THE FEAR FACTOR: EFFECTS OF IMPLICIT AND EXPLICIT PROCESSING ON THE
EMOTIONAL ENHANCEMENT OF MEMORY

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The Fear Factor: Effects of Implicit and Explicit Processing on the Emotional Enhancement of Memory. Ronak Patel, M.A. in Psychology, 2009, Ryerson University.

This thesis examines whether implicit and explicit processing of emotional facial expressions affects the emotional enhancement of memory (EEM). On the basis that explicit processing is associated with relative reductions in amygdala activation and arousal, I predicted that fearful faces, in particular, would lead to a robust EEM effect following encoding with implicit, but not explicit processing. Participants were shown a series of facial expressions (happy, fearful, angry, and neutral) in an “indirect” and a “direct” task designed to elicit implicit and explicit processing, respectively. Later they underwent a recognition memory test using the Remember-Know paradigm. Fearful faces exhibited a unique pattern whereby indirect encoding led to an enhanced subjective sense of recollection, whereas direct encoding prevented an increase in recollection that was observed for all other emotions. These findings may reflect interactions among amygdalar/arousal thresholds and levels of processing (LOP) effects on recognition memory.

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Table of Contents

Declaration.....	ii
Abstract	iii
Acknowledgments.....	iv
Table of Contents.....	v
List of Tables.....	vi
List of Figures.....	vii
List of Abbreviations.....	viii
List of Appendices.....	ix
Introduction.....	1
Method.....	10
Results.....	19
Discussion.....	34
Appendix.....	46
References.....	48

List of Tables

Table 1. Comparison of difference scores and hit rates for Remember responses.....	25
--	----

List of Figures

Figure 1. Exemplar facial emotion photos from the Toronto Rehab Facial Emotion Battery.....	13
Figure 2. Visual representation of “indirect” and “direct” encoding tasks.....	14
Figure 3. Mean arousal ratings for all levels of Emotion.....	20
Figure 4. Mean difference score for old stimuli receiving a Remember response at each level of Encoding task and Emotion.....	23
Figure 5. Mean difference score for old stimuli receiving a Know response at each level of Encoding task and Emotion.....	23
Figure 6. Mean Remember hit rates at each level of Encoding Task and Emotion.....	26
Figure 7. Mean Know hit rates at each level of Encoding Task and Emotion.....	27
Figure 8a. Mean proportion of faces encoded in the indirect task at each level of Confidence	32
Figure 8b. Mean proportion of faces encoded in the direct task at each level of Confidence.....	32
Figure 9. Mean proportion of new faces at each level of Confidence	33
Figure 10. Depiction of levels of processing (LOP) effects masking emotional enhancement of memory (EEM)-related decreases in Remember responses for fearful faces.....	38

List of Abbreviations

ANOVA: Analysis of variance
BOLD: Blood-oxygen level dependent
rCBF: Cerebral blood flow
 P_r : Discrimination index
EEM: Emotional enhancement of memory
FA: False alarm
fMRI: Functional magnetic resonance imaging
K: Know response
LOP: Levels of processing
M: Mean
PET: Positron emission tomography
SAM: Self-assessment manikin
RT: Reaction time
R: Remember response
SCR: Skin conductance response
SD: Standard deviation
SEM: Standard error of the mean
SART: Sustained attention to response test
TR-FEB: Toronto Rehab facial emotion battery

List of Appendices

Appendix A: Remember-Know Instructions.....	45
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The Fear Factor: Effects of Implicit and Explicit Processing on the Emotional Enhancement of Memory

The emotional enhancement of memory (EEM) has been shown to be critically dependent on two components: amygdala involvement and arousal. Studies have demonstrated that implicit and explicit emotional processing can alter these two components in distinct ways. This thesis investigates the effects of implicit and explicit processing on the EEM. Before describing the methods and objectives more specifically, several relevant literatures are reviewed below to provide a background for the rationale. First, I review the concept of the EEM effect, and early experiments in the field. Following this review, I will provide an overview of the relations between the amygdala and sympathetic arousal to the EEM. I then detail the literature that describes how factors such as emotional processing may modulate amygdala-arousal relations and subsequently, how this may affect the EEM effect. To this end, I propose the use of facial emotion expressions in conjunction with behavioural tasks to elicit different processing demands. I further specify why fearful facial expressions, may be particularly effective in examining the specificity of amygdala-arousal contributions to the EEM. Finally, I put forward the Remember-Know paradigm as a means of measuring the EEM.

Introduction

Emotion has profound effects on how we remember events from our past. The presence of affectively charged content can selectively enhance our ability to recall events, a phenomenon known as the EEM. Our ability to experience emotion depends on the interaction of two key dimensional processes: valence and arousal (Russell, 1980). While valence refers to how pleasant (positive) or aversive (negative) an event is perceived, arousal refers to the intensity of an event (i.e. how exciting or calming an event is perceived). Valence and arousal reflect multi-

component processes that comprise both autonomic responses (e.g., changes in peripheral sympathetic activity) and subjective evaluations (e.g., cognitive responses based on individual experience) (Cacioppo *et al.*, 1992; Lang *et al.*, 1993; Soussignan, 2005). The arousal dimension and, more specifically, the physiological aspects of arousal, was the initial focus of early EEM studies.

The Early Studies: A Focus on Arousal

Early studies investigating the EEM effect focused on autonomic indices of arousal, in particular, and used the galvanic skin conductance response (SCR) as a probe into this dimension. SCR is a measure of somatic and neurophysiological activity, presumed to reflect emotional states (Soussignan, 2005). In a seminal study by Kleinsmith and Kaplan (1963), participants were shown a series of words (e.g., *kiss*, *rape*, *vomit*, etc.) paired with numbers, while their SCR was recorded. They were later tested for recall of the numbers at various time intervals, ranging from 2 min to 1 week after encoding. Words associated with high a level of SCR facilitated long-term retention as compared to words associated with lower levels of SCR. Interestingly, participants demonstrated an *inability* to retrieve numbers associated with high arousing words after a short period of time (e.g., 2 min). These findings were consistent with the perseverative-consolidation theory proposed by Walker (1958), which stated that for all effortful learning, a consolidation phase or “active trace process” gradually forms over time. The theory further stipulated a degree of “temporary inhibition of recall” occurs to protect the consolidating trace against disruption (Walker & Tarte, 1963). According to the theory, high arousal during the encoding phase should result in a more intense active trace process, thereby enhancing long-term memory. However, high arousal should also cause a greater temporary inhibition of recall. Additional support for the theory came from others such as Levonian (1967), who presented 83

high school students with continuous emotion-related material while being monitored by SCR sensors. Similar to Kleinsmith and Kaplan, Levonian found that items associated with high levels of arousal facilitated both long-term remembering and short-term forgetting. While researchers have been able to replicate these findings (e.g., Walker & Tarte, 1963) other studies have demonstrated that high arousal can lead to benefits in both long and short-term retention (e.g., Corteen, 1969). Although the findings regarding the effects of arousal on short-term memory have been mixed, these early studies firmly established the robust enhancing effect of high arousal on long-term, episodic memory (memory for specific life events of an individual's past). Over the past few decades, there has been considerable interest in elucidating the neural underpinnings mediating this effect.

Neurobiology of the EEM: Two Critical Components

Animal lesion studies have implicated the amygdala, a structure within the medial-temporal lobe of the brain, as a critical neural substrate in facilitating long-term memory for emotionally arousing events (Cahill, 2000). These findings have extended to humans. For example, a number of studies have shown that patients with lesions to the amygdala show a decrease, and in some cases, complete elimination of the EEM (e.g., Adolphs *et al.*, 1997; Phelps *et al.*, 1998). Findings from functional neuroimaging studies have provided yet another level of support as amygdala activity at encoding predicts whether arousing items will later be remembered or forgotten, an effect that is specific to arousing versus non-arousing items (Kensinger & Corkin, 2004). While these findings confirm the role of the amygdala in the consolidation of emotional arousing events for episodic memory, they do not address the amygdala's relationship to autonomic arousal, a main focus of the early studies.

Autonomic arousal or more specifically, sympathetic arousal, reflects activity driven by the sympathetic nervous system in response to emotional situations. The early EEM studies employed SCR as an indirect measure of this sympathetic activity. Activation of the sympathetic nervous system leads to the release of epinephrine and norepinephrine that bind to adrenergic receptors on peripheral tissues. Animal studies have shown that the administration of epinephrine enhances memory for emotionally arousing events (see McGaugh, Cahill, & Roozental, 1996 for a review). As epinephrine and norepinephrine released in the periphery do not easily cross the blood brain barrier, they are thought to influence memory via stimulation of the vagus nerve (Cahill, 2000). This nerve projects to areas in the brainstem that ultimately connect with the locus coeruleus, which then releases norepinephrine in the amygdala and other brain structures (e.g., hippocampus; LaBar & Cabeza, 2006). The amygdala has been identified as a key neural structure in mediating the enhancing effects of epinephrine on memory. Post-training infusions of β -adrenergic antagonists such as propranolol into basolateral amygdala have been shown to block memory enhancing effects of peripheral epinephrine injections (Liang, Juler, & McGaugh, 1986). The finding that memory enhancing effects of epinephrine are also blocked by a β -adrenergic antagonists that do not readily enter the brain (e.g., sotalol), confirms that epinephrine effects are initiated by activation of peripheral β -adrenergic receptors (Introini-Collison *et al.*, 1992). These findings support McGaugh's *memory modulation hypothesis*, which posits that arousal induced by emotional events activates the amygdala, which in turn engages stress-hormone systems (e.g., noradrenaline and cortisol) to promote memory consolidation (McGaugh, 2004). Enhanced consolidation is further facilitated by the interaction with other brain regions such as the hippocampus. Indeed, lesions to the basolateral amygdala block the memory modulatory effects of glucocorticoid injections in the hippocampus (Roozental & McGaugh,

1997). The extensive findings from animal experiments have unveiled both the amygdala and sympathetic arousal (indexed by the presence of stress hormones such as epinephrine) as two critical components mediating EEM. Findings from human studies have also shed light on the crucial nature of these components.

LaBar and Phelps (1998) conducted a study with patients who had undergone either left or right temporal lobectomy (*en bloc* resection of the anteromedial temporal lobe, including the amygdala, hippocampus, and adjacent cortex). Arousal levels, as indexed by SCR, were recorded while patients were viewing arousing and neutral words. Patients were asked to recall the words immediately after encoding and after a 1-hour delay. While both patients and healthy participants showed equivalent levels of arousal to the emotional words (SCR increased for arousing words relative to neutral words in all groups), the EEM was only observed among healthy controls. The authors demonstrated that arousal, in the absence of amygdala involvement, did not yield the EEM. Their findings were also consistent with the hypothesis that the amygdala plays a critical role in the consolidation of emotionally arousing events. In 2006, Anderson, Yamaguchi, Grabski, and Lacka compared memory for emotional scenes versus emotional faces, both known to evoke significant amygdala activation. The EEM effect was observed only when emotional stimuli were accompanied by increases in sympathetic arousal. The authors concluded that amygdala activation and arousal represent dissociable processes that interact to influence the EEM (also see Patel & Green, 2007). They further proposed the notion of a threshold process, such that a sufficient level of sympathetic arousal is required to enhance memory consolidation for emotionally arousing events. In summary, both animal and human studies have demonstrated a dynamic interplay between arousal and the amygdala in producing the EEM, such that the absence of either component fails to yield the robust memory enhancing

effect. The study of factors that may modulate these components seems particularly important in light of potential consequences on memory; however, few human studies have investigated such factors.

Implicit/Explicit Processing of Emotional Information

The way in which humans process emotional information modulates amygdala activation as well as arousal. Critchley *et al.* (2000) showed that differential processing of facial emotions resulted in distinct neural activation patterns. The authors were interested in whether effortful or *explicit* interpretation of emotion would result in a different pattern of activation than *implicit* interpretation of emotion (i.e. processing emotion without full cognitive awareness). In order to elicit these two types of processing, “implicit” and “explicit” tasks were used. In the implicit task, participants had to make decisions regarding facial gender, whereas the explicit task required participants to attend to and label the emotion being displayed. Thus, the emotional content was *directly* processed during the explicit task, but was more *indirectly* processed in the implicit task. When each task was analyzed separately, the authors found support for the existence of two distinct neural pathways or networks underlying implicit and explicit processing. Moreover, the authors found that when directly comparing the two tasks, the amygdala region was significantly more active during the implicit task in comparison to the explicit task. Another study by Hariri, Bookheimer, & Mazziotta (2000) found similar results when examining cerebral blood flow (rCBF) changes during a matching and labeling task. Matching facial emotion expressions was associated with a bilateral increase of the rCBF response in the amygdala while labeling the same facial expressions, requiring a deeper level of explicit processing, was associated with a diminished rCBF response in the amygdalae. Other studies have also reported the same pattern of amygdala activation in response to implicit and

explicit emotional processing (e.g., Keightley *et al.*, 2003; Lange *et al.*, 2003). Kapler *et al.* (2001) extended these findings by demonstrating that explicit emotion processing not only attenuates amygdala activity but that the reduction in amygdala activation is accompanied by a concomitant suppression of sympathetic arousal. These results are consistent with other studies demonstrating amygdala activity in response to emotionally salient stimuli is positively correlated with increases in SCR (Critchley, Mathias, & Dolan, 2002; Furmark *et al.*, 1997). Taken together, these studies provide reliable evidence that implicit processing of facial emotions results in significant amygdala activation while explicit processing attenuates this response and concomitantly suppresses sympathetic arousal. The current study aims to investigate the effects of differential emotional processing on the EEM. Based on the above neurobiological evidence, I hypothesize that implicit processing will result in the EEM effect whereas explicit processing will result in a relative suppression of this effect.

Probing EEM Specificity using Facial Emotion Expressions

In addition to task-related processing demands, the type of stimulus may affect the strength of the EEM. A recent meta-analysis revealed that amygdala activation peaks across a number of functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) studies yielded a stronger effect size for facial expressions in comparison to other stimuli such as scenes (Sergerie, Chochol, & Armony, 2008). These meta-analytic findings point to the use of facial expressions as a particularly effective method of producing amygdala activation. In addition, the use of different facial emotions affords the opportunity to examine the specificity of amygdala-arousal contributions to the EEM. That is, the degree of amygdala activation in response to facial expressions can depend on the particular type of emotion. Indeed, a growing number of studies suggest that there are distinct neural pathways underlying the expression and

recognition of fear and other emotions such as anger. Whalen, Shin, McInerney, and Fisher (2001) found that the blood-oxygen level dependent (BOLD) signal intensity in the amygdala was greater to facial expressions of fear than of anger. In addition, PET findings from Blair *et al.* (1999) found no evidence of activity in the amygdala for increasing intensities of angry facial expressions. Rather, the same study found that facial expressions of anger were associated with activity in the orbitofrontal cortex and anterior cingulate cortex. A meta-analysis examining the neuroanatomy of emotion recognition supported the view that anger was most significantly associated with activity in the orbitofrontal cortex, while fear was most associated with activity in the amygdala (Murphy, Nimmo-Smith, & Lawrence, 2003). These studies demonstrate that the amygdala is preferentially activated by facial expressions of fear (also see meta-analysis by Phan, Wager, Taylor, & Liberzon, 2002). The robustness of amygdala activation in response to fearful stimuli is further supported by studies that report significant amygdala activation to fearful faces under a variety of experimental manipulations such as masked or unconsciously perceived conditions (Morris, Öhman, & Dolan, 1998; Whalen *et al.*, 1998) and low attentional load conditions (Hsu & Pessoa, 2007).

The contrast between fear and anger further extends to emotions that differ in valence, such as facial expressions of happiness. While amygdala activation has been found in response to the processing of happy faces, the magnitude of activation is often less than that observed in response to fearful faces (Gläscher, Tüscher, Weiller, & Büchel, 2004). These findings are consistent with imaging findings that show bilateral amygdala activation is more associated with negative than positive emotions (Hamann, Ely, Hoffman, & Kilts, 2002). As the EEM critically depends on significant amygdala activation and sympathetic arousal, I predict that implicit processing of fearful faces will lead to a stronger EEM effect as compared to implicit processing

of angry and happy faces. I further expect that such an effect will not be observed, that is, it will be effectively “suppressed”, for fearful faces that are processed under explicit conditions. Importantly, these predictions extend Anderson *et al.*’s (2006) arousal-threshold proposal to suggest that not only is a sufficient level of arousal required to produce the EEM, but the effect is dependent on exceeding a threshold of amygdala activation as well.

EEM and the Remember-Know Paradigm

To test our specific EEM predictions, the current study used the Remember-Know recognition paradigm originally developed by Tulving (1985). In this paradigm, participants are asked to give a “Remember” response for items for which they become consciously aware of specific details that were experienced at the time the item was presented (Wheeler & Stuss, 2003). The critical element of the Remember response is the participants’ sense of re-living or “recollecting” an earlier event. In contrast, “Know” responses are associated with items that are recognized, but for which the participant is not able to retrieve any supporting contextual information. Thus, items with a Know response are thought to feel “familiar” to the participant. The dual process theory of recognition proposes that Remember and Know responses reflect distinct underlying memory processes of “recollection” and “familiarity”, respectively (Yonelinas, 2002). Whereas recollection represents the retrieval of specific information, familiarity represents retrieval in the absence of any detailed information. Recent EEM studies using the Remember-Know paradigm have demonstrated that emotion selectively enhances the subjective experience of recollection as indexed by an increased proportion of Remember responses to emotionally arousing stimuli (Anderson *et al.*, 2006; Sharot, Delgado, & Phelps, 2004; Sharot, Verfaellie, & Yonelinas, 2007). These same studies have also shown that emotion has no effects on the subjective experience of familiarity during recognition, as revealed by

similar levels of Know responding across emotional and neutral stimuli. Interestingly, the enhanced feeling of recollection occurs even though overall recognition accuracy is not necessarily enhanced (Sharot *et al.*, 2004, 2007). That is, the EEM may be more related to the level of conscious recollection than to retrieval accuracy *per se*.

Main Objective & Hypotheses

The main objective of this thesis is to examine the behavioural expression of the EEM for different facial emotions using the Remember-Know paradigm under conditions of implicit and explicit processing. The hypotheses of the current study are:

- 1) Implicit processing of fearful faces will be associated with a heightened recollective experience (as indexed by increased Remember responses) relative to neutral faces.
- 2) The EEM effect for fearful faces will be reduced or 'suppressed' under conditions of explicit, as compared to implicit processing.
- 3) In contrast to fear, angry and happy faces will be associated with a lesser or no increase in recollection relative to neutral faces under conditions of either implicit or explicit processing.
- 4) Facial emotions will have no effect on familiarity-based responses relative to neutral expressions, under conditions of either implicit or explicit processing.

Methods

Participants and Design

Forty students (32 females, 8 males; mean age = 23.3 years, $SD = 6.32$ years) participated in the current experiment. An additional 19 students were recruited to provide subjective ratings of arousal (15 females, 4 males; mean age = 23.84 years, $SD = 8.68$ years). All participants were enrolled at Ryerson University and either given course credit for their participation or

volunteered. Only participants between the ages of 18 to 65, with intact vision and hearing were included in the study. We further screened all participants for any history of neurological or psychiatric disorders, brain injury, substance abuse, or psychotropic medications. All screening interviews were subjected to a blind review following data collection. Four participants were excluded from analysis on the basis of their responses to the screening. Participants provided informed consent after the nature of the experimental procedures had been explained. The experiment consisted of a 2 (Encoding task: indirect, direct) X 4 (Emotion: happy, fearful, angry, neutral) within-subjects design. The study was approved by the Research Ethics Boards of Ryerson University and Toronto Rehabilitation Institute.

Stimuli

Stimuli were selected from the Toronto Rehab Facial Emotion Battery (TR-FEB), a battery currently under development to address the limitations associated with sets of facial affect stimuli that are publicly available. The battery contains a greater number of unique faces, a wider range of emotional expressions, greater ecological validity through semi-controlled environments, and greater ethnic diversity as compared to existing collections (e.g., Pictures of Facial Affect, Ekman & Friesen, 1976; International Affective Picture System, Lang, Bradley, & Cuthbert, 2008; Florida Affect Battery, Bowers, Blonder, & Heilman, 1989; The AR Face Database, Martinez & Benavente, 1998; The Psychological Image Collection at Stirling, <<http://pics.psych.stir.ac.uk>>; Pose, Illumination, and Expression Database, Sim, Baker, & Bsat 2003; The Karolinska Directed Emotional Faces, Lundqvist, Flykt, & Öhman, 1998). A total of 72 faces with normative data were selected from the TR-FEB (see Figure 1 for examples), and the remaining 40 came from a similar set (NimStim Face Stimulus Set, Tottenham *et al.*, in press). Only those photos achieving over 80% agreement on the communicative intent of the

photo were considered in the current study (see Patel, Green, & Girard, 2007 for normative study on TR-FEB photos). In all photos, face orientation was forwards, standardized to black and white, and scaled to the same size using Adobe Photoshop 7.0. Photos of 112 unique individuals portraying one of four emotional expressions (happy, fearful, angry, and neutral) were selected for the experiment. Fourteen photos (7 men and 7 women) representing each emotion were presented at study (56 in total), and an additional 56 photos were used as recognition foils. An additional 2 “buffer” photos were presented at the beginning of the indirect task and end of the direct encoding task (4 buffer photos in total). These 4 buffer items and 4 foils served as practice items during the memory test. All recognition foils were matched to target items in terms of gender, age, race/ethnicity, hair length, and stimulus set. Study items were presented to participants in one of two fixed orders, such that two negative emotions did not occur in immediate succession to one another, in order to prevent participants’ SCRs¹ from habituating to negative emotions. Two separate orders were created to reduce the possibility of results being due to specific ordering of emotions. Due to the careful ordering required and in order to meet the demands for proper SCR synchronization, studied and unstudied sets of faces were the same across participants. More specifically, items at encoding required specialized programming in order to time lock studied items during each task to participants’ SCR recordings through a series of digital pulses that were transmitted between the stimulus presentation and physiological recording equipment. At recognition, the order of presentation of studied and unstudied photos was random for each participant.

To characterize the emotional value of the faces, an independent group of 19 participants rated all photos used in the current study on arousal. Using the Self-Assessment Manikin procedure (SAM; Lang, Bradley, Greenwald, & Hamm, 1993) participants rated each photo

¹ SCR data not presented in this thesis.

along a 5-point, visually based scale. The SAM depicts a graphic character that ranges from sleepy with closed eyes ('1' - *not arousing at all*) to excited with open eyes ('5' - *very arousing*).

Figure 1. Exemplar facial emotion photos from the Toronto Rehab Facial Emotion Battery (TR-FEB).

Encoding Task

Participants sat at a computer where they were presented with two tasks: an “indirect” task and a “direct” task. These tasks were designed to target conditions of implicit and explicit processing respectively. In the indirect task, participants were asked a yes/no question about the gender of the face, e.g., “Are the following faces female?” In the direct task, participants were asked a yes/no question about the emotional expression of the face, e.g., “Are the following faces happy?” (see Figure 2). In each task, participants were presented with four yes/no questions, each of which was followed by a study set of seven faces. For the indirect task, two questions

(male vs. female) were repeated for a total of four trial sets. For the direct task, questions pertaining to each of the four facial emotions were presented for the four trial sets. The ordering of questions within each task (male versus female for indirect and type of emotion for direct) was random. The indirect task always preceded the direct task to avoid the possibility of explicit emotional processing carrying over from the direct to the indirect task.

Figure 2. Visual representation of “indirect” and “direct” encoding tasks. Participants were presented with an “indirect” task and “direct” task to elicit implicit and explicit emotional processing respectively. The indirect task preceded the direct task, and each task involved yes/no questions in order to control for verbal demands.

Each face was presented for a total duration of 2 s and participants were instructed to view each stimulus for its entire duration. An examiner seated behind the participant read each question out loud as it appeared on the screen, and participants responded verbally (“yes” or

“no”) upon presentation of each face (automated responding using a microphone was not undertaken due to problems identified with time locking the microphone’s recording to the SCR signal in addition to time-locking stimulus presentation) . All responses were recorded by the examiner. In between the stimulus, a blank screen containing a fixation point was presented. The fixation point varied between 16-24 s to allow the physiological SCR signal the opportunity to return to baseline levels (Dawson, Schell, & Filion, 2000). The stimuli were presented on a computer screen about 60 cm from the participant using E-Prime version 1.2. (Psychology Software Tools, Inc., 2002). The text was printed in size 18 Courier New font and was presented in black against a white background.

Delay Period

Following the end of the direct task, participants underwent a 15-min distraction period. Participants completed 2 “filler” tasks: the Sustained Attention to Response Test (SART; Roberston *et al.*, 1997) and the Simple and Choice Reaction Time (RT) Tests (Green & Melo, unpublished instrument). Both filler tasks required sustained attention and vigilance to non-face stimuli, and served to minimize the possibility that participants were rehearsing or maintaining online representations of studied faces during the delay period. In the SART, participants were presented with a series of numbers on a computer screen and asked to press a red button every time they saw a number except for when they saw the number ‘3’. Each number was preceded by a fixation point (circle with an ‘x’ through it) in the center of the screen. Participants were asked to focus their attention on the fixation point until the next number appeared on the screen. In the *simple* RT test, participants were asked to press the ‘1’ key every time they saw an arrow. In the *choice* RT test, participants pressed the ‘1’ key if the arrow pointed upwards and the ‘2’ key if the arrow pointed downwards. Participants were instructed to respond as quickly and as

accurately as possible. In both the simple and choice RT tests, a practice phase preceded the test phase.

Recognition task

Participants received a surprise recognition memory test following the distraction period. Recognition was measured using Remember-Know judgments (Tulving, 1985) and with recognition confidence ratings (Yonelinas & Parks, 2007). This procedure was used to target recollection and familiarity based processes in an explicit recognition task. Participants read detailed instructions on how to make Remember-Know judgments (see Appendix A) and were then asked to explain the instructions in their own words to assess their understanding of the difference between a “Remember” and “Know” judgment. Participants completed a series of practice trials and were asked to verbally justify their response choice. Once the experimenter was assured that the participant had a good understanding of the instructions (i.e., “Remembering” a face reflected a specific conscious recollection of having seen the face during study including associated experimental details, thoughts, and/or feelings; whereas “Knowing” reflected similar confidence of having seen a face, but without any accompanying specific recollective details) they proceeded to the recognition test.

In the recognition task, foils consisted of unstudied individuals expressing the same four emotions presented in the encoding task: fearful, angry, happy, and neutral. For example, if individual A’s face was presented during study with a *fearful* expression, then during recognition testing, individual A served as an “old” studied item with the same fearful expression, whereas “new” foils comprised of faces of unstudied individuals. Participants were explicitly told that new faces would not contain photos of old faces with a different emotional expression, thus an old face would appear as it did in the encoding phase or not at all. The stimuli were presented in

a random order on a computer screen using E-prime. Each trial consisted of two, self-paced slides showing the same photo: On the first slide, participants were asked whether the photo was 'new', 'remembered' or 'known' by pressing the appropriate key. On the second slide, the same photo was shown and participants were asked to rate the confidence of their recognition response on a scale of 1 (sure *new*) to 6 (sure *old*) as outlined by Yonelinas and Parks (2007). Participants selected a '6' to indicate that they were sure the item was previously studied, a '5' to indicate that they were unsure if it was studied, and a '4' to indicate if they were guessing that it was studied. Participants responded with a '1' if they were sure it was *not* previously studied, a '2' to indicate that they were unsure it was not previously studied, and a '3' to indicate that they were guessing it was not studied.

Data Analysis

Indices of recognition memory performance in the current study are based on hit rates and false alarm rates. Hit rates are defined as the proportion of Remember (R) or Know (K) responses given to an "old" face (R_{Hit} and K_{Hit} , respectively), whereas false alarms rates are defined as the proportion of Remember or Know responses given to a "new" face (R_{Fa} and K_{Fa} , respectively). Overall recognition accuracy was measured using the discrimination index (P_r) derived from the two-high threshold model (Snodgrass & Corwin, 1988), and calculated as the hit rate minus the false alarm rate².

To examine the effects of emotion on different types of recognition, "emotional difference scores" were calculated as outlined by Sharot *et al.* (2007). These difference scores represent the proportion of emotional faces given a particular recognition response minus the

² False alarms (FA) were not distinguishable by encoding task. New faces were matched to old faces by emotional expression only and presented in the context of a single recognition task. Thus, when calculating any measure that required an FA correction and where 'Encoding Task' was a factor in the analysis, we equally applied the false alarm rate to both the direct and indirect conditions.

proportion of neutral faces eliciting that response (e.g., R_{Hit} for fearful – R_{Hit} for neutral). Larger positive values indicate that the emotion increased the likelihood of an enhancing effect on the relevant response (R, K, or new). These difference scores were used to examine whether emotion enhanced the subjective experience of remembering (R) or whether it influenced recognition in the absence of a feeling of recollection (K). To further quantify the effect of emotional faces on recognition performance, the processes underlying remember and know judgments were also assessed using model-based estimates of recollection and familiarity (Yonelinas *et al.*, 1998). The dual process model assumes that recollection and familiarity reflect distinct memory processes: Recollection represents a threshold process by which participants are able to recall contextual details related to some aspect of the study event. Under this model, recollection is estimated by the proportion of old faces receiving an R response (R_{Hit}) minus the proportion of new faces receiving this response (R_{Fa}), then dividing by the proportion of times a participant could have responded correctly with an R response ($1 - R_{Fa}$): $R_{Hit} - R_{Fa} / (1 - R_{Fa})$ (recollection formula A). Alternatively, recollection is often estimated by simply subtracting R_{Fa} from R_{Hit} (recollection formula B). Since R_{Fa} is usually very close to zero, the two formulae generally provide similar results; however, formula A is thought to reflect *true* recollection based on a high-threshold model, which assumes that, although new items may seem familiar, they cannot truly be recollected (personal communication with Yonelinas via e-mail, May, 2009; Yonelinas *et al.*, 1998). When recollection fails, recognition is thought to be based on a familiarity assessment process, assumed to be well-described by a signal-detection process. Participants are instructed to respond with “Know” if an item cannot be recollected, and thus, familiarity is calculated by computing the probability of receiving a K response given the item

did not receive an R response, corrected for false alarms: Familiarity = $(K_{Hit}/1-R_{Hit}) - (K_{Fa})/(1-R_{Fa})$ (Yonelinas *et al.*, 1998).

The effects of emotion on and high and low confidence recognition responses were also examined to determine if the effects of emotion were observed for the most confidently recognized items. High confidence items were those that received a rating of '6' (*sure* old) whereas low confidence items were those items that received a rating of '5' (*unsure* old).

For all analyses, EEM effects were interpreted with neutral faces as the baseline, any task effects were interpreted in terms of the effects of direct encoding relative to indirect encoding.

Results

Subjective Ratings of Arousal

Subjective ratings were submitted to a 1-way (Emotion: happy, fearful, angry, neutral) within-subjects ANOVA. The main effect of emotion, $F(3, 54) = 46.33, p < .001$, partial $\eta^2 = .72$, revealed that fearful faces were rated as more arousing than angry faces: repeated contrasts, $F(1, 18) = 21.74, p < .001$, partial $\eta^2 = 0.55$, angry faces were more arousing than happy faces, $F(1, 18) = 6.96, p = .008, 1$, partial $\eta^2 = 0.34$, and happy faces were more arousing than neutral faces, $F(1, 18) = 13.54, p = .002$, partial $\eta^2 = 0.43$ (see Figure 3).

Figure 3. Mean subjective arousal ratings for each class of facial emotion expressions. Each emotional expression is significantly different from the next at $p < .05$ (error bars = standard error of the mean, SEM).

Recognition Accuracy (*Pr*)

The effects of emotion on recognition accuracy were examined using a 2 (Encoding task: indirect, direct) X 2 (Response: remember, know) X 4 (Emotion: happy, fearful, angry, and neutral) within-subjects ANOVA. There was a main effect of Task, $F(1, 35) = 9.85$, $p = .003$, partial $\eta^2 = .22$, revealing participants were more accurate at recognizing faces encoded in the direct task ($M = .24$, $SD = .06$) as compared to the indirect task ($M = .19$, $SD = .07$). R responses ($M = .30$, $SD = .12$) were also accompanied by higher accuracy relative to K responses ($M = .12$, $SD = .11$) as indicated by a main effect of Response, $F(1, 35) = 24.86$, $p < .001$, partial $\eta^2 = .42$. There was no main effect of Emotion, $F(3, 105) = 0.92$, $p = .432$, partial $\eta^2 = .03$, which is consistent with several previous studies that have reported emotion has no effect on overall memory accuracy (Dougla & Rotello, 2007; Ochsner, 2000; Sharot *et al.*, 2007; Talarico &

Rubin, 2003). No significant interactions were observed: Task by Response, $F(1, 35) = .61, p = .439$, partial $\eta^2 = .02$; Task by Emotion, $F(3, 105) = 1.58, p = .199$, partial $\eta^2 = .04$; and Response by Emotion, $F(3, 105) = 2.15, p = .098$, partial $\eta^2 = .06$. Likewise, there was no three-way interaction between Task, Response and Emotion, $F(3, 105) = .67, p = .572$, partial $\eta^2 = .02$.

Remember and Know Responses

The effects of emotion on R and K response rates were assessed using a 2 (Encoding task: direct, indirect) x 2 (Response: remember, know) x 3 (Emotion: happy, fearful, angry) ANOVA on the difference scores for old faces (e.g., R_{Hit} for fear minus R_{Hit} for neutral). A main effect of Response, $F(1, 35) = 7.80, p = .008$, partial $\eta^2 = .18$, revealed that emotional faces selectively increased R responses ($M = .08, SD = .13$) as compared to K responses ($M = -.03, SD = .15$). There was no main effect of Task, $F(1, 35) = 2.48, p = .124$, partial $\eta^2 = .07$, and no main effect of Emotion, $F(2, 70) = 0.98, p = .382$, partial $\eta^2 = .03$. No significant interactions were observed: Task by Response, $F(1, 35) = 0.02, p = .897$, partial $\eta^2 = .01$; Task by Emotion, $F(2, 70) = 0.86, p = .426$, partial $\eta^2 = 0.02$; Emotion by Response, $F(2, 70) = 0.61, p = .548$, partial $\eta^2 = .02$; Task by Response by Emotion, $F(2, 70) = 1.26, p = .289$, partial $\eta^2 = .04$. This omnibus ANOVA may have been too insensitive to evaluate the specificity of EEM on remembering across the three emotion types (Rosnow & Rosenthal, 1989). Thus, to assess our *a priori* hypothesis that the EEM would be specific to R responses and most pronounced for fearful faces encoded in the indirect task, focused contrast analyses were carried out using one-sample t tests on difference scores. These focused contrasts assessed whether difference scores were significantly different from zero. Values greater than zero (i.e. positive values) indicated the emotion was having an enhancing effect on responding.

First, one-sample *t* tests were calculated on emotional difference scores for R responses. Fearful faces encoded in the indirect task elicited a greater proportion of R responses relative to neutral faces encoded in indirect task ($M_{diff} = .13$, $SD = .28$), $t(35) = 2.75$, $p = .009$, $d = 0.46$. This effect was *absent* for fearful faces encoded in the direct task ($M_{diff} = .02$, $SD = .22$), $t(35) = 0.59$, $p = .561$, $d = 0.10$. Happy faces encoded in the indirect task also elicited a greater number of R responses as compared to neutral responses ($M_{diff} = .07$, $SD = .22$), although this effect was marginal, $t(35) = 1.95$, $p = .059$, $d = 0.32$. R responses were not significantly increased for happy faces encoded in the direct task ($M_{diff} = .05$, $SD = .23$), $t(35) = 1.37$, $p = .179$, $d = 0.22$. Angry faces encoded in the indirect task also elicited a greater number of R responses as compared to neutral faces ($M_{diff} = .10$, $SD = .25$), $t(35) = 2.30$, $p = .028$, $d = 0.38$, an effect that was also observed for angry faces encoded in the direct task ($M_{diff} = .09$, $SD = .23$), $t(35) = 2.40$, $p = .022$, $d = 0.40$ (see Figure 4 for a summary of these findings).

One-sample *t* tests were then conducted on emotional difference scores for K responses. As expected, no effects of emotion were observed on K responding for faces encoded in the indirect task: happy, $t(35) = -0.46$, $p = .648$, $d = -0.10$; fearful, $t(35) < .01$, $p = 1.000$, $d < 0.01$; and angry, $t(35) = -0.44$, $p = 0.666$, $d = -0.07$. Similarly, no effects of emotion were observed on K responding for faces encoded in the direct task: happy, $t(35) = -1.60$, $p = 0.119$, $d = -0.27$; fearful, $t(35) = -0.25$, $p = .806$, $d = -0.04$; and angry, $t(35) = -1.81$, $p = 0.079$, $d = -0.30$ (see Figure 5 for a summary of these findings).

Figure 4. Mean difference scores for old stimuli receiving an R response by Task and Emotion ($*p < .05$ compared to 0, error bars = SEM)

Figure 5. Mean difference scores for old stimuli receiving a K response by Task and Emotion (there were no significant differences among emotions or compared to 0, error bars = SEM).

Although the reporting of difference scores is consistent with previous studies and a convenient method to display the results (e.g., Sharot *et al.*, 2007), further analyses were conducted in order to confirm whether the results obtained with difference scores were due to changes in recognition for emotional faces versus neutral faces. Table 1 reveals that R_{Hits} for neutral faces were higher after encoding in the direct task than after encoding in the indirect task. Furthermore, the means for the happy and angry faces encoded in the direct task were also higher compared to indirect encoding; but no such increases were observed for fearful faces encoded in the direct task. Thus, R responses increased for all faces encoded in the direct task *except* for fearful faces, (see Figure 6). In other words, direct encoding of fearful faces seemed to *block* the increase in remembering of those faces that was seen for other stimuli under direct conditions. Given that this crucial information was not captured by the difference scores, the rest of the analyses were conducted on rates.

Given the problems identified with difference scores, I reanalyzed the data using rates and assessed *a priori* hypotheses by submitting hit rates (R_{Hits} and K_{Hits}) to a series of 2 (Encoding task: indirect, direct) X 2 (Emotion ‘emotion’, neutral) ANOVAs. To examine the effect of fear on remembering, R_{Hits} for fearful faces were submitted to a 2 (Encoding task: indirect, direct) X 2 (Emotion: fearful, neutral) ANOVA. A main effect of Emotion, $F(1,35) = 5.86, p = .021$, partial $\eta^2 = .14$, revealed that R_{Hits} were significantly higher for fearful faces ($M = .35, SD = .15$) as compared to neutral faces ($M = .27, SD = .16$). There was also a marginal Task by Emotion interaction, $F(1, 35) = 3.40, p = .07$, partial $\eta^2 = .09$. Paired-samples t tests revealed that R_{Hits} were significantly greater for fearful faces encoded in the indirect task relative to neutral faces, but that this effect was not present for fearful faces encoded in the direct task (see Table

1). This interaction was further supported by lack of a main effect of Task, $F(1, 35) = 1.05, p = .313$, partial $\eta^2 = .03$. In contrast, for happy faces, a main effect Task, $F(1, 35) = 5.00, p = .033$,

Table 1. Comparison of Dependent measures for Remember Responses for Old Stimuli:
Difference Scores and Hit Rates

	<i>Mean Hit Rates</i>	<i>SD</i>	<i>Mean Difference</i>	<i>SD_{diff}</i>	<i>P</i>	<i>D</i>
<u>Indirect</u>						
Happy	.31	.19	.07	.22	.059	.33
Neutral	.23	.20				
Fearful	.36	.21	.13	.28	.009*	.46
Neutral	.23	.20				
Angry	.33	.18	.10	.25	.028*	.38
Neutral	.23	.20				
<u>Direct</u>						
Happy	.37	.25	.05	.23	.179	.22
Neutral	.31	.19				
Fearful	.34	.22	.02	.22	.561	.10
Neutral	.31	.19				
Angry	.40	.23	.09	.23	.022*	.40
Neutral	.31	.19				

* $p < .05$. Bolded values highlight the change in neutral hit rates at recognition following direct

(.31) vs. indirect (.23) encoding that must be taken into account when interpreting the effect of emotion.

Figure 6. The mean proportion of Remember hit rates (R_{Hits}) for faces encoded in the indirect and direct tasks (error bars = SEM).

partial $\eta^2 = .12$, revealed that R_{Hits} were higher for faces encoded in the direct task ($M = .34$, $SD = .19$) relative to the indirect task ($M = .27$, $SD = .16$). A main effect of Emotion, $F(1, 35) = 5.00$, $p = .033$, partial $\eta^2 = .12$, revealed that R_{Hits} were significantly higher for happy faces ($M = .34$, $SD = .18$) relative to neutral faces ($M = .27$, $SD = .16$). However there was no Task by Emotion interaction, $F(1, 35) = .13$, $p = .722$, partial $\eta^2 < .01$. Angry faces also showed a main effect of Task, $F(1, 35) = 7.32$, $p = .010$, partial $\eta^2 = .17$, where R_{Hits} were significantly greater for faces encoded in the direct task ($M = .36$, $SD = .18$) in comparison to the indirect task ($M = .28$, $SD = .18$). A main effect of Emotion, $F(1, 35) = 13.66$, $p = .001$, partial $\eta^2 = .28$, revealed R_{Hits} were significantly greater for angry faces ($M = .37$, $SD = .16$) as compared to neutral faces

($M = .27$, $SD = .16$). However there was no significant Task by Emotion interaction, $F(1, 35) = .01$, $p = .942$, partial $\eta^2 < .01$.

Parallel analyses were also conducted on K responses to old stimuli (see Figure 7). K_{Hits} for happy faces were submitted to a 2 (Encoding task: indirect, direct) X Emotion: happy, neutral) ANOVA and revealed no main effect of Task, $F(1, 35) = .56$, $p = .461$, partial $\eta^2 = .02$, no main effect of Emotion, $F(1, 35) = 1.84$, $p = .184$, partial $\eta^2 = .05$, and no Task by Emotion interaction, $F(1, 35) = .46$, $p = .501$, partial $\eta^2 = .01$. Fearful faces had no effect on Know responding as revealed by a non-significant main effect of Task, $F(1, 35) = 1.48$, $p = .231$, partial $\eta^2 = .04$, no main effect Emotion, $F(1, 35) = .02$, $p = .888$, partial $\eta^2 < .01$, and no Task by Emotion interaction, $F(1, 35) = .30$, $p = .864$, partial $\eta^2 < .01$. Finally, angry faces did not show any effect on know responding as revealed by a non-significant main effect of Task, $F(1, 35) = .81$, $p = .375$, partial $\eta^2 = .02$, no main effect of Emotion, $F(1, 35) = 2.36$, $p = .134$, partial $\eta^2 = .06$, and no Task by Emotion interaction, $F(1, 35) = .24$, $p = .631$, partial $\eta^2 < .01$.

A 2 (Response: Remember, Know) X 4 (Emotion: happy, fearful, angry, neutral) within-subjects ANOVA was conducted to examine false alarms. The ANOVA revealed a highly reliable main effect of Response, $F(1, 35) = 84.39$, $p < .001$, partial $\eta^2 = .71$, indicating that participants made a fewer proportion of R_{Fa} ($M = .04$, $SD = .04$) than K_{Fa} ($M = .18$, $SD = .10$). This finding suggests that participants were in fact using the Remember-Know paradigm correctly, reserving their remember responses for only highly specific details they could recall. A main effect of Emotion, $F(3, 105) = 4.70$, $p = .004$, partial $\eta^2 = .12$, revealed that *only* fearful faces ($M = .13$, $SD = .08$) were particularly susceptible to false alarms as compared to neutral faces ($M = .10$, $SD = .07$), $F(1, 35) = 6.66$, $p = 0.014$, partial $\eta^2 = 0.160$ (happy: $F(1, 35) = 0.97$,

$p = 0.332$, partial $\eta^2 = .03$; angry: $F(1,35) = 0.01$, $p = .928$, partial $\eta^2 < .01$). There was no significant Response by Emotion interaction, $F(3, 105) = 0.23$, $p = .879$, partial $\eta^2 < .01$

Figure 7. The mean proportion of Know hit rates (K_{Hits}) for faces encoded in the indirect and direct tasks (error bars = SEM).

Recollection and Familiarity Estimates

Recollection estimates (derived from formula A) and familiarity estimates were submitted to a 2 (Encoding task: indirect, direct) x 2 (Response: recollection, familiarity) x 4 (Emotion: happy, fearful, angry, neutral) within-subjects ANOVA. A main effect of Task, $F(1,35) = 11.27$, $p = .002$, partial $\eta^2 = .24$, revealed increased recognition for faces encoded in direct task ($M = .33$, $SD = .03$) as compared to the indirect task ($M = .27$, $SD = .03$). There was no main effect of Response, $F(1, 35) = 0.20$, $p = .654$, partial $\eta^2 = .01$, and no main effect of Emotion, $F(3, 105) = 1.56$, $p = .203$, $\eta^2 = .04$. No significant interactions were observed: Task

by Response, $F(1, 35) = 0.42, p = .520$, partial $\eta^2 = .01$; Task by Emotion $F(3, 105) = 1.76, p = .159$, partial $\eta^2 = .05$; and Response by Emotion, $F(1, 35) = 0.65, p = .587$, $\eta^2 = .02$. Likewise, there was no three-way interaction between Encoding task, Response, and Emotion, $F(3, 105) = 0.21, p = .888$, partial $\eta^2 = .01$.

Planned contrasts to address our *a priori* hypotheses were conducted using 2 (Encoding task: indirect, direct) X 2 (Emotion: 'emotion', neutral) ANOVAs on estimates of recollection and familiarity. The ANOVA on recollection for fearful faces revealed a marginally significant interaction, $F(1, 35) = 3.59, p = .067$, partial $\eta^2 = .09$. Paired *t* tests revealed that recollection was significantly enhanced for fearful faces encoded in the indirect task ($M = .32, SD = .21$) relative to neutral faces ($M = .22, SD = .18$), $t(35) = 2.11, p = .042, d = 0.35$, whereas this effect was absent in the direct task condition (fearful: $M = .29, SD = .23$; neutral: $M = .29, SD = .18$), $t(35) = -0.12, p = .906, d = -0.02$. There was no main effect of Task, $F(1, 35) = .98, p = .330$, partial $\eta^2 = .03$ and no main effect of Emotion $F(1, 35) = 1.94, p = .173$, partial $\eta^2 = .05$. For happy faces, a main effect of Task, $F(1, 35) = 5.10, p = .030$, partial $\eta^2 = .13$, revealed greater recollection for faces encoded in the direct task ($M = .32, SD = .17$) relative to the indirect task ($M = .25, SD = .14$). A main effect of Emotion, $F(1, 35) = 6.27, p = .017$, partial $\eta^2 = .15$, revealed recollection was significantly enhanced for happy faces ($M = .32, SD = .16$) relative to neutral faces ($M = .26, SD = .14$). There was no Task by Emotion interaction, $F(1, 35) = .12, p = .695$, partial $\eta^2 < .01$. Angry faces also showed a main effect of Task, $F(1, 35) = 7.81, p = .008$, partial $\eta^2 = .18$, revealing recollection was greater for faces encoded in the direct task ($M = .34, SD = .16$) relative to the indirect task ($M = .26, SD = .14$). A main effect of Emotion, $F(1, 35) = 11.23, p = .002$, partial $\eta^2 = .24$, revealed recollection was significantly enhanced for angry faces ($M = .34, SD = .16$) relative to neutral faces ($M = .26, SD = .13$). There was no Task by Emotion

interaction, $F(1, 35) = .01, p = .940$, partial $\eta^2 < .01$. Overall these results are consistent with the focused contrast analyses conducted on R responses. As expected, both recollection formulae A and B yielded almost identical results (data not shown).

Parallel analyses were also conducted on estimates of familiarity. Familiarity estimates for fearful faces showed a marginal main effect of Task, $F(1, 35) = 2.89, p = .098$, partial $\eta^2 = .08$ (indirect: $M = .25, SD = .16$; direct: $M = .31, SD = .14$), no main effect of Emotion $F(1, 35) = .03, p = .874$, partial $\eta^2 < .01$, and no Task by Emotion interaction, $F(1, 35) = .88, p = .355$, partial $\eta^2 = .02$. For the happy 2 X 2 ANOVA, a main effect of Task, $F(1, 35) = 4.15, p = .049$, partial $\eta^2 = .11$, revealed greater familiarity for faces encoded in the direct task ($M = .32, SD = .17$) relative to the indirect task ($M = .26, SD = .20$). There was no main effect of Emotion, $F(1, 35) = .12, p = .735$, partial $\eta^2 < .01$ and no Task by Emotion interaction, $F(1, 35) = .52, p = .477$, partial $\eta^2 = .02$. For the angry ANOVA, a main effect of Task, $F(1, 35) = 8.12, p = .007$, partial $\eta^2 = .198$, revealed greater familiarity for faces encoded in the direct task ($M = .34, SD = .13$) relative to the indirect task ($M = .25, SD = .20$). There was no main effect of Emotion, $F(1, 35) = .40, p = .531$, partial $\eta^2 = .01$, and no Task by Emotion interaction, $F(1, 35) = .01, p = .92$, partial $\eta^2 < .01$. In contrast to the pattern for K_{Hits} , familiarity estimates generally yielded a Task effect that revealed a greater sense of familiarity for all faces encoded in the direct task relative to the indirect task. Interestingly, this effect was observed for all faces except for fearful faces. Similar to the pattern of K responses, emotional faces showed no effect on familiarity relative to neutral faces, demonstrating the enhancing effects of emotion on memory are specific to recollection.

Confidence Ratings

An examination of whether EEM effects were restricted to faces recognized with high confidence was undertaken using a 2 Encoding task (indirect and direct) X 2 Confidence response ('6' *sure old*, '5' *unsure old*) X 4 Emotion (happy, fearful, angry, neutral) within-subjects ANOVA for old faces. A main effect of Task, $F(1, 35) = 8.49, p = .006$, partial $\eta^2 = .20$, revealed a greater proportion of faces encoded in the direct task ($M = .32, SD = .06$) correctly received an 'old' rating relative to the indirect task ($M = .28, SD = .07$). A main effect of Confidence, $F(1, 35) = 66.34, p < .001$, partial $\eta^2 = .66$, revealed a greater proportion of old faces received a high confidence 'old' rating ($M = .44, SD = .13$) relative to the proportion receiving a low confidence rating ($M = .17, SD = .09$). That is, the majority of recognition hits were accompanied by a high level of confidence. There was a significant Task by Emotion interaction, $F(3, 105) = 5.97, p = .001$, partial $\eta^2 = .15$, and a marginal three-way interaction between Task, Response, and Emotion, $F(3, 105) = 2.23, p = .085$, partial $\eta^2 = .06$. Follow-up paired t tests revealed no EEM effect within high and low confidence responses for faces encoded in the indirect task (see Figure 8a). For faces encoded in the direct task, the proportion of angry faces associated with a high confidence recognition response was greater relative to neutral faces, whereas this effect was not observed for low confidence items (see Figure 8b). Visual comparison of Figures 8a and b reveals an interesting pattern of results that may also be driving the three-way interaction. Negative emotions encoded in the indirect task received a lower proportion of correct old confidence ratings, whereas both fearful and angry faces received a higher proportion of correct old confidence ratings in the direct task. This pattern was especially pronounced for faces rated as highly confident.. There was no main effect of Emotion, $F(3, 105) = 1.42, p = .248$, partial $\eta^2 = .04$, no Task by Confidence response interaction, $F(1, 35) = 1.42,$

$p = .241$, partial $\eta^2 = .04$, and no Confidence response by Emotion interaction, $F(3, 105) = .380$, $p = .768$, partial $\eta^2 = .01$.

A.

B.

Figure 8. The proportion of old stimuli receiving either a high or low 'old' confidence rating for the A) indirect task and B) direct task (* $p < .05$, error bars = SEM).

A 2 (Confidence: '6' *sure* old, '5' *unsure* old) X 4 Emotion (happy, fearful, angry, neutral) within-subjects ANOVA was conducted for new faces (i.e., false alarms). A main effect of Emotion, $F(1, 35) = 2.80, p = .044$, partial $\eta^2 = .07$, revealed that fearful faces ($M = .22, SD = .15$) elicited a greater proportion of 'old' confidence responses overall as compared to happy faces ($M = .16, SD = .15$), $t(35) = -2.81, p = .008, d = 0.47$, and angry faces ($M = .17, SD = .15$), $t(35) = 2.02, p = .052$ (marginal), $d = 0.34$. *A priori* testing revealed that the proportion of fearful faces receiving a high confidence response was significantly greater than that of neutral faces whereas this effect was not observed for low confidence items (see Figure 9).

Figure 9. The proportion of new stimuli receiving either a high or low 'old' confidence rating (* $p < .05$., error bars = SEM).

Discussion

This thesis showed that explicit processing of happy, angry, and neutral, but not fearful facial expressions at encoding, unexpectedly increased recollection relative to implicit processing. In addition, implicit processing of fearful faces enhanced participants' subjective sense of recollection relative to neutral faces, whereas explicit processing did not. These findings suggest that implicit and explicit processing of emotional information have different effects on memory and that fearful stimuli, in particular, play a unique role in shaping these effects.

Increases in Recollection for Faces Encoded in the Direct Task

One of the most striking patterns in our data was the increase in recollection for faces encoded in the direct task. Higher levels of familiarity, accuracy, and confidence were also associated with these faces. Critically, this effect extended to neutral faces, which suggests that a non-emotion specific mechanism likely accounts for this unexpected finding. One such mechanism may relate to the levels of processing (LOP) theory proposed by Craik & Lockhart (1972). The LOP theory contends that various levels of semantic processing at encoding can have profound effects on memory retention. Studies revealed that deep encoding of words (e.g., asking whether a word fits in a particular category, e.g., "Is the word the name of an animal?") in contrast to shallow encoding (e.g., examining the perceptual characteristic of the word, e.g., "Is the word in capital letters?") resulted in higher levels of memory performance (see Craik & Tulving, 1975). The LOP effect has been consistently replicated and has also extended to various memory paradigms assessing recollection and familiarity (e.g., remember/know, process-dissociation, and receiver operating characteristic curve, ROC, procedures). These studies have shown that deep encoding leads to a large increase in recollection and a smaller but very consistent increase in familiarity (see Yonelinas 2002 for a review). LOP may account for the increases in performance associated with the direct encoding condition. That is, the emotional

discrimination task may have facilitated a deeper form of processing than the gender discrimination task. Explicit focus on emotional expressions is likely to have led participants to extract information about the portrayed individual's internal emotional state, their intentions, or reactions to events in the immediate environment (Whalen *et al.*, 2009). It seems plausible that processing such aspects may reflect a deeper level of processing than the judgments made in the gender discrimination task. While this assertion remains to be empirically tested, it is offered as an interesting and plausible explanation for the observed increases in recognition performance associated with the direct task.

Another possibility underlying the increases in recollection for directly encoded happy, angry, and neutral faces relates to transfer appropriate processing (TAP; Roediger & Blaxton, 1987). The TAP model proposes that memory performance benefits from the extent to which processes at test overlap with those engendered by the encoding condition. The explicit processes underlying R responses reflect that participants were experiencing conscious recollection of details associated with the events of studying specific faces at encoding. To the extent that these details involved processing of the emotional content of the faces, corresponding R responses may more closely resemble the explicit emotional nature of the direct encoding task (i.e. participants were required to make judgments about emotion type). Future exploration of a TAP hypothesis would be aided by an implicit test of recognition that similarly maps on to the implicit processing of emotion tapped by the indirect task.

EEM Effects

In addition to the increase in recollection associated with direct encoding, angry and happy faces also showed an EEM effect such that they selectively enhanced recollection relative to neutral faces. These findings are supported by studies demonstrating that the

amygdala is responsive to most facial emotions (Fitzgerald *et al.*, 2006; Somerville *et al.*, 2004; Yang, 2002). Notable, however, is the specific pattern of EEM findings for faces encoded in the indirect task, where fearful faces exhibited the strongest EEM effect, followed by angry and happy faces. This same pattern of results was also observed with the subjective ratings, where participants rated fearful faces as the most arousing, followed by angry and happy expressions. These parallel sets of findings are consistent with studies assessing human amygdala responses to all expressions, which provide evidence that the amygdala is most sensitive to fearful faces. For example, Fitzgerald *et al.* (2006) observed that the degree and spatial extent of amygdala activation tended to be greater for fearful faces than angry, happy, neutral, and other expressions. In addition, studies directly contrasting fearful faces against the other expressions have shown significantly greater amygdala activity to fearful faces than to angry faces (Whalen *et al.*, 2001) and happy faces (Morris *et al.*, 1996).

Interestingly, fearful faces exhibited a unique profile reflecting differential effects of task on expression of the EEM. Further exploration revealed that implicit processing of fearful faces enhanced recollection, whereas this effect was not observed for fearful faces processed under explicit conditions. More specifically, the analysis demonstrated that, unlike the other emotions, explicit processing of fearful faces was not accompanied by an increase in recollection of those faces. Several possibilities that may account for these findings are discussed.

The Fear Factor: What's Happening?

An examination of Figure 6a revealed there was a slight decreasing trend in R_{Hits} for fearful faces encoded under direct vs. indirect conditions. As hypothesized, this trend may be associated with reduced amygdala-arousal activity known to occur during explicit processing. The specificity of this effect to recollection is supported by studies that have demonstrated that

amygdala activation at encoding is related to subsequent memory for emotional items (Kensinger & Schacter, 2006) and “remember” judgments for those items (Dolcos, LaBar, Cabeza, 2004). This interpretation, however, begs the question as to why angry and happy faces were not susceptible to our task manipulation in the same manner as fearful faces. Consistent with the pattern of EEM results during implicit processing, the subjective ratings, and with evidence from the imaging literature, fear may have exceeded a threshold of amygdala-arousal activity that was differentially sensitive to the effects of our tasks (a “threshold model”). However without the presence of direct fMRI observation, it is not possible to confirm this hypothesis. Furthermore, while the vast majority of brain imaging studies report attenuated amygdala activity during explicit processing, there are exceptions (e.g., Habel *et al.*, 2007). Nonetheless, on the basis of the literature, I propose that the lack of an increase in recollection associated with fearful faces encoded under explicit conditions is associated with attenuated amygdala-arousal activity.

I further consider an intriguing possibility whereby EEM-related decreases in recollection for fearful faces encoded in direct task are being masked by LOP effects. In other words, not taking the LOP effect into account, I predicted a significant decrease in recollection for fearful faces encoded during the direct task. However in the presence of the LOP effect, and its associated increases in recollection, any decreases in recollection due to explicit processing may have been disguised. The unique profile associated with fearful faces may therefore reflect the presence of two factors: An intact LOP effect, where direct encoding yielded increases in recollection, and an LOP-independent effect, characterized by the EEM effect for fearful faces encoded in the indirect task and a diminished EEM effect under direct encoding conditions (see Figure 10).

Figure 10. Depiction of possible decreases in R responses for fearful faces being masked by LOP-related increases in R responses for both fearful and neutral faces encoded in the direct condition.

One final possibility I consider is that some qualitative difference unique to fearful versus other emotional expressions may account for the observed pattern of results. In other words, processing of fearful faces may have somehow interfered with mechanisms underlying the task effect (i.e., LOP-related processes). More specifically, there is reason to believe that indirect encoding of fearful faces was not susceptible to the effects of shallow processing of emotional information. Instead, a deeper form of processing may have taken place because in contrast to other emotions, the detection of fear-related information is highly automatic. The processing of

threat-related information, such as facial expressions of fear, is thought to be mediated by pre-attentive mechanisms that do not involve consciously controlled processes (Christianson, 1992). This notion is supported by studies that have manipulated subjective awareness. Using various techniques such as backward masking and binocular suppression, these studies have demonstrated the amygdala reliably responds to the presentation of fearful facial expressions that are outside conscious awareness (Morris *et al.*, 1998, 1999; Whalen *et al.*, 1998; Williams *et al.*, 2004). These findings have even extended to specific facial features such as fearful eye whites. Whalen and colleagues (2004) showed that backward masking of fearful eye whites, in contrast to other eye conditions (e.g., happy eye whites) produced circumscribed activation in the ventral regions of the amygdala. Taken together, these results suggest that the processing of fear-related information relies upon a high degree of “automaticity”. That is, I hypothesize that this type of specialized processing facilitated a deeper form of processing under indirect encoding conditions as compared to the other emotions. Moreover, the absence or inhibition of such automated processing under more explicit conditions may underlie the lack of increase in recollection observed in the direct encoding task. In evolutionary terms, further increases in recollection may not be necessary when conscious evaluation of threatening information is undertaken (e.g., assessing source of threat, degree of potential harm). Whereas under conditions of reduced stimulus analysis, recollection is high, ensuring that potentially significant events are not forgotten.

Enhanced Recollection versus Accuracy and Response Bias

Our analyses also revealed that emotional faces selectively enhanced the subjective sense of recollection relative to neutral faces; however this “boost” was not associated with enhanced overall memory accuracy. The recollective boost that accompanies highly vivid, emotional

memories has generally been assumed to be associated with greater accuracy. However this assumption has been challenged. A study by Talarico and Rubin (2003), for example, examined accuracy of flashbulb memories, extremely vivid, emotional-laden, unexpected events such as the terrorist attacks of September 11, 2001. Overall accuracy for the flashbulb memory did not differ from the accuracy for everyday events, in both cases declining with the passage of time. However, ratings of recollection and belief in accuracy remained heightened for the flashbulb memory, while those for everyday memories decreased over time. This dissociation between objective accuracy and the subjective recollective boost and for emotional information is further supported by studies examining memory for stimuli learned in the laboratory. Sharot and Yonelinas (2008) manipulated the encoding contexts in which emotional and neutral photos were presented to participants, and later asked them to provide remember/know judgments after a delay. While they found emotion enhanced an individual's recollective experience as revealed by a boost in "remember" judgments for emotional photos, participants were no better at recalling the type of task that was performed during the encoding of the emotional photos relative to neutral photos. Additional studies have also documented the dissociation between the enhanced subjective sense of recollection and accuracy using emotional words (e.g., Dougal & Rotello, 2007; Kapucu, Rotello, Ready, & Seidl, 2008). Our findings extend this growing body of evidence to the recognition of emotional faces.

Studies have begun to unravel the factors contributing to the enhanced subjective sense of recollection. Recent ROC modeling studies (e.g., Dougal & Rotello, 2007; Kapucu *et al.*, 2008) have demonstrated that recognition of emotional information is associated with a more liberal response bias, revealing participants are more willing to accept having previously experienced an emotional event even if it did not occur. Indeed our findings revealed that participants showed

greater false alarm rates to fearful faces as compared to neutral faces, which is consistent with other studies that reported increased false alarm rates for emotional events (e.g., Sharot *et al.*, 2004). While examining response bias was considered in the current study, the differential EEM effects observed for fearful faces that had been encoded in the indirect vs. direct conditions in our study cannot solely be explained by changes in bias. New items in our study represented photos of unstudied individuals expressing the same four emotions at study. Thus, because new items at recognition were not distinguishable by task conditions, there was no way for participants to employ differential task-related response criteria at test (personal communication with Benjamin, A., June, 2009). One possible future direction may be to directly test the influence of response bias when presented with differential encoding conditions. Transforming our design to a between-subjects design or using emotional stimuli that allow us to create false alarms that are identifiable by task would allow us more readily to assess response bias effects.

Confidence Ratings

Noteworthy is the pattern of confidence ratings that appeared to contradict the main finding of EEM for fearful faces in the indirect, but not direct, task. Although a non-significant trend, a greater proportion of negative faces encoded in the direct task was associated with higher confidence relative to neutral faces, and the opposite pattern was found for negative faces in the indirect task. This pattern of confidence ratings appear discrepant with the finding that R responses were increased for fearful faces in the indirect task only and suggest that R responses are not always accompanied by the highest levels of confidence. Indeed modeling studies have shown that participants use a range of confidence levels to report “remembering” (Dougal & Rotello, 2007). Participants were also explicitly told that R and K responses can be accompanied by equal levels of recognition confidence (Appendix A), allowing participants to use the entire

confidence range when providing an R response.

Limitations and Future Directions

There are several limitations in the current study. The encoding tasks were designed to reflect differential engagement of the amygdala and physiological arousal. As mentioned earlier, brain imaging will be needed to confirm that our indirect task, designed to elicit implicit emotional processing, is associated with significantly greater amygdala activity relative to explicit processing. In order to confirm the pattern of arousal activity across both encoding tasks, measurements of SCR can also be recorded simultaneously during brain imaging. Similar to the results of the subjective ratings, it is predicted that fearful faces under indirect encoding conditions, in particular, will elicit the greatest change in SCR and amygdala activation relative to the other emotions. Such within-subject measurements of arousal will also afford the opportunity to assess correlations between arousal and the EEM.

Also noteworthy is that whereas the vast majority of studies have reported relative decreases in amygdala activation during explicit processing, there is at least one known exception. Habel *et al.* (2007) found significantly greater bilateral amygdala activation during an explicit task (emotion discrimination) as compared to an implicit task (age discrimination). Thus, the possibility that the observed increases in recollection for directly encoded faces may be due to greater amygdala-arousal activity during explicit processing cannot be ruled out. However, our findings would not support this hypothesis, as one would have predicted the largest increase in recollection to occur for fearful faces encoded in the direct task. Moreover, Habel *et al.*'s (2007) findings are difficult to interpret in light of unequal task demands. Participants' accuracy for the implicit age-discrimination task was significantly lower than the explicit emotion-discrimination task. The authors suggest that the increased difficulty of their implicit task may have

inadvertently elicited greater cortical prefrontal areas leading to less amygdala activation due to inhibitory effects. Previous studies comparing performance accuracy between gender and emotion discrimination tasks such as the ones used in the current study have found no differences in accuracy between tasks (e.g., Critchley *et al.*, 2000). Participants in our study also reported no difficulties in performing either of the tasks. A future route of investigation includes assessing differences in task performance using measures of accuracy and reaction time. While no difference in accuracy between tasks is expected, it is predicted that direct encoding will be associated with longer reaction times, reflecting a deeper form of processing relative to indirect encoding.

Another limitation includes the possibility of task carry-over effects on our EEM findings. The indirect task was placed before the direct task to avoid the possibility of explicit emotional processing carrying over from the direct to indirect task. However it is possible that carry-over effects from the gender discrimination task influenced the emotion-discrimination task in ways that may have affected our findings. In addition to such carry-over effects, the temporal ordering of the tasks may have also resulted in different consolidation periods (longer consolidation time for faces encoded in the indirect task) and susceptibility to proactive and retroactive interference. Counterbalancing the task order across participants or employing a between-subject design are possible future directions in order to rule out the possibility of any task-ordering effects on our results.

The majority of our participants were female, which reflected the disproportionate amount of females enrolled in 1st year Psychology courses at Ryerson University. There is evidence to suggest that females are superior to males in facial emotion processing (e.g., faster reaction times for accurately identified facial emotions, Rahman, Wilsons, & Abrahams, 2004);

however, it is unknown how such differences may affect the EEM. Future studies may be aimed at investigating the role of possible sex differences in our findings.

Lastly, while recollection and familiarity estimates were used to assess the memory processes underlying Remember and Know judgments, ROC curves are also commonly used for assessing recollection and familiarity. These curves are generated by plotting hit rates against false alarm rates, and are useful for delineating the effects on accuracy and response bias (Dougla & Rotello, 2007). However one critical limitation of the ROC method is that in order to derive stable ROCs it is necessary to collect a large number of responses from each subject. ROCs based on less than 60 items per subject/condition (i.e. 60 new items plus 60 old items from each study condition) have been found to yield poorly behaved ROCs that are noisy and irregularly shaped (Yonelinas & Parks, 2007). In order to generate stable ROCs in the current study, a total of 240 unique faces would be needed. As mentioned earlier, the facial emotion databases currently available present a significant challenge to obtaining such a high stimulus number.

Clinical Implications

While future studies are needed to elucidate the mechanisms underlying the effects implicit and explicit processing on the EEM, implications for cognitive rehabilitation arising from this work are particularly important. A crucial aspect of Robertson and Mure's (1999) model of rehabilitation specifies that the target process of rehabilitation, in this case memory, be precisely and repeatedly activated by either bottom-up (stimulus oriented) or top-down (attention-related) techniques. If the target process, subserved by a damaged neural network, is repeatedly activated by means of these techniques, then the model proposes reinstatement of connectivity can occur (Bornhofen & McDonald, 2008). Neuroimaging evidence supports the

notion that implicit and explicit processing of emotional information map on to bottom-up and top-down processes respectively, as the former elicits greater subcortical involvement while the latter is associated with greater frontal involvement. In certain cases, one type of processing may be preferable over another. For example, based on the findings from the current study, I would predict that implicit-based techniques (practice orientation to cues such as eyes and mouth in the facial expression) applied to fearful faces would lead to greater memory relative to explicit-based technique (i.e. enhanced attention towards making emotional judgements) If such enhancement is found to be associated with greater amygdala-arousal activity relative to explicit processing, this would suggest cognitive recovery may be better stimulated under indirect emotional processing conditions that allow for maximal activation of networks.

Conclusion

This thesis demonstrates that implicit processing of emotional facial expressions via gender judgments enhanced participants' subjective sense of recollection for fearful faces, whereas explicit processing via emotion discrimination judgments blocked increases in recollection. In contrast to facial expressions of fear, happy, angry, and neutral facial emotion expressions were associated with increases in recollection following explicit processing. These findings lend themselves to the possibility of several interpretations, all of which await future testing. In addition to specifying the effects of implicit and explicit processing on memory for emotional information, a better understanding of their underlying mechanisms will have important rehabilitative implications for clinical populations that suffer from memory impairment.

Appendix A

Remember-Know Computerized Instructions:

Slide 1: In the first part of this experiment, you saw a series of faces. This was called the "study phase". You will now be shown all the faces you saw in the study phase along with new faces. You will be asked which faces are new and which ones you recognize from the study phase...

Slide 2: There are different kinds of recognition. For instance, recognition can bring back to mind something you recollect about what it is that you recognize. For example, you might recognize someone's face and REMEMBER thinking that person had similar eyes to yours.

At other times, recognition brings nothing back to mind about what it is you recognize. As when, for example, you are confident that you recognize someone, and you KNOW you recognize them, because of strong feelings of familiarity - but you have no recollection of seeing this person before. You do not recall anything specific about them.

Slide 3: The purpose of this part of the experiment is to look at how these different types of recognition apply to the faces that you saw earlier today in the study phase. I will briefly describe these now and then we will practice a few examples together to confirm that the instructions are clear.

Sometimes when you recognize a face as one you saw in the study phase, recognition will bring back to mind something you REMEMBER thinking about when the face appeared then. You recollect something you consciously experienced at that time.

Other times recognizing a face as one you saw in the study phase will not bring back to mind anything specific you remember about seeing it then. Instead, the face will seem familiar, so that you feel confident and KNOW that it was one you saw in the study phase, even though you do not recollect anything you experienced when you saw it then

Slide 4: You will be asked to indicate whether the face being shown to you is:

"NEW" (you did not see it in the study phase)

"REMEMBER"(you saw it in the study phase and remember something specific about it from when you saw it)

"KNOW"(you saw it in the study phase but you cannot remember any specific details)

Slide 5: So just to recap, you will answer "NEW" if you did not see the face in the study phase.

You will answer "REMEMBER" if recognition is accompanied by some specific or vivid recollective experience.

OR you will answer "KNOW" if you recognize a face with strong feelings of familiarity, but without any specific recollective experience.

Slide 6: After you make your selection of either "NEW", "REMEMBER" or "KNOW", you will be asked to rate how confident you are in your response. Let's practice...[proceed to verbal instructions]

Supplementary Oral Instructions to Computerized Instructions:

This can be a tricky task to keep straight because of all the types of responses. So although you've just read the instructions, I'm going to now go over them with you again and show how things will look on the computer.

You will see the faces one at a time. If you do not recognize the face as previously being in the "study phase" then you press **N** for "**New**". If you recognize a face, we would like to know how well you remember it. If it triggers something that you experienced when you saw it previously, like, for example, something about its appearance on the screen or the order in which the face came in, then I would like you to indicate this kind of recognition by pressing **R** for **Remember**. In other instances the face may remind you of something you thought about when you saw it previously, like it reminded you of a friend or family member, or an image that you formed when you saw the face, or something of personal significance that you associated with the face. Again, if you can recollect any of these aspects of when the face was presented, then I would like you to press **R** for **Remember**.

Do you have any questions about Remember responses? Can you give me an example of something that you remember? (confirm or clarify understanding as necessary)

At other times you will see a face and you will recognize it as one that you saw in the study phase, but the face will not bring back to mind anything you remember about seeing it then, the face will just seem extremely familiar. When you feel confident that you saw the face, even though you do not recollect anything you experienced when you saw it, I would like you to indicate this kind of recognition, by pressing **K** for **Know**. With know responses you are sure about seeing the face in the study phase but cannot remember the circumstances in which the face was presented, or the thoughts elicited when the word was presented. Do you have any questions about Know responses?

Following your selection of either "New", "Remember", or "Know" you will be asked how confident you were in your response. If you are confident that *have* seen the face, then we would like to know how sure you are by pressing **1** for "**Sure**", **2** for "**Unsure**" and **3** for "**Guessing**". If you were confident that you *have not* seen the face then we would also like to know how sure you are by pressing "**S**" for **Sure**, **U** for "**Unsure**" and **G** for "**Guessing**". Do you have any Q's? Let's practice...

It might be helpful to know that all of the faces that you saw in the study phase will be presented to you at some point. I'll stay here for the first while and you can ask me if you have any Qs as you go along, but then I might slip out for a bit. This last part will take about 15-20 minutes and is at your own pace. Whenever you're ready, press the spacebar to begin...

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