obtain the measure of galvanic SCR, eligible participants could not have any history of seizures or cardiac conditions (e.g., use of artificial pacemaker, heart failure).

Stimuli and Apparatus

The stimuli and apparatus were identical to Experiment 2, with the following exceptions. This experiment was presented on a 13” MacBook computer running Mac OSX, version 10.5 Leopard and using SuperLab Version 4.0.7 for Mac. A Galvanic Skin Response Amp (model No. ML116; http://www.adinstruments.com/products/hardware/research/product/ML870*P/) was used to collect measures of physiological arousal in response to the face stimulus on each trial. These measures of physiological arousal were sent to Lab Chart via StimTracker, provided by Cedrus Corporation (San Pedro, CA). As in Experiment 2, because there are more men faces than women faces in the AR face database, 72 men and 48 women were selected. Again, within the set of male faces as well as the set of female faces, 1/3 of the faces displayed an *Angry* facial expression, 1/3 of the faces displayed a *Neutral* facial expression, and 1/3 of the faces displayed a *Happy* facial expression.

Also, before running each participant, customized software was used to randomly distribute the items from the face collections (*Angry Men, Angry Women, Neutral Men, Neutral Women, Happy Men, Happy Women)* into *Remember* (n=30), *Forget* (n=30), and recognition *foil* (n=60) collections; each participant therefore had a unique combination of *Remember*, *Forget*, and *foil* items.

Procedure

During the study phase, the participant's SCR was measured using physiological equipment and software provided by AD Instruments (Colorado Springs, CO). Participants wore dry electrodes on the medial phalanges of the index and middle fingers of their non-dominant hand. These were connected to a Galvanic Skin Response amplifier and a PowerLab data acquisition unit, which sent input to LabChart Version 7.0 Pro for Mac.

The general procedure was identical to Experiment 2, except for the timing of events within each trial in the study phase. As shown in Figure 4, each trial began with a 1500 ms fixation interval, during which the fixation stimulus ('+') appeared alone in the centre of the computer monitor. The fixation interval was followed by a face that was centered on the computer monitor for 1000 ms. Following a further 1000 ms inter-stimulus interval during which a blank screen was presented, the tone that served as the memory instruction played over the headphones for 400 ms. Because it can take up to

10000 ms for a galvanic SCR to occur, we increased the inter-trial interval to 6000 ms (as opposed to the 2000 ms inter-trial interval used in Experiments 1 and 2). During the inter-trial interval, no stimuli were presented. The total duration of all events in each study trial was equal to 9900 ms, from the beginning of the fixation to the end of the inter-trial interval. Therefore, in contrast to Experiments 1 and 2, each trial in the study phase was 4800 ms longer in duration. This was to ensure that there was sufficient time for a SCR to occur and return to baseline.

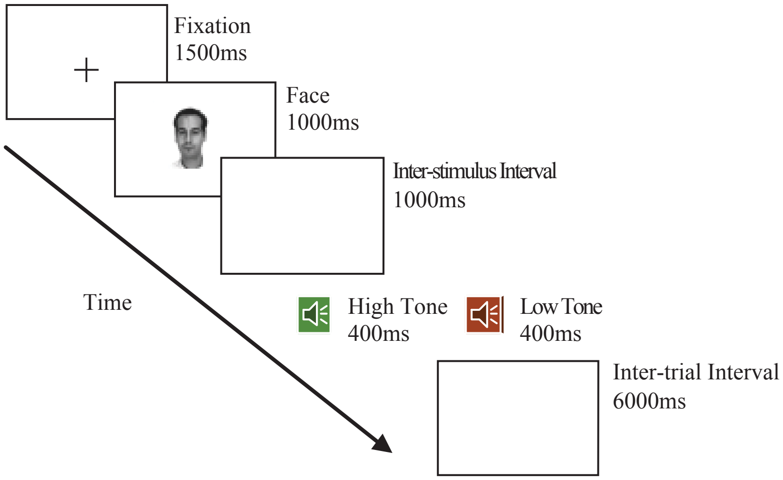

Figure 4 Experiment 3: Schematic of a single study phase trial. Stimulus duration is shown below each trial event.

Results

Recognition Performance

Mean uncorrected ‘y’ responses as a function as a function of word type (*Remember*, *Forget, foil*) and type of facial expression (*Angry, Neutral, Happy*) are shown in Table 2. The proportions of false alarms to unstudied foils on the recognition test were analyzed in a one-way ANOVA, with type of facial expression (*Angry, Neutral, Happy*) as a within-subjects factor. This analysis did not reveal a significant difference in the false alarm rate as a function of type of facial expression, *F*(2,24)=.750, *MSe*=.008, *p*=.483 (η= .059).

As described in Experiment 1, hit rates within each level of the type of facial expression factor were corrected on a subject-by-subjects basis for their respective false alarm rates (see Baddeley, 2004). The corrected hit rates were analyzed in a 3 x 2 repeated measures ANOVA with memory instruction (*Remember*, *Forget*) and type of facial expression (*Angry, Neutral, Happy*) as within-subjects factors. As shown in Figure 5, this analysis revealed a marginally significant main effect of memory instruction, *F*(1,12)=4.100, *MSe*=.018, *p*=.066 (η= .255), which suggests a trend for a directed forgetting effect with overall greater recognition of *Remember* items (*M*=.437, *SE*=.051) than *Forget* items (*M*=.376, *SE*=.043). There was no significant main effect for type of facial expression, *F*(2, 24=.203, *MSe*=.033, *p*=.818 (η= .017). Also, the two-way interaction of memory instruction and type of facial expression was not significant, *F*(2,24)=1.029, *MSe*=.015, *p*=.373 (η= .079), indicating that the magnitude of the directed forgetting effect was not significantly different across the three types of facial expression (*Angry, Neutral, Happy*). Nevertheless, planned contrasts were used to examine the directed forgetting effect for each type of facial expression (*Angry, Neutral, Happy*). These planned contrasts revealed a significant directed forgetting effect for *Neutral* facial expressions, (*Remember*: *M*=.438, *SD*=.197; *Forget*: *M*=.338, *SD*=193; *t*(12)= 2.55, *p*=.025) but no significant directed forgetting effect for *Angry* facial expressions, (*Remember*: *M*=.458, *SD*=.223; *Forget*: *M*=.381, *SD*=.144; *t*(12)= 1.198, *p*=.254) or *Happy* facial expressions, (*Remember*: *M*=.415, *SD*=.266; *Forget*: *M*=.408, *SD*=.225; *t*(12)= .192, *p*=.851).

Table 2 Experiment 3: Means (and standard deviations) for uncorrected hit rates as a function of memory instruction (*Remember, Forget, foil*) and type of facial expression (*Angry, Neutral, Happy*).

	Remember	Forget	Foil
Angry	.631 (.197)	.554 (.226)	.173 (.159)
Neutral	.608 (.150)	.508 (.166)	.169 (.142)
Happy	.623 (.164)	.615 (.157)	.208 (.160)

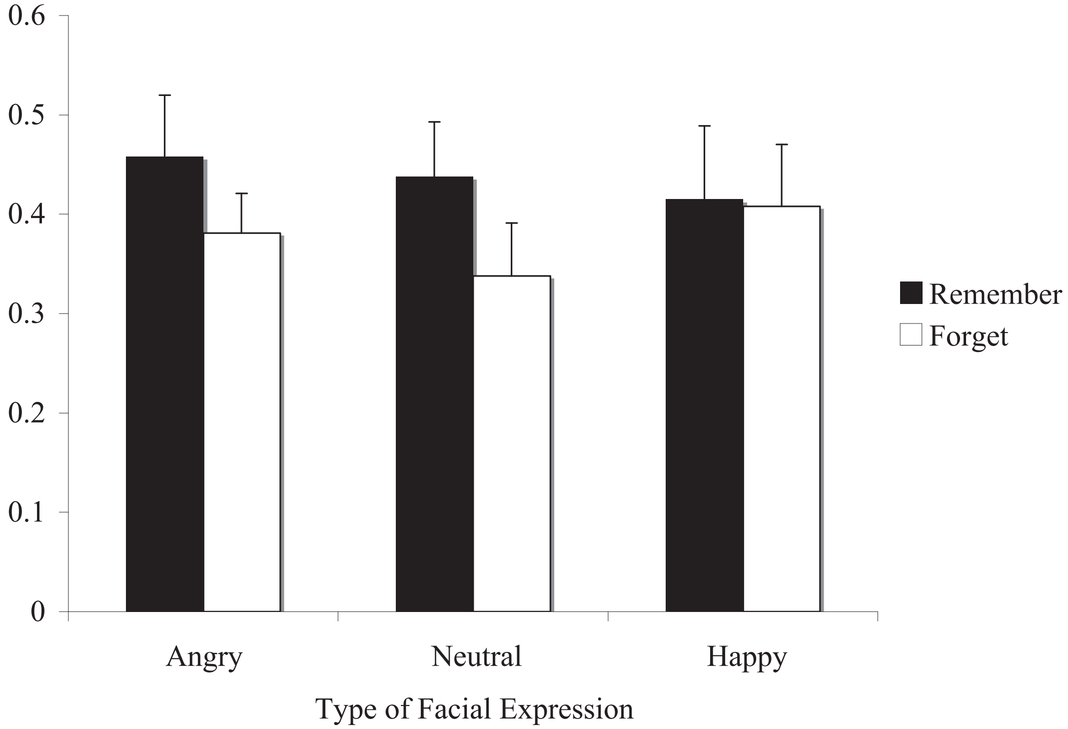

Figure 5 Experiment 3: The corrected hit rates on the recognition test as a function of memory instruction (*Remember, Forget)* and type of facial expression (*Angry, Neutral, Happy*); error bars represent one standard error.

SCR Recordings

Custom software written by Carl Helmick using Python 2.5 condensed the raw SCR sampling output to provide four pieces of information for each trial: 1) amplitude of the SCR peak within the first five seconds of the trial; 2) time of the first SCR peak; 3) amplitude of the SCR peak within the last five seconds of the trial; and 4) time of the second SCR peak. These variables are shown in a sample graph of a single trial from a single participant in Figure 6. The change in SCR amplitude was calculated on a trial-by-trial basis for each participant by subtracting an averaged start frame value (the five SCR samples before the onset of the fixation [the end of the previous trials; equivalent to 500 ms] and the ten SCR samples after the onset of the fixation [equivalent to 1000 ms]) on each trial from the largest of the two possible SCR peak amplitudes following the onset of the face stimulus within each trial[1]. The averages for change in SCR amplitude to *Angry*, *Neutral,* and *Happy* facial expressions were calculated for each participant.

It can take between 5000 and 10000 ms for SCRs to occur, so given that the duration of a single study phase trial was 9900 ms, it was not possible to measure and record a SCR separately to both the face stimulus and the memory instruction. In any case, SCR to the emotionally expressive face stimulus was the primary interest of this Experiment; there was no reason to expect that the counterbalanced high- and low-pitched tones used for memory instruction would result in consistent differences in arousal or that they would interact with the arousal produced by the facial expression. Nevertheless, the mean change in SCR amplitude was analyzed in a two-way ANOVA

---

[1] Because we only predicted a difference in the change in SCR amplitude as a function of type of facial expression and not memory instruction, we used the largest of the two possible peak amplitudes within each trial (e.g., the first time window following the onset of the face stimulus and the time window following the onset of the memory instruction).

with memory instruction (*Remember, Forget*) and type of facial expression (*Angry, Neutral, Happy*) as within-subjects factors. As evident in Figure 7, this analysis revealed no significant effect of memory instruction, *F*(1, 12)=.092, *MSe*=.056, *p*=.767, (η=.009) or type of facial expression, *F*(2, 24)=.147, *MSe*=.216, *p*=.864, (η=.052). Also, the two-way interaction of memory instruction and type of facial expression failed to reach significance, *F*(2, 24)=1.306, *MSe*=.083, *p*=.288, (η=.137).

Despite the non-significant effect of type of facial expression, because SCRs to type of facial expression were critical to the current Experiment, a series of planned contrasts examined whether the change in SCR amplitude was significantly different between any of the three types of facial expression (*Angry, Neutral, Happy*). There was no significant difference in the change in SCR amplitude for *Angry* facial expressions (*M*=.483; *SD*=.545) compared to *Neutral* facial expressions, (*M*=.45; *SD*=.525; *t*(14)=.753, *p*=.464) or for *Angry* facial expressions compared to *Happy* facial expressions, (*M*=.432; *SD*=.444; *t*(14)=818, *p*=.427). Also, there was no significant difference in the change in SCR amplitude for *Happy* facial expressions compared to *Neutral* facial expressions, *t*(14)=.37, *p*=.717.

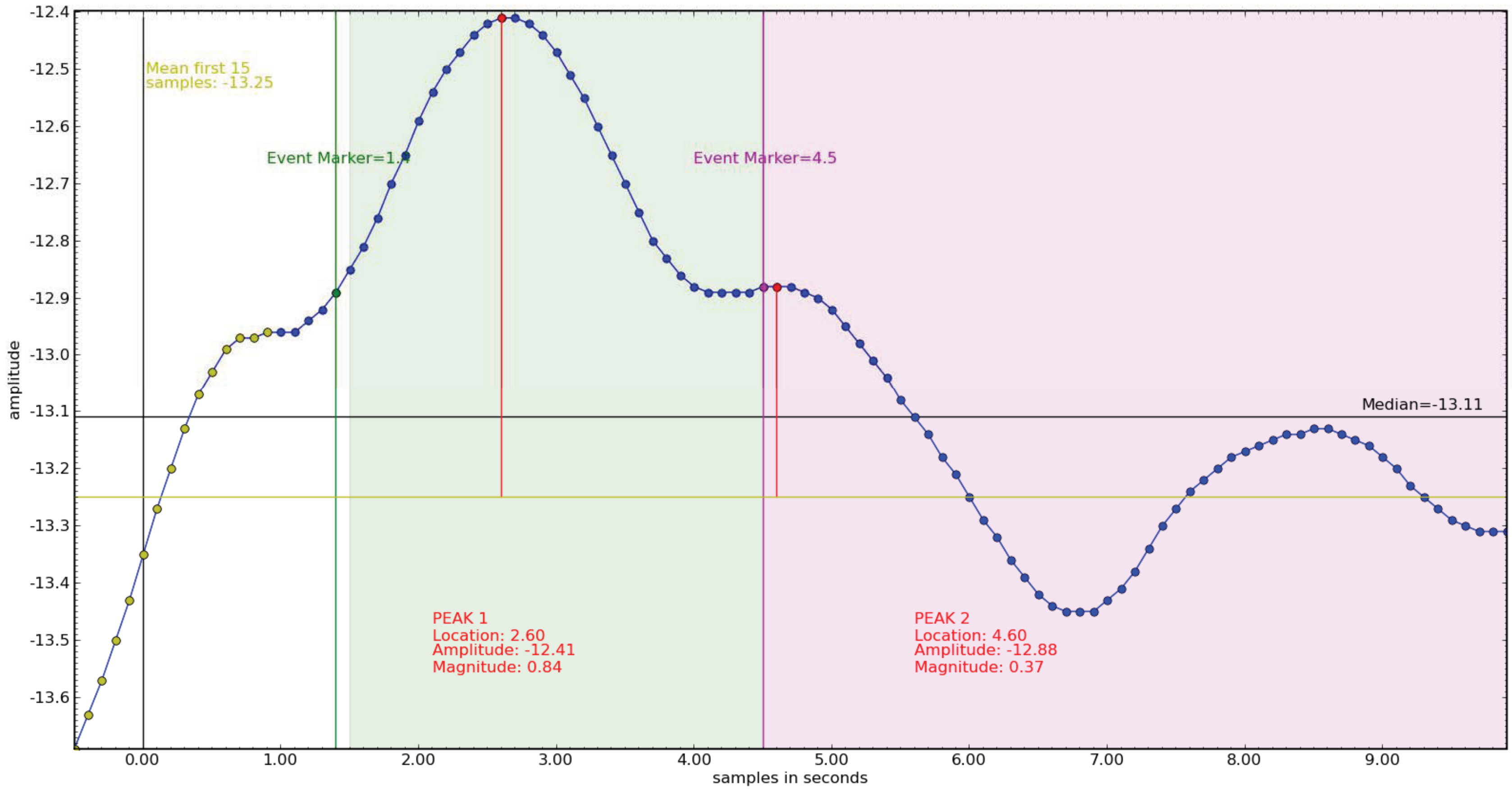

Figure 6 Experiment 3: A sample graph of the data output from a single study phase trial from a single participant. Event marker 1 refers to the onset of the face stimuli; event marker 2 refers to the onset of the memory instruction.

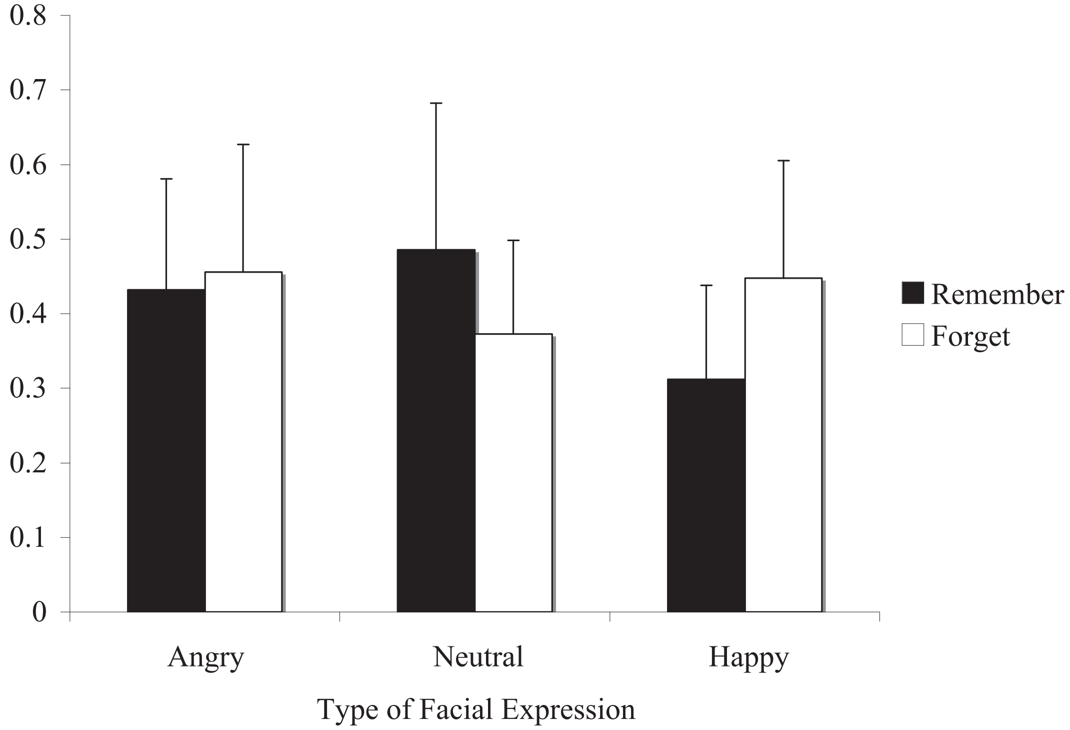

Figure 7 Experiment 3: The mean change in SCR amplitude (the peak amplitude minus the baseline amplitude at the start of the trial) as a function of memory instruction (*Remember, Forget*) and type of facial expression (*Angry, Neutral, Happy*); error bars represent one standard error.

Discussion

The goal of Experiment 3 was to extend the findings of Experiment 2 by incorporating galvanic SCR to dissociate the effects of valence and arousal on item-method directed forgetting for *Angry*, *Neutral*, and *Happy* facial expressions. Similar to Experiment 2, there was not a significant interaction between memory instruction (*Remember, Forget*) and type of facial expression (*Angry, Neutral, Happy*) in the omnibus ANOVA. Because the directed forgetting effect was relatively small for all three types of facial expression (M_{Angry}=.077; $M_{Neutral}$=.10; M_{Happy}=.008), this finding was not surprising. Nevertheless, planned contrasts were used to examine the directed forgetting effect within each type of facial expression. Replicating Experiment 2, in the current Experiment there was no significant directed forgetting effect for *Angry* facial expressions, but there was a significant directed forgetting effect for *Neutral* facial expressions. However, in contrast to Experiment 2, and unexpectedly, there was no significant directed forgetting effect for *Happy* facial expressions in the current Experiment. Although the magnitude of the directed forgetting effect for *Happy* facial expressions in the current experiment (M=.008; SD=.181) was not significantly different than in Experiment 2, (M=.08; SD=.144; $t(67)$=1.344, p=.184), the means clearly suggest a large difference: the directed forgetting effect for *Happy* facial expressions was non-existent in the current Experiment (<1%) and approximately 8% in Experiment 2.

Importantly, there were no significant differences in the proportion of corrected hits made to *Remember*-cued items as a function of facial expression (*Angry, Neutral, Happy*), all *p*'s>.242. This suggests that the reduced ability to recognize *Remember*-cued *Angry* facial expressions compared to *Neutral* facial expressions in Experiment 2 may have been an anomaly. In the current experiment, the non-significant directed forgetting effect appeared to be attributable to a trend (albeit not significant) for recognition on *Forget* trials to be better for *Angry* facial expressions (*M*=.381, *SD*=.144) than for *Neutral* facial expressions (*M*=.338, *SD*=.197). Also, again although not statistically significant, the descriptive statistics show that recognition on *Remember* trials was greater for *Angry* facial expressions (*M*=.458, *SD*=.223) than *Neutral* facial expressions (*M*=.438, *SD*=.193).

With regard to the SCR data, there was no significant difference in the change in SCR amplitude as a function of memory instruction (*Remember, Forget*) and type of facial expression (*Angry, Neutral, Happy*). Furthermore, none of the planned contrasts that examined the change in SCR amplitude across the three types of facial expression were significant. Because the goal of this Experiment was to examine galvanic SCR to types of facial expression and not memory instructions, the relation between *Remember* and *Forget* memory instructions and arousal will not be considered further.

Galvanic SCR is a measure of physiological arousal and thus a *difference* in SCR is indicative of a *difference* in physiological arousal; if there is no difference in SCR, then there is no difference in physiological arousal. Because there was a directed forgetting effect for *Neutral* facial expressions, but no directed forgetting effect for *Angry* facial expressions and there was no difference in the change in SCR amplitude (the measure of arousal in the current Experiment) for *Angry* and *Neutral* facial expressions, these findings suggest that the inability to intentionally forget *Angry* facial expressions was not due to the arousal associated with the *Angry* facial expressions (e.g., intensity/excitement), but due to the valence of the *Angry* facial expressions (e.g., negativity). This conclusion is consistent with Quinlan and Taylor (under revision) who found no significant directed forgetting effect for negative words but a significant effect for neutral and positive words, when controlling for ratings of arousal.

Our findings are in disagreement with many studies that have implicated arousal in enhancing memory for emotional stimuli (e.g., Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004) as well as studies that have highlighted the importance of the connections between the amygdala and other neural structures involved in memory (e.g., the hippocampus). These neural structures are typically activated in response to arousing stimuli (e.g., Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004); however, activation of these structures sometimes depends on valence, such that arousal influences the connections between the amygdala and other neural structures (and thus memory) only if the stimuli are negative in valence (e.g., Garavan et al., 2001; Morris et al., 1996; Steinmetz et al., 2010). Our findings are also inconsistent with the modulation model (see Hamann, 2001; McGaugh, 2004 for reviews), which proposes that memory for negative stimuli is better than memory for neutral stimuli because the increased activity in the basolateral nucleus of the amygdala is produced by increased *arousal* associated with emotional stimuli. Although the findings of the current Experiment cannot speak to the neural mechanisms of memory and emotion, to the extent that amygdala activation and SCRs are positively correlated (Phelps et al., 2001), the electrophysiological data from the current Experiment do not support the role of arousal in the memory enhancing effects of emotion.

A surprising finding in the current Experiment was that there was no significant directed forgetting effect for *Happy* facial expressions. This is in contrast to Experiment

2, where I found a significant directed forgetting effect for these same *Happy* facial expressions. The non-significant directed forgetting effect for *Happy* facial expressions is also in contrast to past research that has examined the effect of emotional words (Quinlan & Taylor, under revision) as well as emotional pictures (Quinlan, unpublished Honour's thesis) on the directed forgetting effect. We (Quinlan & Taylor, under revision; Quinlan, unpublished Honour's thesis) have reliably found a significant directed forgetting effect for positive stimuli. It is possible to speculate on reasons why there was no significant directed forgetting effect for *Happy* facial expressions in the current experiment, but none of them are wholly satisfying.

Besides incorporating a measure of galvanic SCR, the only other crucial difference between the current Experiment and Experiment 2 was the timing of the inter-trial interval. Because it can take 5000-10000 ms for an SCR to be produced in response to a stimulus, the inter-trial interval was extended by 4000 ms in the current Experiment compared to Experiment 2. Lee, Lee, and Tsai (2007) examined item-method directed forgetting in a study that manipulated the amount of time available for encoding following the presentation of the *Remember* and *Forget* memory instructions (1000 ms versus 5000 ms). They observed a significant directed forgetting effect for both recall and recognition. However, they also found that increasing the post-cue encoding time from 1000 ms to 5000 ms (which is similar to the time difference for the inter-trial intervals in Experiment 2 and the current Experiment) resulted in a significant increase in the number of *Forget*-cued items recognized (*M*=.51 for 1000 ms versus *M*=.71 for 5000 ms). Critically, increasing the post-cue encoding time did not effect the number of *Remember*-cued items recognized (*M*=.83 for 1000 ms versus *M*=.86 for 5000 ms; Lee et al., 2007).

Instead, participants processed the *Forget*-cued items to a greater extent when the post-cue encoding time was increased. In a second experiment, Lee et al. (2007) incorporated a Remember/Know judgment into the test phase and found that the increased number of *Forget*-cued items recognized was a result of conscious recollection and not just familiarity. Therefore, the findings of Lee et al. (2007) seem to suggest that when participants are given additional post-cue encoding time, *Forget*-cued items are more likely to be given additional processing and rehearsal, and as a result, these items are less vulnerable to intentional forgetting over time. Indeed, there was a near-significant trend for *Forget*-cued *Happy* facial expressions to be better recognized in Experiment 3 (*M*=.408; *SD*=.225) compared to Experiment 2, (*M*=.286; *SD*=.209; *t*(67)=1.860, *p*=.067). This trend was similar for *Forget*-cued *Angry* facial expressions, ($M_{Experiment2}$=.29, $SD_{Experiment2}$=.18; $M_{Experiment3}$=.381, $SD_{Experiment3}$=.144; *t*(67)=1.70, *p*=.094), but not for *Forget*-cued Neutral facial expressions, ($M_{Experiment2}$=.32, $SD_{Experiment2}$=.17; $M_{Experiment3}$=.338, $SD_{Experiment3}$=.193; *t*(67)=.335, *p*=.739). Therefore, perhaps in the context of the present study, the *Happy* facial expressions benefited more from the increased post-cue encoding time than the *Angry* and *Neutral* stimuli, although it is not entirely clear why this would be the case.

One possibility is that poor source information for emotional stimuli (compared to neutral stimuli) plus an extended post-cue encoding time functioned to produce a non-significant directed forgetting effect for both *Angry* and *Happy* facial expressions. Because emotional facial expressions tend to capture attention to a greater extent than *Neutral* facial expressions (Bradley, Mogg, Millar, Boham-Carter, Fergusson, Jenkins, & Parr, 1997; Hansen & Hansen, 1988; Vuilleumier & Schwartz, 2001; White, 1995), this capture of attention may interfere with the memory instruction that is presented at a very short time interval following the facial expression (1000 ms after the offset of the facial expression). More specifically, participant's attention may be so focused on the emotional facial expression that they miss or fail to attend to the memory instruction. As a result, this causes poor source information (the inability to distinguish between a *Remember*-cued and a *Forget*-cued facial expression) for emotional facial expressions compared to *Neutral* facial expressions. Faulty source tagging may have conspired with increased post-cue encoding to produce greater processing of the emotionally valenced faces compared to the *Neutral* faces.

To further explore the impact of timing on the ability to intentionally forget *Happy* facial expressions, Experiment 4 reverted to the 2000 ms inter-trial interval used in Experiment 2, with the expectation that there would again be a directed forgetting effect for *Happy* faces. In addition, Experiment 4 sought to extend the findings of the previous three Experiments by investigating whether or not the stimulus presentation duration (e.g., the duration of the presentation of the face stimuli in the study phase) would modulate the magnitude of the directed forgetting effect as a function of the type of facial expression (*Angry, Neutral, Happy*).

CHAPTER 5 EXPERIMENT 4

The overall magnitude of the directed forgetting effect was very small in the previous three Experiments (e.g., .059 in Experiment 1 for *Neutral* facial expressions to .10 in Experiment 3 for *Neutral* facial expressions) and thus, there was likely little room for emotional facial expressions (e.g., *Angry* and *Happy* facial expressions) to modulate the magnitude of the directed forgetting effect (as evident by the non-significant two-way interaction of memory instruction and type of facial expression in Experiments 2 and 3). Perhaps if the face stimuli in the study phase of the item-method paradigm were exposed for a shorter duration of time, the amount of time available for encoding will be decreased (cf. Bornstein, 1989) and function to magnify (or increase) any differences in the magnitude of the directed forgetting effect as a function of the type of facial expressions (*Angry, Neutral, Happy*). The main purpose of Experiment 4 was to examine this possibility.

Experiment 4 used faces that displayed *Angry*, *Neutral*, and *Happy* facial expressions and, similar to the previous three Experiments, these faces were obtained from the AR Face Database (Martinez & Benavente, 1998). Each face was presented one at a time and following the disappearance of each face, participants received a tone that instructed them to *Remember* or *Forget* the preceding face. The timing of the study phase trials were identical to Experiment 2 with the exception that the face stimuli were only presented for 500 ms, rather than 1000 ms. This also had the effect of reducing the total time between subsequent face presentations (see Lee et al., 2007). Following the presentation of all study trials, participants performed a yes-no recognition task.

Performance in this task was used to assess the magnitude of the directed forgetting effect as a function of the type of facial expression (*Angry, Neutral,* and *Happy*).

Method

Participants

Participants were 24 undergraduate students who volunteered in exchange for credit towards their grade in an eligible Psychology class at Dalhousie University. The experiment was run in one session lasting less than one hour. All participants reported normal or corrected-to- normal vision and a good understanding of the English language.

Stimuli and Apparatus

The stimuli and apparatus were identical to Experiment 2.

Procedure

The general procedure was identical to Experiment 2, except that the face stimulus was presented for 500 ms on each study trial, rather than 1000 ms (see Figure 8). The total duration of all events in each study trial was 4600 ms, from the beginning of the fixation to the end of the inter-trial interval, rather than 5100 ms (as in Experiment 2).

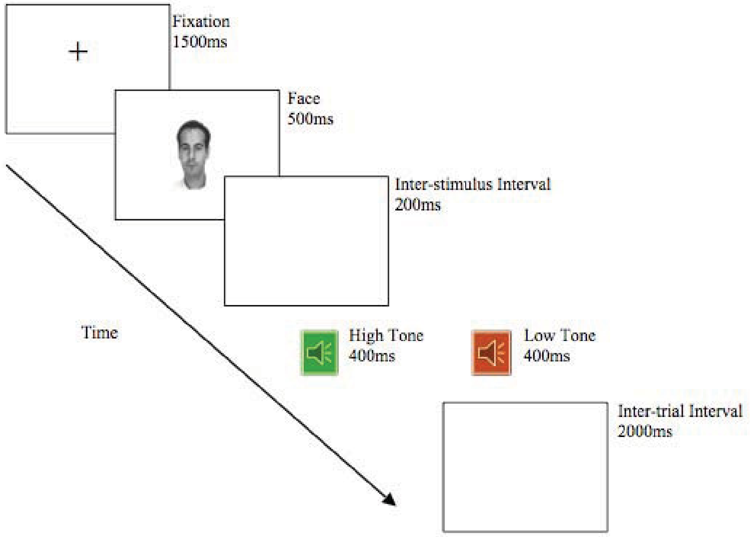

Figure 8 Experiment 4: Schematic of a single study phase trial. Stimulus duration is shown below each trial event.

Results

Mean uncorrected 'y' responses as a function of word type (*Remember*, *Forget, foil*) and type of facial expression (*Angry, Neutral, Happy*) are shown in Table 3. The proportion of false alarms to unstudied *foils* on the recognition test were analyzed in a one-way ANOVA, with facial expression (*Angry, Neutral, Happy*) as a within-subjects factor. This analysis revealed a significant difference in the false alarm rate as a function of type of facial expression, *F*(2, 46)=4.307, *MSe*=.011, *p*=.019 (η=.158). Planned contrasts revealed that significantly more 'y' responses were made to unstudied *Angry foils* (*M*=.287, *SD*=.139) than unstudied *Neutral foils* (*M*=.206, *SD*=.152; *t*(23)=3.616, *p*=.001), and marginally more 'y' responses were made to unstudied *Happy foils* (*M*=.277, *SD*=.160) than unstudied *Neutral foils*, *t*(23)=1.972, *p*=.061; however, there was no significant difference for the number of 'y' responses made to unstudied *Angry foils* and unstudied *Happy foils, t*(23)=.312, *p*=.758.

As described in Experiment 1, hit rates were corrected for their respective false alarm rates within each type of facial expression on a subject-by-subject basis (see Baddeley, 2004). The corrected hit rates were analyzed in a 3 x 2 repeated measures ANOVA with memory instruction (*Remember*, *Forget*) and type of facial expression (*Angry, Neutral, Happy*) as within-subjects factors. As shown in Figure 9, this analysis revealed a significant main effect of memory instruction, *F*(1,23)=14.092, *MSe*=.037, *p*=.001 (η=.380), which confirms a directed forgetting effect with overall greater recognition for *Remember* items (*M*=.330, *SE*=.035) than *Forget* items (*M*=.209, *SE*=.037). In contrast, there was not a significant main effect of type of facial expression, *F*(2, 46)=1.524, *MSe*=.029, *p*=.229 (η=.062). Also, the two-way interaction of memory instruction and type of facial expression was not significant, *F*(2, 46)=.051, *MSe*=.023, *p*=.950 (η=.002), indicating that the magnitude of the directed forgetting effect was not significantly different across the three types of facial expression (*Angry, Neutral, Happy*). Nevertheless, planned contrasts were conducted to examine the directed forgetting effect for each type of facial expression (*Angry, Neutral, Happy*). These planned contrasts revealed a significant directed forgetting effect for *Happy* facial expressions, (*Remember*: *M*=.334, *SD*=.233; *Forget*: *M*=.224, *SD*=.229; *t*(23)= 3.23, *p*=.004), *Neutral* facial expressions, (*Remember*: *M*=.356, *SD*=.235; *Forget*: *M*=.232, *SD*=.230; *t*(23)= 2.241, *p*=.035), and also for *Angry* facial expressions, (*Remember*: *M*=.299, *SD*=.192; *Forget*: *M*=.171, *SD*=.197; *t*(23)= 2.469 *p*=.021.

Table 3 Experiment 4: Means (and standard deviations) for uncorrected hit rates as a function of word type (*Remember, Forget, foil*) and type of facial expression (*Angry, Neutral, Happy*).

	Remember	Forget	Foil
Angry	.586 (.212)	.458 (.239)	.287 (.164)
Neutral	.562 (.235)	.438 (.246)	.206 (.155)
Happy	.611 (.175)	.501 (.178)	.277 (.157)

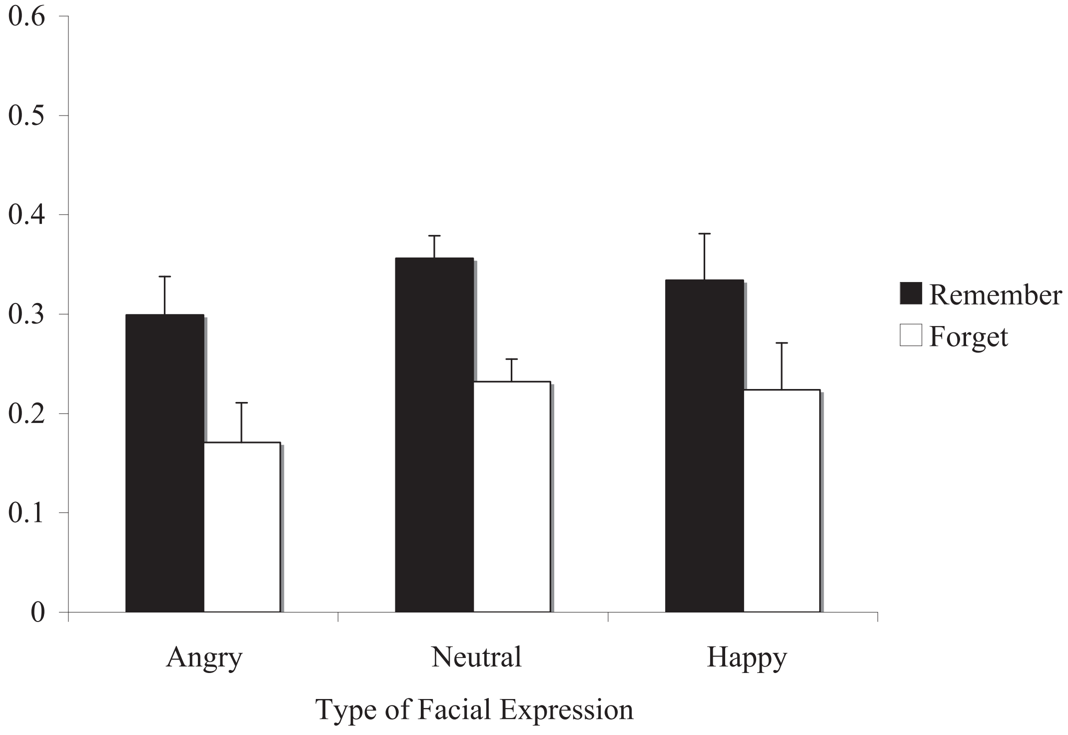

Figure 9 Experiment 4: The corrected hit rates on the recognition test as a function of memory instruction (*Remember, Forget)* and type of facial expression (*Angry, Neutral, Happy*); error bars represent one standard error.

Discussion

The goal of Experiment 4 was to extend the findings of the previous three Experiments by investigating whether or not the stimulus presentation duration (e.g., the duration of the presentation of the face stimuli in the study phase) would modulate the magnitude of the directed forgetting effect as a function of the type of facial expression (*Angry, Neutral, Happy*). Experiment 4 examined this research question by replicating Experiment 2 with the exception that the stimulus presentation duration was reduced from 1000 ms to 500 ms, with a corresponding reduction in the ITI.

There was a significant directed forgetting effect for all three types of facial expression (*Angry, Neutral, Happy*) —for which the magnitude did not differ as indicated by the non-significant two-way interaction of memory instruction and type of facial expression. Although the significant directed forgetting effect for *Neutral* facial expressions has remained consistent across all three Experiments, the findings of the current experiment are in contrast to both Experiment 2, which found no significant directed forgetting effect for *Angry* facial expressions as well as Experiment 3, which found no significant directed forgetting effect for *Angry* or *Happy* facial expressions.

The finding of a significant directed forgetting effect for *Happy* facial expressions in the current Experiment suggests that the extended inter-trial interval in Experiment 3 may have influenced the ability to intentionally forget *Happy* facial expressions relative to the shorter intervals used in Experiments 2 and 4. Similar to Lee et al. (2007) who found that when post-cue encoding time was increased, there was greater memory for *Forget*-cued items, when the inter-trial interval was increased from Experiment 2 to Experiment 3, there was a significant increase in the number of *Forget*-cued *Happy* facial expressions recognized. Moreover, when recognition performance for *Forget*-cued *Happy* facial expressions was compared between Experiment 2 (*M*=.286, *SD*=.209) and the current Experiment (*M*=.224, *SD*=.229) where the inter-trial intervals were both 2000 ms, there was no significant difference, *t*(78)=1.18, *p*=.241. In contrast, there was significantly lower recognition of *Forget*-cued *Happy* facial expressions in the current Experiment compared to Experiment 3 (*M*=.408, *SD*=.225; *t*(35)=2.339, *p*=.025). Together, these findings suggest that the extended inter-trial interval in Experiment 3 increased the recognition of *Forget*-cued *Happy* facial expressions and hindered the ability to intentionally forget.

In contrast to Experiments 2 and 3, the current Experiment found a significant directed forgetting effect for *Angry* facial expressions. Significantly greater recognition of *Forget*-cued *Angry* facial expressions in Experiment 2 (*M*=.29, *SD*=.18) compared to the current Experiment (*M*=.171, *SD*=.197; *t*(78)=2.623, *p*=.01) suggests that when the stimulus presentation duration decreases, the recognition of *Forget*-cued *Angry* facial expressions also decreases. Interestingly, there was no significant difference in recognition of *Remember*-cued *Angry* facial expressions in Experiment 2 (*M*=.326, *SD*=.213) compared to the current Experiment (*M*=.299, *SD*=.192; *t*(78)=.520, *p*=.604). Because stimulus presentation duration and the inter-face interval or trial duration were the only differences between Experiment 2 and the current Experiment, and this difference only affected the encoding of *Forget*-cued items, these findings suggest that when participants are pressured by a decrease in encoding time, they give priority processing to *Remember*-cued items. Perhaps a decrease in the stimulus presentation duration places an increased demand on already limited cognitive resources. This notion is supported by the findings of Bornstein (1989) who found that the incidental recognition of stimuli (e.g., polygons, photographs of faces) presented for 500 ms was significantly greater than the incidental recognition of stimuli presented for 5 ms. Although Bornstein's (1989) study was examining the effect of stimulus presentation duration and recognition in the mere exposure paradigm, it demonstrates an important finding for many types of cognitive research, including the item-method directed forgetting paradigm: As stimulus presentation duration increases, subsequent recognition of that stimulus also tends to increase. Applying this to Experiment 4, when stimulus presentation duration was decreased, subsequent *Forget*-cued recognition also decreased (at least for emotional facial expressions).

To date, there have not been many studies that have examined the impact of stimulus presentation duration on the ability to intentionally forget in the item-method paradigm. Although levels of significance were not reported, one study conducted by Woodward and Bjork (1971) reported that increasing the stimulus presentation duration from 1000 ms to 4000 ms did not have an effect on the directed forgetting effect. These researchers suggested that the increased stimulus presentation duration probably did not have an effect on the directed forgetting effect because participants waited for the memory instruction before they began to process the item (Woodward & Bjork, 1971). Nevertheless, it is important to note that the descriptive data for both the immediate and final recall of *Forget*-cued items increased as the stimulus presentation duration increased. For instance, the final proportion of *Forget*-cued items recalled in the 1000 ms presentation duration condition was .36, whereas the final proportion of *Forget*-cued items recalled in the 4000 ms presentation duration condition was .72. Because the final recall of *Forget*-cued items is almost doubled when stimulus presentation duration increased from 1000 ms to 4000 ms, the findings of Woodward and Bjork (1971) seem to suggest that stimulus presentation duration impacts memory for *Forget*-cued items, which is consistent with the findings from the current Experiment. More specifically, both the current Experiment as well as Woodward and Bjork (1971) found that memory performance for *Forget*-cued items is worse for short stimulus presentation durations compared to long stimulus presentation durations (e.g., 500 ms versus 1000 ms in the current Experiment and 1000 ms versus 4000 ms in Woodward & Bjork, 1971).

It seems as though timing —whether it be the timing of the inter-trial interval or the timing of the stimulus presentation duration— is an important factor in modulating the effect of emotional facial expressions (*Angry, Happy*) on the ability to intentionally forget. Specifically, for emotional facial expressions (both *Angry* and *Happy* facial expressions), when the duration of the inter-trial interval is increased (as in Experiment 3 compared to Experiment 2; see discussion of Experiment 3 for analysis), the recognition of *Forget*-cued items increases; however, when the duration of the stimulus presentation is decreased (as in the current Experiment compared to Experiment 2; see above discussion for analysis), the recognition of *Forget*-cued items decreases. Surprisingly, *Neutral* facial expressions were not affected by the changed in timing across the four experiments.. Regardless of the inter-trial interval (e.g., Experiment 3 compared to Experiment 2), recognition of *Forget*-cued *Neutral* facial expressions was not significantly different, ($M_{Experiment2}$=.32, $SD_{Experiment2}$=.17; $M_{Experiment3}$=.338, $SD_{Experiment3}$=.193; $t(78)$=335, p=.739), and regardless of the stimulus presentation duration (e.g., the current Experiment compared to Experiment 2), the recognition of

Forget-cued *Neutral* facial expressions was only marginally greater in Experiment 2 (*M*=.32, *SD*=.17) compared to the current Experiment, (*M*=.232, *SD*=.23; *t*(78)=1.912, *p*=.06). Since only emotional facial expressions (*Angry, Happy*; and not *Neutral* facial expressions), were affected by this timing manipulation, it suggests that emotion within the context of the item-method directed forgetting paradigm may be particularly sensitive to timing manipulations.

CHAPTER 6 EXPERIMENT 5

In Experiment 3, I did not find any differences in physiological arousal for *Angry* facial expressions; this was contrary to our predictions and may have occurred for two reasons. One reason is that valence and not arousal is the critical factor in eliminating the directed forgetting effect for *Angry* facial expressions (as suggested by the electrophysiological data in Experiment 3). The other possibility is that the different types of facial expression used the previous experiments actually did not differ in arousal. Faces from the AR face database (Martinez & Benavente, 1998) have not been previously rated for valence and arousal (they have only been categorized based on the type of facial expression that they are displaying). If the different types of facial expression from the AR face database (Martinez & Benavente, 1998) do not differ in ratings of arousal, then the findings of Experiment 3 do not aid in disentangling the effect of valence and arousal on the ability to intentionally forget *Angry* facial expressions. The purpose of Experiment 5 was to obtain subjective ratings of both valence and arousal.

Method

Participants

Participants were 7 undergraduate students who volunteered in exchange for credit towards their grade in an eligible Psychology class at Dalhousie University. The experiment was run in one session lasting less than one hour. All participants reported normal or corrected-to- normal vision and a good understanding of the English language.

Stimuli and Apparatus

The hardware used in the current Experiment was identical to Experiment 2. The valence and arousal rating scales used in this experiment were identical to those used to obtain ratings for IAPS photos (see Figure 10; Lang et al., 2005). Both valence and arousal ratings were on a nine-point manikin scale; for valence, one meant extremely negative, whereas nine meant extremely positive; for arousal, one meant extremely relaxed, whereas nine means extremely aroused. During the experiment, the scale was displayed at the top of the computer screen in an invisible rectangular port that measured 28° degrees of visual angle horizontally and 4.5° degrees of visual angle vertically. The faces were displayed in the centre of the computer screen in an invisible square port that measured 8° degrees of visual angle horizontally and 7° degrees of visual angle vertically. Rating responses were displayed at the bottom of the screen in a black six-point outline rectangle, measuring 3° degrees of visual angle horizontally and 2° degrees of visual angle vertically. The faces were the same 120 faces that were drawn from the AR Face database (Martinez & Benavente, 1998), and used in Experiments 2, 3, and 4.

Procedure

Before beginning the experiment, the experimenter provided verbal instructions, which were later reiterated on the computer monitor at the start of the experiment. Participants were instructed that they would be presented a set of nine figures arranged along a continuum (Self-Assessment Manikin; SAM) and that they would be using this set of figures to rate how they felt while viewing a series of faces, one at a time. Half of the participants were asked to rate the faces for valence, and then they were asked to rate the same faces for arousal (in two separate blocks of 120 trials each); this order was reversed for the other half of the participants.

As described in Lang et al. (2005), for the valence scale, participants were told that the scale was an unhappy-happy SAM scale. At one extreme of the unhappy versus happy scale, participants may have felt completely unhappy, annoyed, unsatisfied, melancholic, despaired, and bored. This would correspond to pressing ‘1’ on the computer keyboard. At the other end of the scale, participants may have felt completely happy, pleased, satisfied, content, and hopeful. This would correspond to pressing ‘9’ on the computer keyboard. Participants were told that they could choose intermediate levels of pleasure by inputting numbers corresponding to the middle figures. If participants felt completely neutral —neither happy nor unhappy (as indicated by the figure in the middle), they were told to press ‘5’ on the computer keyboard.

Again, as described in Lang et al. (2005), for the arousal scale, participants were told that the scale was a calm-excited SAM scale. At one extreme of the calm versus excited scale, participants may have felt completely relaxed, calm, sluggish, dull, sleepy, and unaroused. This would correspond to pressing a ‘1’ on the computer keyboard. At the other end of the scale, participants may have felt completely stimulated, excited, frenzied, jittery, wide-awake, and aroused. This would correspond to pressing a ‘9’ on the computer keyboard. Participants were told that they could choose intermediate levels by inputting numbers corresponding to the middle figures. If participants felt not at all excited, nor at all calm (as indicated by the figure in the middle), they were told to press ‘5’ on the computer keyboard.

In both the valence and arousal blocks, faces were drawn randomly without replacement from the *Angry, Neutral* and *Happy* face collections that had been used in Experiments 2-4. On each trial, the valence or arousal scale (depending upon the particular block) was presented at the top of the computer screen and a single face was presented in the centre of the computer screen. Participant’s keyboard response was displayed on-screen in a six-point black outlined rectangle box presented near the bottom of the computer screen. Participants could change their response by pressing the backspace key and submit their response by pressing the space bar. The task was self-paced. Immediately following the completion of the first block (either valence or arousal), participants began the second block (i.e., if the valence block was completed first, then the arousal block, but if the arousal block was completed first, then the valence block). Upon completion of both rating blocks, participants were debriefed.

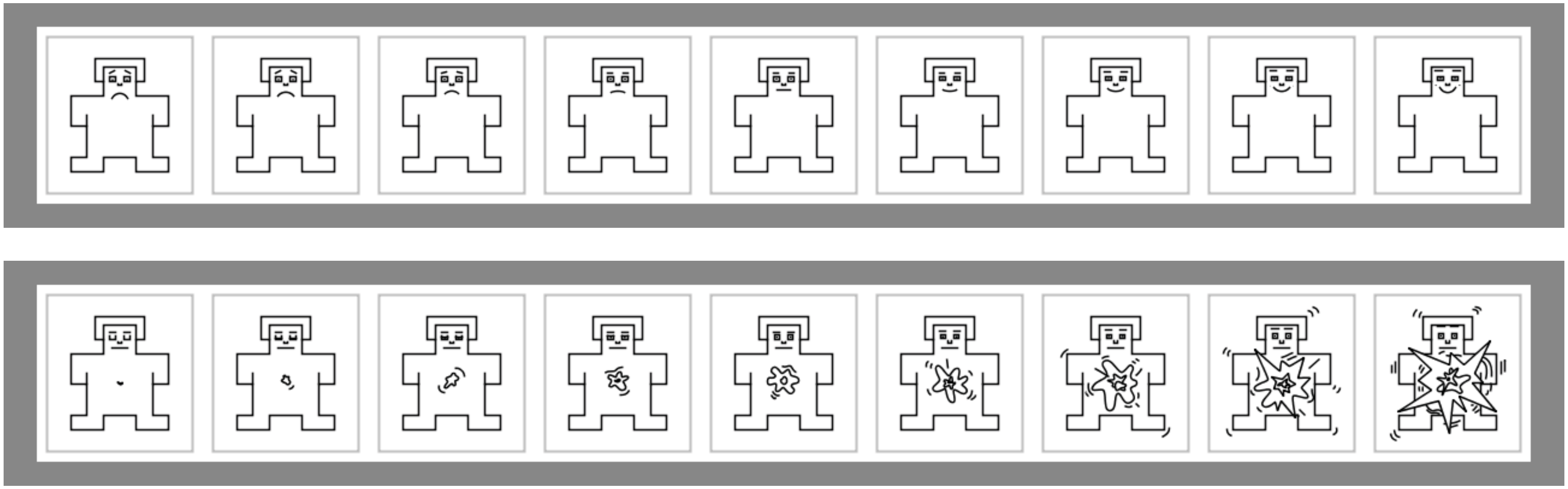

Figure 10 An example of the valence (top) and arousal (bottom) SAM rating scales obtained from the IAPS database (Lang et al., 2005).

Results

Ratings of Valence

The ratings of valence were analyzed in a one-way ANOVA, as a function of type of facial expression (*Angry, Neutral Happy*). As shown in Figure 11, this analysis revealed a significant main effect of type of facial expression, *F*(2, 12)=41.659, *MSe*=.497, *p*<.001, (η=.874). Planned contrasts revealed that *Angry* facial expressions (*M*=3.558; *SD*=.853) were rated as significantly more unpleasant than *Neutral* facial expressions, (*M*=3.937; *SD*=.737; *t*(6)=4.349, *p*=.005) or *Happy* facial expressions, (*M*=6.709; *SD*=.599; *t*(6)=6.611, *p*=.001). *Happy* facial expressions were rated as significantly more pleasant than *Neutral* facial expressions, *t*(6)=6.336, *p*=.001.

Ratings of Arousal

The ratings of arousal were analyzed in a one-way ANOVA, as a function of type of facial expression (*Angry, Neutral Happy*). Again, as shown in Figure 11, this analysis revealed a significant main effect of type of facial expression, *F*(2, 12)=10.883, *MSe*=1.195, *p*=.002, (η=.645). Planned contrasts revealed that *Neutral* facial expressions (*M*=3.053; *SD*=1.55) were rated as significantly lower less arousing/exciting than *Angry* facial expressions, (*M*=3.569; *SD*=1.427; *t*(6)=4.404, *p*=.005) or *Happy* facial expressions, (*M*=5.629; *SD*=.984; *t*(6)=3.439, *p*=.014). *Angry* facial expressions were rated as significantly less arousing/exciting than *Happy* facial expressions, *t*(6)=3.073, *p*=.022.

Figure 11 Experiment 5: The mean ratings of valence and arousal as a function of type of facial expression (*Angry, Neutral, Happy)*; error bars represent one standard error.

Discussion

The goal of Experiment 5 was to examine whether or not the types of facial expression used in the previous four Experiments actually differed in ratings of valence and arousal. This is important because the faces from the AR face database (Martinez & Benavente, 1998) have not been previously rated for valence and arousal, and Experiments 1-4 presumed that their valence and arousal would correspond with their categorization; they have only been categorized based on the type of facial expression that they are meant to be displaying. As such, Experiment 5 sought to determine the subjective ratings of valence and arousal for the three types of facial expression (*Angry, Neutral, Happy*) used in the previous four experiments. The ratings of valence were significantly lower for *Angry* facial expressions than for *Neutral* or *Happy* facial expressions, and significantly greater for *Happy* facial expressions than *Neutral* facial expressions. This indicates that *Angry* facial expressions were more unpleasant than *Neutral* and *Happy* facial expressions and that *Happy* facial expressions were more pleasant than *Neutral* facial expressions. Furthermore, the ratings of arousal were significantly greater for *Happy* facial expressions compared to *Neutral* or *Angry* facial expressions, and greater for *Angry* facial expressions than *Neutral* facial expressions. This indicates that *Happy* facial expressions were more arousing/exciting than *Angry* and *Neutral* facial expressions and that *Angry* facial expressions were more arousing/exciting than *Neutral* facial expressions.

These findings suggest that valence and not arousal is a key factor in limiting the ability to intentionally forget *Angry* facial expressions. If arousal were the key factor in limiting the ability to intentionally forget *Angry* facial expressions, ratings of arousal should have been significantly greater for *Angry* facial expressions compared to *Neutral* and *Happy* facial expressions. Moreover, Experiment 3 should have found that the change in SCR amplitude was significantly greater for *Angry* facial expressions compared to *Neutral* and *Happy* facial expressions. However, neither of these findings occurred. It is interesting to note that in contrast to the SCR findings, there were differences in arousal for the subjective ratings. Both *Angry* facial expressions as well as *Happy* facial expressions were rated as significantly more arousing than *Neutral* facial expressions. This may suggest the possibility of a potential link between arousal and the directed forgetting effect, but perhaps this link did not emerge in the SCR findings because the intensity of these emotional facial expressions was not great enough to produce differences in physiological arousal. In particular, the ratings of valence and arousal for *Angry* facial expressions and *Neutral* facial expressions were very similar. Future research should examine the effect of more intense or extreme emotional facial expressions on the directed forgetting effect.

The findings of Experiment 3 and the current Experiment highlight the importance of valence in hindering the ability to intentionally forget and are inconsistent with past literature, which has suggested that arousal plays a key role in enhancing memory for emotional stimuli (e.g., Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004). As was the case for Experiment 3, the findings of the current Experiment are also inconsistent with the modulation model (see Hamann, 2001; McGaugh, 2004 for reviews), which proposes that memory for negative stimuli is better than memory for neutral stimuli because the increased activity in the basolateral nucleus of the amygdala is produced by the *arousal* of emotional stimuli.

CHAPTER 7 GENERAL DISCUSSION

7.1 OVERVIEW OF EXPERIMENTS AND FINDINGS

Five experiments were presented, four of which used different types of facial expression (*Angry, Neutral, Happy)* in the item-method directed forgetting paradigm and one of which obtained ratings of valence and arousal for the different types of facial expression that were used in the previous four experiments. The goal of these five experiments was to investigate the ability to intentionally forget highly memorable, visually complex, and socially relevant facial expressions. As a review, Experiment 1 explored intentional forgetting of *Neutral* facial expressions. Experiments 2, 3, and 4 investigated the relationship between different types of facial expression (*Angry, Neutral, Happy*) and the ability to intentionally forget. Experiment 3 included a measure of galvanic SCR to investigate the role of the valence and arousal on the ability to intentionally forget, whereas Experiment 4 reduced the stimulus presentation duration to explore whether doing so would change or affect the magnitude of the directed forgetting effect as a function of the type of facial expression. Finally, Experiment 5 served as manipulation check to determine whether or not the three types of facial expression differed in subjective ratings of valence and/or arousal.

Across all four Experiments that used the item-method directed forgetting paradigm, there was a significant directed forgetting effect for *Neutral* facial expressions. There was also a significant directed forgetting effect for *Happy* facial expressions in all of the Experiments except Experiment 3. Only one experiment revealed a significant directed forgetting effect for *Angry* facial expressions, Experiment 4. See Table 4 for an overview of the behavioural findings of Experiments 1 to 4. Experiment 5 indicated that both ratings of valence as well as ratings of arousal were significantly different for the types of facial expression (*Angry, Neutral, Happy*). *Angry* facial expressions were rated as more negative/unpleasant than *Neutral* or *Happy* facial expressions and *Happy* facial expressions were rated as more positive/pleasant than *Neutral* facial expressions. *Happy* facial expressions were rated as more arousing/exciting than *Neutral* and *Angry* facial expressions, and *Angry* facial expressions were also rated as more arousing/exciting than *Neutral* facial expressions. These findings have several important implications regarding the ability to intentionally forget different types of facial expression.

Table 4 Means (and standard deviations) for uncorrected hit rates (*Remember, Forget, foil)*, corrected hit rates (*Remember, Forget*), and magnitude of the directed forgetting effect as a function of Experiment (*Experiment 1, Experiment 2, Experiment 3, Experiment 3)* and type of facial expression (*Angry, Neutral, Happy*).

		Uncorrected R	Uncorrected F	Foil	Corrected R	Corrected F	Magnitude DF
Experiment 1	Neutral	.530 (.214)	.471 (.194)	.205 (.145)	.325 (.181)	.266 (.139)	.059* (.141)
Experiment 2	Angry	.580 (.215)	.544 (.200)	.254 (.164)	.326 (.213)	.290 (.180)	.036 (.181)
	Neutral	.602 (.203)	.518 (.191)	.198 (.155)	.404 (.226)	.320 (.170)	.084* (.181)
	Happy	.610 (.200)	.530 (.193)	.244 (.169)	.366 (.210)	.286 (.17)	.08* (.181)
Experiment 3	Angry	.631 (.197)	.554 (.226)	.173 (.159)	.458 (.223)	.381 (.144)	.077 (.231)
	Neutral	.608 (.15)	.508 (.166)	.169 (.142)	.438 (.197)	.338 (.193)	.100* (.141)
	Happy	.623 (.164)	.615 (.157)	.208 (.160)	.415 (.266)	.408 (.225)	.007 (.144)
Experiment 4	Angry	.586 (.212)	.458 (.239)	.287 (.164)	.299 (.192)	.171 (.197)	.128* (.254)
	Neutral	.562 (.235)	.438 (.246)	.206 (.155)	.356 (.235)	.232 (.23)	.124* (.272)
	Happy	.611 (.175)	.501 (.178)	.277 (.157)	.334 (.233)	.224 (.229)	.110* (.166)

*p <.05

7.2 DIRECTED FORGETTING AND NEUTRAL FACIAL EXPRESSIONS

Despite evidence suggesting that we have a specialized system that is used for the processing, encoding, and recognition of faces (e.g., Allison et al., 1994; Bentin et al., 1996; Camel & Bentin, 2002; Eimer, 2000; Holmes, et al. 2003; Sommer et al., 1991), this system did not override instructions to *Forget*. Across all four Experiments, there was consistently a significant directed forgetting effect for faces with *Neutral* expressions. This was somewhat surprising, given that manipulations designed to enhance encoding tend to eliminate (e.g., Earles & Kersten, 2002; Hourihan & MacLeod, 2008; MacLeod & Daniels, 2000; Sahakyan & Foster, 2009) or reduced the magnitude of the directed forgetting effect (e.g., Hauswald & Kissler, 2008; Quinlan et al., 2010). Although the findings of the current thesis are inconsistent with Reber et al. (2002) who found no significant directed forgetting effect for neutral faces, Reber et al. (2002) did conclude that their foil false alarm rate might have been too high to detect a directed forgetting effect and/or that poor image quality of their face stimuli may have affected memory. Because the present experiments consistently demonstrated a directed forgetting effect for *Neutral* facial expressions, it suggests that the methodology (e.g., poor image quality of the faces) used by Reber et al. (2002) may have affected the outcome of their study (i.e., high foil false alarm rate, no significant directed forgetting effect). The data from the current thesis provides evidence that a directed forgetting appears to be robust for *Neutral* facial expressions (see also Paller, Bozic, Ranganath, Grabowecky, & Yamada, 1999). As noted in the discussion of Experiment 1 (Chapter 2), the magnitude of the directed forgetting effect for faces was significantly smaller than the directed forgetting effect for words and marginally smaller than the directed forgetting effect for line drawings (Quinlan et al., 2010). So, although the directed forgetting effect for *Neutral* facial expressions was significant, it was quite small across the four Experiments. It ranged from a low of .059 in Experiment 1 to a high of .124 in Experiment 4.

Even though the directed forgetting effect was relatively small, it did differ across experiments. In contrast to Experiment 1, Experiments 2-4 used a mixed-blocks within-subjects presentation of neutral and emotional stimuli, which likely impacted the processing of neutral items. Hadley and MacKay (2006) have suggested that the binding of emotional stimuli to contextual cues gives emotional stimuli priority processing over neutral stimuli. This priority processing of emotional stimuli is thought to impair the contextual binding of neutral stimuli, which results in memory differences for emotional versus neutral stimuli. This suggests that when *Neutral* facial expressions were presented in a mixed-blocks within-subjects design the emotional stimuli may have been given priority processing over *Neutral* stimuli. This tendency to prioritize processing of emotional facial expressions would make *Neutral* facial expressions relatively easier to intentionally forget in a mixed-blocks presentation.

In terms of the passive and active views of the item-method directed forgetting effect, these findings do not necessarily provide direct support for either account. To explicitly investigate the mechanisms following *Remember* and *Forget* memory instructions, these experiments would have had to include some type of dependent measure following the memory instructions on each trial (e.g., an attention probe; see Fawcett & Taylor, 2008). These experiments included no such measure. Nevertheless, because faces are processed, encoded, and recognized by a specialized system, and this system did not override the ability to intentionally forget (e.g., eliminate the directed forgetting effect), it suggests that upon the instantiation of a *Forget* memory instruction, participants engage in some type of active and effortful process that functions to eliminate *Forget*-cued faces from working memory (Fawcett & Taylor, 2008; Zacks et al., 1996). If participants simply and effortlessly allowed *Forget*-cued faces to decay from working memory, then this specialized face system should have overridden the ability to intentionally forget. The significant directed forgetting effect for *Neutral* facial expressions across Experiments 1-4 suggests that the mechanisms used to intentionally forget are extremely efficient and we are able to control the selective encoding of even elaborately processed and encoded faces.

7.3 DIRECTED FORGETTING AND EMOTIONAL FACIAL EXPRESSIONS

Consistent with research on memory and emotion, which has demonstrated enhanced memory for negative stimuli (e.g., Adolphs et al., 1999; Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004; Tranel et al., 2006), in the current study, *Angry* facial expressions limited the ability to intentionally forget (Experiment 2 and Experiment 3). This limited ability to intentionally forget *Angry* facial expressions appears to be due to the negative valence of these stimuli, rather than any increased arousal that they are presumed to evoke (e.g., Anderson, 2005; Cahill & McGaugh, 1995; Hamann & Mao, 2002; Kensinger, 2004; see also Hamann, 2001; McGaugh, 2004 for reviews). The change in SCR amplitude measured in Experiment 3 was not significantly greater for *Angry* facial expressions than for *Neutral* or *Happy* facial expressions, despite the fact that Experiment 5 confirmed that *Angry* facial expressions are rated as being significantly more negative or unpleasant than *Neutral* and *Happy* facial expressions. These findings converge with those of Quinlan and Taylor (under revision) who were able to control for the arousal of words, only manipulating valence. Quinlan and Taylor (under revision) found no significant directed forgetting effect for negative words and likewise suggested that valence (as opposed to arousal) is the key factor in reducing the directed forgetting effect for negative stimuli.

Nevertheless, the current study was not without caveats, two of which are particularly important. First, when the stimulus presentation duration was decreased from 1000 ms to 500 ms (as in Experiment 4), there was a directed forgetting effect for *Angry* facial expressions, which suggests that when participants are pressured by a decrease in encoding time, it places an increased demand on already limited cognitive resources and participants give priority processing to *Remember*-cued items. Second, when the inter-trial interval was increased from 2000 ms to 6000 ms (as in Experiment 3), there was no significant directed forgetting effect for *Happy* facial expressions, which suggests that when there is an increase in encoding time, more *Forget*-cued *Happy* facial expressions are encoded.

The effects of timing on the directed forgetting effect for emotional stimuli, but not neutral stimuli, are surprising but perhaps can be explained by the processing-speed theory (Salthouse, 1996). Originally, this theory was proposed to explain age-related differences in cognitive processing and how differences in processing speed can lead to impairments in cognitive processing abilities. This theory is composed of two core components: the limited time principle and the simultaneity principle. Essentially, the limited time principle is that greater processing produces better performance. If processing operations occur relatively quickly, there is time for more information to be processed, whereas if processing operations occur relatively slowly, there is limited time for information to be processed. Therefore, if processing is slow, there may not be enough time for all necessary processing operations to occur. The simultaneity principle posits that if processing is slow, earlier processing operations may be lost by the time they are needed for later processing operations, which may result in impairments for these later processing operations, such as abstraction and elaboration.

The limited time and simultaneity principles can be applied to the current series of experiments to help explain the findings of Experiment 3. Emotional stimuli have been shown to engage early processing mechanisms. For instance, compared to neutral stimuli, ERP studies have found that emotional stimuli (both negative and positive) evoke a larger P1 component, which is indicative of early processing and in particular, early attention in the extrastriate visual cortex (Smith, Cacioppo, Larsen, & Chartrand, 2003). Also, emotional facial expressions (both angry and happy) tend to capture attention more quickly than *Neutral* facial expressions (Bradley et al., 1997; Hansen & Hansen, 1988; Vuilleumier & Schwartz, 2001; White, 1995). Because emotional stimuli are processed more rapidly than neutral stimuli, the limited time principle would suggest that there is more time for the information in emotional stimuli to be processed compared to information in neutral stimuli, whereas the simultaneity principle would propose that later processing operations like abstraction and elaboration are more likely to occur for emotional stimuli compared to neutral stimuli. Because emotional stimuli are given early, fast, and efficient processing over neutral stimuli (e.g., Smith et al., 2003), not only does the extended inter-trial interval in Experiment 3 potentially allow for more information to be processed for emotional stimuli than neutral stimuli, the additional time also allows for more later processing (e.g., abstraction, elaboration) to occur. This would function to increase memory for emotional stimuli and thus, eliminate the directed forgetting effect for both *Angry* as well as *Happy* facial expressions.

The processing-speed theory can also be applied to the findings of Experiment 4. The reduced stimulus presentation duration limited the time available for processing, and as a result, it limited the amount of information in the stimulus that could be processed as well as the extent of subsequent downstream processing (e.g., abstraction, elaboration). This functioned to reduce memory performance and increase the magnitude of the directed forgetting or in the case of *Angry* facial expressions, make the directed forgetting effect significant.

Despite the potential utility of a processing-speed theory for interpreting the directed forgetting effects, there is still a puzzling result that needs to be explained. When there was no significant directed forgetting effect, there was not necessarily overall enhanced memory for emotional facial expressions (as evident by the non-significant main effect of type of facial expression in the recognition data from Experiments 2- 4).[2] The non-significant directed forgetting effect for *Angry* and *Happy* facial expressions in Experiment 3 was driven by an increase in the proportion of *Forget*-cued items. As such, it seem as though emotion influences the directed forgetting effect via the processes or mechanisms used to intentionally forget, rather than those used to intentionally remember. One explanation for this is that because emotional stimuli (specifically, negative stimuli) are processed earlier, faster, and more efficiently than neutral stimuli,

---

[2] Although there was no directed forgetting effect for *Angry* facial expressions in Experiment 2, this finding will not be included in the following discussion because as indicated by the findings of Experiment 3, the reduced ability to remember *Remember*-cued items in Experiment 2 was likely an anomaly (as it did not occur in Experiments 3 or 4).

encoding may occur more *automatically* and as a consequence, it is difficult for participants to selectively encode *Remember* and *Forget* items (e.g., poor source information; see discussion of Experiment 3). In other words, for emotional stimuli, perhaps a substantial degree of processing has occurred prior to the memory instruction making it difficult to effectively forget *Forget*-cued items, In contrast, neutral stimuli are not encoded as early, fast, and efficiently as emotional stimuli and thus, participants may be able to better *selectively* encode *Remember* and *Forget* items. If so, this highlights the role of selective encoding on the ability to intentionally forget as well as the importance of cognitive control on the ability to intentionally forget. Both are key in producing the directed forgetting effect in the item-method paradigm.

Although faces generally are more difficult to rehearse than other stimuli, such as words and pictures, perhaps emotional facial expressions are particularly difficult to rehearse. There may be more variation among *Neutral* facial expressions compared to emotional facial expressions. For instance, the range in differences between the mouths of *Neutral* facial expressions is greater than the range in differences between the mouths of *Angry* facial expressions (e.g., a scowling mouth). Thus, *Remember*-cued *Angry* expressions may benefit less from rehearsal than *Remember*-cued *Neutral* facial expressions. This, in combination with poor source information for emotional facial expressions compared to *Neutral* facial expressions likely functioned to reduce the directed forgetting effect for *Angry* facial expressions. Moreover, the reduced ability to rehearse *Remember*-cued *Angry* facial expressions can account for why the non-significant directed forgetting effect for *Angry* facial expressions in Experiment 2 was driven by reduced memory for *Remember*-cued items rather than increased memory for *Forget*-cued items.

7.4 FUTURE DIRECTIONS

Because the current series of Experiments found that *Angry* facial expressions impact the ability to intentionally forget, further research should investigate whether or not other types of negative valenced facial expressions have a similar impact on the ability to intentionally forget. For instance, do fearful and sad facial expressions also eliminate the directed forgetting effect? Although the current series of Experiments found no evidence for the role of arousal in limiting the ability to intentionally forget, it is important that future research incorporate other electrophysiological techniques (besides galvanic SCR) to measure arousal. Galvanic SCR is one of the best measures of arousal in the autonomic nervous system; however, it can be a variable and sometimes unreliable measure or at least more so than brain-imaging techniques. And, since brain-imaging studies have shown that arousal is linked to activation in the amygdala (e.g., Morris et al., 1996; Whalen et al., 1998), which in turn influences memory via its interactions with other brain structures such as the hippocampus, it may be worthwhile to explore the relationship between brain activation, emotion, and intentional forgetting by using EEG and/or fMRI techniques. Brain-imaging may be a more reliable measure of arousal than galvanic SCR and thus, it may further elucidate the mechanisms that underlie the ability (or lack of ability) to intentionally forget emotional stimuli.

It appears as though timing plays an important role in modulating the directed forgetting effect for emotional facial expressions. Given that *Neutral* facial expressions remained unaffected by timing manipulations, it follows that timing may modulate the directed forgetting effect for only *emotional* stimuli. Future studies should focus on explicitly examining the role of timing and its effect on the ability to intentionally forget emotional stimuli. For instance, it would be valuable to further explore the effect of post-cue encoding time as well as stimulus presentation duration on the ability to intentionally forget emotional stimuli and in particular, *Angry* and *Happy* facial expressions. Also, do these same timing effects occur when other emotional stimuli, such as words or pictures are used, or are they specific to emotional facial expressions?

The faces used in the current series of experiments were novel unfamiliar faces. Because the functional model for face recognition suggests that unfamiliar and familiar faces are processed and recognized differently (Bruce & Young, 1986), it would be interesting to investigate whether or not the findings from unfamiliar faces extend to familiar faces. If participants are given training with faces, will a directed forgetting effect occur? This thesis found that the mechanisms engaged to intentionally forget were able to override the stored pictorial code of unfamiliar faces; however, would these same mechanisms be able to override the stored identity-specific semantic code of familiar faces?

7.5 CONCLUSION

In conclusion, the two critical findings of the current thesis were a significant directed forgetting effect for *Neutral* facial expressions and no significant directed forgetting effect for *Angry* facial expressions. Together, these two findings suggest that while the mechanisms engaged upon the instantiation of a *Forget* memory instruction can override the processing carried out by highly specialized systems, the efficiency of these mechanisms can be reduced or overwritten by negative emotional valence.

REFERENCES

Adolphs, R., Russell, J.A., & Tranel, D. (1999). A role for the human amygdala in recognizing emotional arousal from unpleasant stimuli. *Psychological Science, 10*, 167-171.

Allison, T., McCarthy, G., Nobre, A., Puce, A., & Belger, A. (1994). Human extrastriate visual cortex and the perception of faces, words, numbers and colours. *Cerebral Cortex, 5*, 544-554.

Anders, S., Lotze, M., Erb, M., Grodd, W., & Birbaumer, N. (2004). Brain activity underlying emotional valence and arousal: A response-related fMRI study. *Human Brain Mapping, 23*, 200-209.

Anderson, A.K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General*, 134, 258-281.

Arntz, A., de Groot, C., & Kindt, M. (2005). Emotional memory is perceptual. *Journal of Behavior Therapy and Experimental Psychiatry, 36*, 19-34.

Backman, L., & Nilsson, L.G. (1985). Prerequisites for lack of age differences in memory performance. *Experimental Aging Research, 11*, 67-73.

Baddeley, A.D. (2004). The psychology of memory. In A.D. Baddeley, M.D. Kopelman, & B.A. Wilson (Eds.), *The Essential Handbook of Memory Disorders for Clinicians* (pp. 1-13). Chichester, UK: Wiley.

Bauer, R.M. (1998). Physiological measures of emotion. *Journal of Clinical Neurophysiology, 15*, 388-396.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans, *Journal of Cognitive Neuroscience, 8*, 551-565.

Bjork, R.A. (1970). Positive forgetting: The noninterference of items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior*, *9*, 255-268.

Bohannon, J.N. (1988). Flashbulb memories for the space shuttle disaster: A tale of two theories. *Cognition, 29*, 179-196.

Bornstein, R.F. (1989). Exposure and affect: Overview and meta-analysis of research, 1968-1987. *Psychological Bulletin*, *106*, 265-289.

Botzel, K., & Grusser, O.J. (1989). Electric brain potentials evoked by pictures of faces and non-faces: A search for ‘‘face-specific’’ EEG-potentials. *Experimental Brain Research, 77,* 349-360.

Bradley, B.P., Mogg, K., Millar, N., Boham-Carter, C., Fergusson, E., Jenkins, J., & Parr, M. (1997). Attentional biases for emotional faces. *Cognition and Emotion, 11*, 25-42.

Bruce, C., Desimone, R., & Gross, C.G. (1981). Visual properties of neurons in a polysensory area in superior temporal sulcus of the macaque. *Journal of Neurophysiology, 46*, 369-384.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*, 305-327.

Cahill, L., & McGaugh, J. L. (1995). A novel demonstration of en- hanced memory associated with emotional arousal. *Consciousness & Cognition, 4*, 410-421.

Cahill, L., & McGaugh, J.L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neuroscience,* 21, 292-299.

Calder, A.J., Lawrence, A.D., & Young, A.W. (2001). Neuropsychology of fear and loathing. *Nature Reviews, 2,* 352-363.

Carey, S. (1992). Becoming a face expert. *Philosophical Transactions Royal Society of London, 335*, 95-103.

Camel, D., & Bentin, S. (2002). Domain specificity versus expertise: factors influencing distinct processing of faces. *Cognition, 83*, 1-29.

Clark, V.P., Keil, K., Maisog, J.M., Courtney, S., Ungerleider, L.G., & Haxby, J.V. (1996). Functional magnetic resonance imaging of human visual cortex during face matching: a comparison with positron emission tomography. *NeuroImage, 4,* 1-15.

Cohen, R.L. (1981). On the generality of some memory laws. *Scandanavian Journal of Psychology, 22,* 267-281.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling psychology experiments. *Behavior, Research Methods, Instruments, and Computers*, 25, 257-271.

Cooper, R.M., & Langton, S.R.H. (2006). Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour Research and Therapy*, 44, 1321-1329.

Craik, F.I., & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior, 11,* 671-678.

Crutcher, R.J., & Healy, A.F. (1989). Cognitive operations and the generation effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 669-675.

de Haan, M., Pascalis, O., & Johnson, M.H. (2002). Specialization of neural mechanisms underlying face recognition in human infants. *Journal of Cognitive Neuroscience*, *14*, 199-209.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General*, *115*, 107-117.

Damasio, A.R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Putnam.

Dobson, E., & Rust, J.O. (1994). Memory for objects and faces by the mentally retarded and nonretarded. *The Journal of Psychology, 128*, 315-322.

Dolcos, F., LaBar, K.S., & Cabeza, R., (2004). Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. *Neuron, 42*, 855-863.

Earles, J.L., & Kersten, A.W. (2002). Directed forgetting of actions by younger and older adults. *Psychonomic Bulletin & Review, 9*, 383-388.

Eastwood, J.D., Smilek, D., & Merikle, P.M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception & Psychophysics, 63*, 1004-1013.

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion, 6*, 169-200.

Eimer, M., (2000). The face-specific N170 component reflects late stages in the structural encoding of faces. *Neuroreport, 11*, 2319-2324.

Edelberg, R. (1993). Electrodermal mechanisms: A critique of the two-effector hypothesis and a proposed replacement. In J. C. Roy, W. Boucsein, D.C. Fowles, & J.H. Gruzelier (Eds.), *Progress in electrodermal research* (pp. 7-30). New York: Plenum.

Farah, M. (2004). *Visual agnosia* (2nd Edition). Cambridge: MIT Press.

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

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

Fischer, H., Sandblom, J., Nyberg, L., Herlitz, A., & Backman, L. (2007). Brain activation while forming memories of fearful and neutral faces in women and men. *Emotion, 7*, 767-773.

Frischen, A., Eastwood, J.D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin, 134*, 662-676.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition & Emotion, 16,* 355-379.

Garavan, H., Pendergrass, J.C., Ross, T.J., Stein, E.A., & Risinger, R.C. (2001). Amygdala response to both positively and negatively valenced stimuli. *NeuroReport, 12,* 2779-2783.

Glascher, J., & Adolphs, R. (2003). Processing of the arousal of subliminal and supraliminal emotional stimuli by the human amygdala. *Journal of Neuroscience, 23*, 10274-10282.

Golding, J.M., & MacLeod, C.M. (1998). *Intentional forgetting: Interdisciplinary approaches*. Mahwah, NJ: Lawrence Erlbaum Associates.

Hadley, C.B., & MacKay, D.G. (2006). Does emotion help or hinder immediate memory? Arousal versus priority-binding mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 79-88.

Halgren, E., Walter, R.D., Cherlow, D.G., & Crandall, P.H. (1978). Mental phenomena evoked by electrical stimulation of the human hippocampal formation and amygdala. *Brain*, *101*, 83-117.

Halgren, E., Dale, A.M., Sereno, M.I., Tootell, R.B.H., Marinkovic, K., & Rosen, B.R. (1999). Location of human face-selective cortex with respect to retinotopic areas. *Human Brain Mapping, 7*, 29-37.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, 5, 394-400.

Hamann, S., & Mao, H. (2002). Positive and negative emotional verbal stimuli elicit activity in the left amygdala. *Neuroreport, 12,* 15-19.

Hansen, C.H., & Hansen, R.D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, *54*, 917-924.

Hauswald, A., & Kissler, J. (2008). Directed forgetting of complex pictures in an item method paradigm. *Memory, 16,* 797-809.

Haxby, J.V., Grady, C.L., Horwitz, B., Ungerleider, L.G., Mishkin, M., Carson, R.E., Herscovitch, P., Schapiro, M.B., & Rapoport, S.I. (1991). Dissociation of object and spatial visual processing pathways in human extrastriate cortex. *Neurobiology, 88*, 1621-1625.

Heuer, F., & Reisberg, D. (1990). Vivid memories of emotional events: The accuracy of remembered minutiae. *Memory & Cognition, 18,* 496-506.

Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research, 16,* 174-184.

Horovitz, S.G., Rossion, B., Skudlarski, P., & Gore, J.C. (2004). Parametric design and correlational analyses help integrating fMRI and electrophysiological data during face processing. *NeuroImage, 22,* 1587-1595.

Hourihan, K.L., & MacLeod, C.M. (2008). Directed forgetting meets the production effect: Distinctive processing is resistant to intentional forgetting. *Canadian Journal of Experimental Psychology*, *62*, 242-246.

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.

Iidaka, T., Matsumoto, A., Haneda, K., Okada, T., & Sadato, N. (2006). Hemodynamic and electrophysiological relationship involved in human face processing: Evidence from a combined fMRI-ERP study. *Brain and Cognition*, *60*, 176-186.

Jacoby, L.L. (1978). On interpreting the effects of repetition: Solving a problem versus remembering a solution. *Journal of Verbal Learning and Verbal Behaviour*, *17*, 649-667.

James, W. (1890) *The Principles of Psychology* (Vol. I). New Work: Holt.

Johnson, M.H., & Morton, J. (1991). *Biology and cognitive development: The case of face recognition*. Oxford, UK: Blackwell.

Johnston, R.A., & Edmonds, A.J. (2009). Familiar and unfamiliar face recognition: A review. *Memory*, *17*, 577-596.

Kanwisher, N., McDermott, J., & Chun, M.M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience, 17*, 4302-4311.

Kapucu, A., Rotello, C.M., Ready, R.E., & Seidl, K.N. (2008). Response bias in "remembering" emotional stimuli: A new perspective on age differences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 703-711.

Kensinger, E.A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences,* 241-253.

Kensinger, E.A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition, 31,* 1169-1180.

Kensinger, E.A., & Corkin, S. (2004). Two routes to emotional memory: Distinct neural processes for valence and arousal. *Proceedings of the National Academy of Sciences, 101*, 3310-3315.

Keyser, C., & Gazzola, V. (2006). Towards a unifying neural theory of social cognition. In S. Anders, G. Ende, M. Junghofer, J. Kissler, & D. Wildgruber (Eds.), *Progress in Brain Research* (pp. 379-401).

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

Korfine, L., & Hooley, J.M. (2000). Directed forgetting of emotional stimuli in borderline personality disorder. *Journal of Abnormal Psychology, 109*, 214-221.

Lang, P.J., Greenwald, M.K., Bradley, M.M., & Hamm, A.O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*, 261-273.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (2005). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual* (pp.1-56). Technical Report A-6. University of Florida, Gainesville, FL.

Lee, Y.S., Lee, H.M., & Tsai, S.H. (2007). Effects of post-cue interval on intentional forgetting. *British Journal of Psychology, 98,* 257-272.

Lehman, E.B., McKinley-Pace, M., Leonard, A.M., Thompson, D., & Johns, K. (2001). Item-cued directed forgetting of related words and pictures in children and adults: Selective rehearsal versus cognitive inhibition. *Journal of General Psychology, 128*, 81-97.

MacLeod, C.M. (1975). Long-term recognition and recall following directed forgetting. *Journal of Experimental Psychology: Human Learning and Memory, 1,* 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,* 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, Inc.

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

MacLeod, C.M., Gopie, N., Hourihan, K.L., Neary, K.R., & Ozubko, J.D. (2010). The production effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36,* 671-685.

Malone, D.R., Morris, H.H., Kay, M.C., & Levin, H.S. (1982) Prosopagnosia: a double dissociation between the recognition of familiar and unfamiliar faces. Journal of Neurology, Neurosurgery, and Psychiatry, 45, 820–822.

Martinez, A.M., & Benavente, R. (1998). The AR Face Database: CVC Technical Report 24.

Maurer, D., Le Grand, R., & Mondloch, C.J. (2002). The many facees of configural processing. *Trends in Cognitive Sciences, 6,* 255-260.

McCarthy, G., Puce, A., Gore, J.C., & Allison, T. (1997). Face-specific processing in the human fusiform gyrus. *Journal of Cognitive Neuroscience, 9,* 605-610.

McGaugh, J.L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annual Review of Neuroscience*, 27, 1-28.

McGaugh, J.L., & Roozendaal, B. (2002). Role of adrenal stress hormones in forming lasting memories in the brain. *Current Opinion in Neurobiology*, 12, 205-210.

McNally, R.J., Metzger, L.J., Lasko, N.B., Clancy, S.A., & Pitman, R.K. (1998). Directed forgetting of trauma cues in adult survivors of childhood sexual abuse with and without posttraumatic stress disorder. *Journal of Abnormal Psychology, 107*, 596-601.

McNally, R.J., Otto, M.W., Yap, L., Pollack, M.H., & Hornig, C.D. (1999). Is panic disorder linked to cognitive avoidance of threatening information? *Journal of Anxiety Disorders, 13*, 335-348.

McNamara, D.S., & Healy, A.F. (2000). A procedural explanation of the generation effect for simple and difficult multiplication problems and answers. *Journal of Memory and Language, 43*, 652-679.

Morris, J.S., Frith, C.D., Perrett, D.I., Rowland, D., Young, A.W., Calder, A.J., & Dolan, R.J. (1996). A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature* , 383, 812–815.

Moulds, M.L., & Bryant, R.A. (2002). Directed forgetting in acute stress disorder. *Journal of Abnormal Psychology, 111*, 175-179.

Muther, W.S. (1965). Erasure or partitioning in short-term memory. *Psychonomic Science, 3*, 429-430.

Nelson, D.L. (1979). Remembering picture and words: Appearance, significance, and name. In L.S. Germak & F.I.M Craik (Eds.), *Levels of processing in human memory* (pp. 45-76). Hillsdale, NJ: Erlbaum.

Quinlan, C.K. (2009). Emotional effects of intentional forgetting. Unpublished honour's thesis, Dalhousie University, Halifax, Nova Scotia, Canada.

Quinlan, C.K., & Taylor, T.L. (under revision). Does attention mediate the ability to intentionally forget emotional words? *Cognition & Emotion.*

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

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Journal of Canadian Psychology*, 45, 255-287.

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.

Phelps, E.A., O'Connor, K.J., Gatenby, C., Gore, J.C., Grillon, C., & Davis, M. (2001). Activation of the left amygdala to a cognitive representation of fear. *Nature Neuroscience, 4*, 437-441.

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

Puce, A., Allison, T., Gore, J.C., & McCarthy, G. (1995). Face- sensitive regions in human extrastriate cortex studied by functional MRI. *Journal of Neurophysiology*, *74*, 1192–1199.

Reber, P.J., Siwiec, R.M., Gitelman, D.R., Parrish, T.B., Mesulam, M.M., & Paller, K.A. (2002). Neural correlates of successful encoding identified using functional magnetic resonance imaging. *The Journal of Neuroscience, 22,* 9541-9548.

Reisberg, D., & Heuer, F. (1992). Remembering the details of emotional events. In E. Winograd & U. Neisser (Eds.), *Affect and accuracy in recall: Studies of "flashbulb" memories*. Cambridge, MA: Harvard University Press.

Rolls, E.T., & Baylis, G.C. (1986). Size and contrast have only small effects on the responses to faces of neurons in the cortex of the superior temporal sulcus of the monkey. *Experimental Brain Research, 65*, 38-48.

Rossion, B., Curran, T., & Gauthier, I. (2002). A defense of the subordinate-expertise account for the N170 component. *Cognition, 85*, 189-196.

Safer, M.A., Christianson, S., Autry, M.W., & Osterlund, K. (1998). Tunnel memory for traumatic events. *Applied Cognitive Psychology, 12*, 99-117.

Sahakyan, L., & Foster, N.L. (2009). Intentional forgetting of actions: Comparison of list-method and item-method directed forgetting. *Journal of Memory and Language, 61,* 134-152.

Saito, H., Yukie, M., Tanaka, K., Hikosaka, K., Fukada, Y., & Iwai, E. (1986). Integration of direction signals of image motion in the superior temporal sulcus of the macaque monkey. *Journal of Neuroscience, 6*, 145-157.

Salthouse, T.A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*, 403-428.

Scott, L.S., Tanaka, J.W., Sheinberg, D.L., & Curran, T. (2002). The role of category learning in the acquisition and rentention of perceptual expertise: A behavioural and neurphysiological study. *Brain Research, 1210,* 204-215.

Sergent, J., Ohta, S., & MacDonald, B. (1992). Functional neuroanatomy of face and object processing: A positron emission tomography study. *Brain, 115*, 15–36.

Smith, K.N., Cacioppo, J.T., Larsen, J.T., & Chartrand, T.L. (2003). May I have your attention please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia*, 41, 171-183.

Sommer, W., Schweinberger, S.R., & Matt, J. (1991). Human brain potentials correlates of faces encoding into memory. *Electroencephalography and clinical Neurophysiology, 79*, 457-463.

Steinmetz, K.R.M., Addis, D.R. & Kensinger, E.A. (2010). The effect of arousal on the emotional memory network depends on valence. *NeuroImage, 53,* 318-324.

Tanaka, J.W., & Curran, T. (2001). A neural basis for expert object recognition. *Psychological Science, 12*, 43-47.

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

Taylor, M.J., McCarthy, G., Saliba, E., & Degiovanni, E. (1999). ERP evidence of developmental changes in processing of faces. *Clinical Neurophysiology, 110*, 910-915.

Tolin, D.F., Hamlin, C., & Foa, E.B. (2002). Directed forgetting in obsessive-compulsive disorder: replication and extension. *Behavioural Research and Therapy, 40*, 793-803.

Tranel, D., Gullickson, G., Koch, M., & Adolphs, R. (2006). Altered experience of emotion following bilateral amygdala damage. *Cognitive Neuropsychiatry, 11*, 219-232.

Vuilleumier, P., & Schwartz, S. (2001). Emotional expressions capture attention, *Neurology, 56*, 153–158.

Whalen, P.J., Rauch, S.L., Etcoff, N.L., McInerney, S.C., Lee, M.B., & Jenike, M.A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, 18, 411–418.

White, M. (1995). Preattentive analysis of facial expressions of emotion. *Cognition & Emotion, 9*, 439-460.

Wilhelm, S., McNally, R.J., Baer, L., & Florin, I. (1996). Directed forgetting in obsessive-compulsive disorder. *Behavioural Research and Therapy, 34*, 633-641.

Woodward, A.E. Jr., & Bjork, R.A. (1971). Forgetting and remembering in free recall: Intentional and unintentional. *Journal of Experimental Psychology*, 89, 109-116.

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*, 670-682.

Young, M.P., & Yamane, S. (1992). Sparse population coding of faces in the inferotemporal cortex. *Science*, *256,* 1327-1331.

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

Zald, D.H., Donndelinger, M.J., & Pardo, J.V. (1998). Elucidating dynamic brain interactions with across-subjects correlational analyses of positron emission tomographic data: the functional connectivity of the amygdala and orbitofrontal cortex during olfactory tasks. *Journal of Cerebral Blood Flow & Metabolism, 18*, 896–905.