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The role of recursive reminders on memory updating of emotional stimuli

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THE ROLE OF RECURSIVE REMINDINGS ON MEMORY UPDATING OF EMOTIONAL STIMULI

A Dissertation

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Louisiana State University and
Agricultural Mechanical College
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in

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by

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Abstract

It has been argued that emotional memories are harder to update than neutral memories (Novak & Mather, 2009; Sakaki, Niki, & Mather, 2012) and that the cause is that emotional memories are subject to greater levels of proactive interference. This explanation was questioned in this paper and another explanation – the recursive reminding hypothesis (Hintzman, 2004) was considered. This hypothesis was used to explain the previous findings by suggesting that the reminders embedded in emotional memory representations are stronger than neutral reminders (as supported by a preliminary experiment) and therefore attract attention internally during re-presentation, resulting in less attention toward the external stimulus and thus poorer encoding of it. The hypothesis served as the motivation for two experiments using the memory updating task. In each, the critical conditions involved manipulations designed to reduce the amount of attention directed externally during re-presentation. The noticing manipulation in Exp. 1 did not have an effect on memory performance, however the measure did show that people are equal in noticing emotional and neutral discrepancies. Highlighting a location change (Warning condition) in Exp. 2 also did not have an effect on memory performance, however providing feedback (Feedback condition) did. Specifically, providing corrective feedback during re-study reduced the repetition of emotional errors and promoted better veracity assessments of emotional location memories. The results of both experiments indicated that previous updating findings are not as robust as previously thought. The results also indicate that differences in meta-cognitive processes between emotional and neutral information are important in understanding how repetition affects memory representations.

Introduction

The world we live in is dynamic and constantly changing. Therefore it is important that we are able to adapt to these changes and learn efficiently. Some factors or properties of an event may affect how we are able to learn, and some may not. For example, imagine you are at a convenience store and two men enter, one of whom is holding a gun. They yell out to everyone to take out all of their money. You try to hide behind something but realize they have already seen you, so you move back and have them in your view again. The man with the gun hands it off to the other thief, so he can walk over to the attendant to retrieve money. Now imagine a more neutral version of this scenario with similar components. You are at the store and two men enter; one of them has a cellular phone in his hand. They yell out that somebody has left their lights on in a car outside. You turn to get a drink from the cooler and when you turn back they are again in your view. The man with the phone passes it to the other man, so he can walk over to the attendant to pay for gas. Both scenarios are complex and raise some interesting questions about what information you will remember about the event. Will you better remember the gun or the cellular phone (*item memory*)? Will you better remember the men holding the gun or the ones holding the cellular phone (*associative memory*)? Will you better remember which person last held the gun or last held the phone (*memory updating*)? This last question is of most interest in this paper: Is updating memory different for negatively arousing items than for neutral items?

In this paper, I begin by reviewing research regarding the effect of emotion on item memory (Christianson & Loftus, 1991; Kensinger, 2004; Kensinger & Corkin, 2004; Sharot & Yonelinas, 2007; Talmi & Moscovitch, 2004), associative memory (Guillet & Arndt, 2009; Jones, O’Gorman, Byrne, 1987; Mather, 2007; Mather & Sutherland, 2011; Pierce & Kensinger, 2011), and meta-memory processes (Kensinger, 2009; Magnussen et al., 2006; Phelps & Sharot, 2008; Talarico & Rubin, 2003; Zimmerman & Kelley, 2010). I continue by describing the results of research on emotion and memory updating that show that neutral memory representations are more accurately updated than emotional memory representations (Novak & Mather, 2009; Sakaki, Niki, & Mather, 2012). Similarly, the results of harbinger research show that neutral cues associated to neutral items are more easily used to create subsequent associations than cues previously associated to emotional stimuli (Mather & Knight, 2008; Sakaki, Herrera, & Mather, 2013). I will then describe the relationship between the findings on memory updating

to research conducted in our lab where repetition benefitted neutral item memory more than emotional item memory (Karam-Zanders & Lane, 2013). I will argue that current explanations of the effect of emotion on memory updating and related findings are insufficient, and therefore propose one based on the recursive reminding hypothesis (Hintzman, 2004; 2010). This hypothesis states that memory representations for repeated stimuli include reminders of those previous encounters. I will assert that when items are presented more than once, the memory representation for emotional items develops a stronger embedded reminding than the memory representation for neutral items, and discuss the results of a preliminary experiment that supports this notion. In this view, more attention is focused internally toward the reminders of emotional repetitions causing less attention to be directed toward the external stimulus, leading to *less benefit* from repetition for emotional than neutral reminders. I describe two experiments that manipulate how much attention is allocated to the external stimulus at re-presentation. The first experiment was designed promote a comparison of the external stimulus and the internal memory representation. The second experiment was designed to alert the participants to the need to pay increased attention to the external stimulus. I conclude with a discussion of how these results contribute to the scientific literature and suggest future directions.

Emotion's General Effect on Memory

The effect emotion has on memory formation and representation has been studied extensively (see Kensinger, 2009; Levine & Edelman, 2009; Mather, 2007; and Reisberg & Heuer, 1994 for reviews). Despite the layperson's perception that emotion generally enhances memory (Kensinger, 2009), the actual pattern of findings is more complex. Compared to neutral stimuli, people tend to have better item memory (e.g., Burke et al., 1992) and reduced forgetting over a delay (e.g., Sharot & Yonelinas, 2008) for emotionally arousing stimuli. Furthermore, there is evidence that emotion has effects across all stages of memory processes including encoding, consolidation and retrieval. I review this research next.

Emotion and Encoding.

Encoding is the process of inputting information into the memory system for storage and later retrieval. One major difference between emotional and neutral memories is the way information is attended at encoding. Attention is a limited resource, and the amount of attention we use and how selectively we focus our attention on an external stimulus can depend on our task and properties of the

environment (Treisman, 2006). It is thought that emotional information receives more focused and enhanced attentional resources relative to neutral stimuli (Easterbrook, 1959; Levine & Edelman, 2009; Mather & Sutherland, 2011). There are three separate, but similar explanations of how this difference in attention is processed.

According to the narrowing-of-attention hypothesis (Easterbrook, 1959), emotional arousal narrows the focus of attention to central information and away from peripheral information, resulting in more accurate memory for central details. In the store scenario, the gun or the phone would be considered *central information*¹ as it is important to an understanding of the event (see Levine & Edelman, 2009, for a debate about what constitutes central information). Other less important information such as the store clerk, other customers, or what items were on the counter would be considered *peripheral information*. In contrast, with a neutral event, attention is more likely to be spread more broadly across central and peripheral information, with the result that less central detail is encoded than in an emotional event. An example of research that supports this hypothesis comes from an experiment (Christianson & Loftus, 1991) where participants were shown a series of slides depicting an event that varied in terms of whether a critical slide was either negatively arousing or neutral in nature. The results indicated better memory for the central details and poorer memory for the peripheral details when the critical slide was emotional, and the difference between these two types of details was not as large when the critical slide was neutral, thus supporting Easterbrook's (1959) narrowing-of-attention hypothesis.

Levine and Edelman (2009) argue that attention is allocated differently to emotional and neutral information because emotional stimuli tend to be more relevant to the goals of the observer (the *goal-relevance hypothesis*). According to this approach (Levine & Edelman, 2009), information relevant to the goal of the perceiver is salient and attracts attention. When no other prominent goal is in mind, negatively arousing stimuli are thought to trigger the universal goal of survival and therefore attract attention.

¹ Common definitions of "central features" include: *attentional magnets* which are perceptual features that capture attention; *spatially integral features* which are a part of or proximal to the critical stimulus; *temporally integral features* which occur during the time of the critical event; *conceptually integral features* are important to the story of the event so much so that the event would not make sense if the features were omitted; and *goal-relevant features* are critical to the perceiver's current goal (Levine & Edelman, 2009).

Similarly, Mather and Sutherland's (2011) arousal-biased competition model explains that information is in constant competition for attention, which is limited, and therefore priority has to be given to some items over others. They assert that arousal increases this competition, resulting in enhanced processing of attended information when arousal is present. Priority can be given to items that perceptually attract attention (bottom-up) or that are relevant to the perceiver's goal (top-down). With all else being equal, emotional stimuli tend to be more perceptually salient and consequently receive bottom-up priority. Because of this, emotional stimuli tend to be deemed important, similar to the claims made by the goal-relevance approach (Levine & Edelman, 2009). Despite minor differences in the underlying mechanisms, all three theories posit that emotional information tends to attract attention as a result of its inherent importance, resulting in enhanced memories of emotional items (the *emotionality advantage*, Kensinger, 2007).

Enhancement to the encoding of emotional stimuli occurs even when attention is disrupted (Clark-Foos & Marsh, 2008; Kensinger & Corkin, 2004). In Clark-Foos and Marsh, participants were presented with words that were negative and arousing, negative and non-arousing, or neutral. Participants studied these words alone or while performing a concurrent task (thus dividing attention). The results showed that when there was no concurrent task, memory for both negative word types (arousing and non-arousing) was better than for the neutral words; however, when attention was divided, recognition memory for negative *arousing* words, but not negative non-arousing words, was better than memory for neutral words. These findings indicate that the memory benefit for emotionally arousing stimuli tends to occur more automatically, and processing is less controlled and deliberate compared to neutral or negative non-arousing stimuli.

The encoding of emotional information also activates different neuroanatomical structures than the encoding of neutral information. When an emotional stimulus is attended, the amygdala (a brain structure in the medial temporal lobe that processes emotional information) becomes activated, which increases activation in the hippocampus (a brain structure in the medial temporal lobe that processes memorial information). This excitatory relationship enhances memories of emotional information (Kensinger, 2004, 2009). The activation for attended neutral information bypasses the amygdala and thus does not receive enhanced hippocampal activation. Studies have shown that activation of the

amygdala at encoding is correlated with accurate memory retrieval at test (Cahill et al., 1996; LaBar & Cabeza, 2006). In addition, the amygdala can enhance activation in sensory cortices, which promotes perceptual processing of emotional stimuli (Kensinger, 2004). Therefore, encoding of emotional information is more likely to activate the amygdala which enhances processing in the hippocampus and sensory cortices, all of which increases the likelihood that emotional items will be more effectively encoded into memory than neutral items.

Emotion and Consolidation.

The neurological differences between the processing of emotional and non-emotional information extend to consolidation (the process by which information transfers from shorter- term memory into a stable long-lasting long- term memory representation, usually during a sleep cycle). Studies have repeatedly shown that an emotionality advantage in memory is more likely to occur after a delay long enough for consolidation to occur (given that consolidation occurs during sleep, one night's sleep suffices for consolidation effects to be obtained; Cahill, Gorski, & Le, 2003; Pierce & Kensinger, 2011; Sharot & Yonelinas, 2007). Furthermore, this consolidation enhancement has been tied to neurological processes that are induced at encoding for emotional stimuli. Patients who have damage to the amygdala (LaBar & Phelps, 1998), or people who have their stress hormone receptors in the amygdala blocked (using the drug propranolol; LaBar, 2007; LaBar & Cabeza, 2006), do not show an emotionality advantage in memory. Altogether, emotionally arousing information is neurologically processed differently from neutral information, which can lead to stronger consolidation, resulting in a more accurate memory representation over time.

Emotion and Retrieval.

Retrieval (the processes involved in accessing target memories in response to a cue) is enhanced by emotionality because the increased attention, neurological activation, and consolidation of emotional memories result in increased accessibility to these memories. In addition to encoding and consolidation factors, the retrieval process itself can be different for emotional and neutral memories. Talmi and Moscovitch (2004) found that emotional items appear to be more strongly related to each other by way of category membership. Participants in this experiment studied lists of words that were emotional, categorized neutral, or uncategorized neutral, and were allowed to freely recall them. Results

revealed that the emotional and categorized neutral items were recalled more than the uncategorized items. The authors argue that these results are due to the fact that emotional information tends to be more strongly related semantically and belong to the same category (e.g. “negatively arousing information”), which aids subsequent memory. Essentially when an emotional memory is retrieved, this activates the amygdala (Buchanan, 2007), which reinstates the emotional category (Mather, 2009) by way of reinstating the emotion itself (e.g. mood-dependent memory effects²; Eich & Metcalfe, 1989). This process can trigger the retrieval of other (related) emotional memories that can facilitate the retrieval process by way of their strong contextual relationship.

Overall, when an emotionality advantage has been found in the literature, there are a number of factors that may contribute to this effect: improved encoding via attention, enhanced consolidation via activation of brain structures and the release of stress hormones, or more successful retrieval via increased accessibility and categorical similarity.

Emotion and Associative Memory.

Most of the benefits of emotional over neutral information in memory are at the item memory level. Referring back to the scenario discussed in the beginning, the gun is a *negatively arousing item* and the cellular phone is a *neutral item*. The person holding the item would be associated with the item. In order to remember who has the item, you must *bind* the item and who has it into your memory representation for that item. Therefore, binding the item to the person who has possession of it is considered *associative memory*, or *memory binding*.

Research has shown that information associated to emotional items is sometimes less likely to be bound and remembered than information associated to neutral items (see Kensinger, 2009 and Mather, 2007 for reviews), especially on an immediate test (Jones et al., 1987; Pierce & Kensinger, 2011). For example, Pierce and Kensinger (2011) had participants study pairs of words that were negatively arousing, positively arousing, or neutral. At test, pairs of words were presented that were *intact* (the same studied words were presented in their original pairing), *rearranged* (both words had been studied, but had

² Mood-dependent memory effects refer to the finding that information that is learned when a person is in one mood (e.g. sadness or happiness) is better retrieved when in the same mood, than when he or she is in a different mood (Eich & Metcalfe, 1989).

been paired with different words), or *new* (neither word in the pair had been previously studied), and the participant indicated if the pair was intact, rearranged, or new. This procedure was designed to solely test memory for the association without being confounded by memory for the items (as all of the items in the intact and rearranged pairs were old and therefore familiar). They found that on an immediate test the judgments for the negatively arousing rearranged pairs yielded the most errors compared to the positively arousing and neutral pairs. This suggested that memory binding for the negative words were worse than for positive and neutral words. There are data suggesting that the timing of the test might influence the effect of emotion on associative memory, as Jones et al. (1987) and Pierce and Kensinger (2011) found that emotional word associations were better remembered than neutral associations after a delay. However, this pattern may differ according to stimuli type. For example, Butler (2013) found poorer associative memory for emotional than neutral pictures both immediately and after a delay. Thus, findings are inconsistent in the literature with respect to the effects of emotion on associative memory.

It has been suggested that emotional arousal affects some types of features positively and other features negatively or not at all. More specifically, there is evidence to suggest that if the information is intrinsic to the object (Kensinger, 2009; within-object, Mather, 2007), such as its color or location, then its association is more likely to be enhanced by emotional arousal than if the information is extrinsic to it (between-object), such as another item. However, this overall pattern is not always obtained as within-object binding is not always more successful for emotional items than neutral items (Novak & Mather, 2009), and between-object binding has been sometimes been found to be more successful for emotional items than neutral items (Guillet & Arndt, 2009).

The typical finding of worse associative memory for emotional items is thought to occur as a byproduct of the way attention is allocated at encoding (Mather, 2007; Mather & Sutherland, 2011). As described above, emotional information attracts attention, which results in less attention directed towards peripheral information. Attention is needed in order to bind the item to its associate. Returning to our store scenario, the gun may usurp so much attention that there may not be enough to accurately bind the person to the gun in the memory representation, as compared to the situation where the person is holding

a phone (e.g. the *weapon focus effect*³, see Steblay, 1992, for a meta-analysis). However, the effect of emotional arousal on binding can vary depending on how attention is focused at encoding. According to the arousal-biased competition model (Mather & Sutherland, 2011), if associating information together is a priority, then arousal can enhance the binding (Guillet & Arndt, 2009). However if creating an association is not intentional, then binding will less likely occur if there is emotional arousal due to attention deployment.

Emotion and Meta-memory Processes.

People believe that memory processes are affected by whether we are remembering emotional or neutral information (Kensinger, 2009). For example, Magnussen et al. (2006) administered surveys to 1000 people in order to determine what laypeople believe about memory. They found that people believe that dramatic events are more memorable than neutral events. When they asked participants “*Sometimes people become witnesses to dramatic events. Do you think memory for such events is worse, as good as, or better compared to memory for everyday events?*” Seventy percent of respondents indicated that in general, memory is better for dramatic events than everyday events. Interestingly, that belief is incorrect. A majority of the research surrounding this topic comes from research on flashbulb memories (e.g. Talarico & Rubin, 2003).

A flashbulb memory is an unusual, important event that elicits intense emotional arousal. Flashbulb memories are characterized as memories of events we sense are remembered perfectly in its entirety, including all surrounding contextual information. Typical examples of flashbulb memories are the assassination of American president John F. Kennedy, and more recently, the terrorist attacks in New York City and the Pentagon on September 11th, 2001. People who remember events such as these usually feel as though they remember everything about their experience of those moments: where they were, who they were with, how they learned about the event, the time and day, and importantly, how they felt. Research on flashbulb memories has consistently found that the accuracy of the contextual details remembered from a flashbulb event is not better than for memory for details of contextual information of

³ The weapon focus effect is a finding in the eyewitness memory literature that people often have worse memory for a perpetrator when he or she is holding a weapon as opposed to when holding something non-threatening or neutral. This effect is thought to be a function of where attention is allocated during encoding (toward the threatening item and away from the perpetrator holding it). See Steblay (1992) for a meta-analysis of research that has examined this effect.

most other life events (Talarico & Rubin, 2003). The difference between these highly emotional events and ordinary ones concerns people's *sense* of memory accuracy, or the confidence in such memories. Research has shown that while confidence can be a reliable indicator of accuracy for neutral memories, it is less so for emotional memories (Phelps & Sharot, 2008).

Phelps and Sharot (2008) suggest that when judging the confidence we have in the accuracy of a memory, we rely on different processes if the memory was emotional in nature as opposed to if it is neutral. Specifically, neuroimaging studies have demonstrated that when people report a strong sense of recollecting details of a neutral memory, the posterior parahippocampus is activated. This area is also related to memory recognition of perceptual scene details. Activation in this area, however, is not related to the subjective sense of recollection of emotional events. Instead, activation of the amygdala is related to the recollective experience of emotional memories. In other words, when retrieving complex neutral memories, people use activation of a brain area responsible for memorial detail to judge the strength and accuracy of that memory. On the other hand, when retrieving a complex emotional memory, people use activation of a brain area responsible for processing emotion to determine the strength and accuracy of the memory. Essentially, people are basing judgments regarding the confidence they have in their own memory of an emotional event on the wrong kind of information.

According to Phelps and Sharot (2008), a possible reason for the difference in the source of confidence-related judgments could be due to the difference in how information is processed at encoding. As was already mentioned, emotional arousal appears to narrow attention during encoding (Easterbrook, 1959), resulting in the processing of less information as compared to neutral information. As a result, fewer pieces of information are processed, but presumably processed more deeply. Therefore, when it comes time to judge the accuracy of the memory for an event, it could be that people rely on the strength of the memory for the information they do have, which involves a small number of central details in the emotional scenario, and more numerous central and peripheral details in the neutral scenario. So, as an example, people could encode the central details (e.g., a gun) very well but not who held the gun, and when judging confidence in their associative memory, rely on the strength of the item memory and memory for the emotion they experienced (via activation of the amygdala). On the other hand, in the neutral event, people have enough attentional resources to encode the item and its location, so when

they judge confidence in their associative memory they could be relying more directly on the strength of their memory binding (activation of the posterior parahippocampus). Overall, people tend to be more confident in their memories for emotional events than for neutral events, despite the fact that memory accuracy is equal. It appears as though people are making these meta-memory judgments on information that is not as indicative of accuracy for emotional memories the way they are for neutral memories.

The overconfidence in emotional memory representations in the above studies were assessed at retrieval. Research has also shown that people are more confident that they will later remember emotional information during encoding than they are about future retrieval of neutral information (Zimmerman & Kelley, 2010). By asking people to judge the memorability of word pairs by using judgments of learning (JOLs), Zimmerman and Kelley (2010) found that people rated negatively emotional word pairs as more memorable than neutral word pairs. Importantly, the judgments of learning were not related to performance on a cued-recall test of the word pairs. This finding reflects what people generally believe about memory for dramatic events (Magnussen et al., 2006).

Emotional meta-memory processes seem to be vastly different than those of neutral information and not related to memory accuracy per se. Confidence in emotional memory representations are based on different mnemonic and activation processes than confidence in neutral memory representations.

Repetition and Updating – Effects of Emotional Arousal

Another line of research suggests that emotional arousal that sometimes harms memory involves repetition of the information, particularly when aspects of the information change. Specifically, neutral memories appear to benefit more from repeated presentations than emotional memories (e.g. Karam-Zanders & Lane, 2013; Novak & Mather, 2009). An example of this work comes from the *memory updating* literature. Memory updating⁴ refers to modifying a long-term memory representation in order to account for a change in the external stimulus. For example, in order to accurately remember who is

⁴ The term *memory updating* used in this paper should be distinguished from *working memory updating*. In the working memory (WM) literature, memory updating occurs when a person is presented with an amount of information that exceeds his or her WM capacity. Given that WM is a temporary and limited store, one must replace older information with newer information in such an instance (Kessler & Oberauer, 2014; Szmalec, Verbruggen, Vandierendonck, & Kemps, 2011). The current use of memory updating is referring to long-term memory whereby one modifies an existing memory representation.

currently holding the gun or the phone in our store scenario, one would need to update their memory representation to reflect the newly changed handler.

Novak and Mather (2009) found that memory for the location of emotional pictures is harder to update than location memory for neutral pictures. In Experiment 1, participants saw a series of pictures (half negatively arousing, half neutral) in one of eight locations in a grid. After every block of study trials, participants were presented with each picture in the middle of the screen and were asked to indicate in which of the eight possible locations that picture was just presented. This study-test-study-test (STST) procedure repeated until the participant made each location judgment correctly for two blocks in a row. Overall, there was no difference in accuracy between emotional and neutral stimuli in the first block, but there was a difference in later blocks. Specifically, when participants made an error in the test phase in earlier blocks, they were more likely to repeat that same error for emotional items in later blocks, despite the fact that they had the opportunity to study the correct location in between test trials. In other words, participants failed to encode an accurate memory representation initially and then failed to update this error after seeing the correct stimulus again. These *repeat errors* were also correlated with arousal ($r = .36$) and valence ($r = -.31$) ratings as assessed in the pretesting of the stimuli. These results indicate that when an erroneous binding of item and location was made, it was harder to correct the mis-binding when the item was emotional in nature than when the item was neutral.

In a second experiment, the location changed for half the pictures after the third study-test block (refer to Appendix A for a schemata of the procedure). Experiment 2 was conducted in order to determine if proactive interference (a situation where previously learned information interferes with the learning of new information) was the cause of the Experiment 1 results. The researchers changed the location of half of the pictures in the fourth learning block, and compared location memory in the blocks before and after the change. Overall, there were more errors made in the block immediately after the change (Block 4) than in the block immediately before the change (Block 3). There were also more errors made for the emotional items than for the neutral items. This was qualified by a significant interaction that demonstrated that the difference in errors between emotional and neutral items was only evident *after* the change but not before the change. According to the authors, these results suggest that updating

emotional memories is harder than updating neutral memories because emotional memories produce greater proactive interference.

Further support for Novak and Mather's (2009) conclusions that there are differences in the way that emotional and neutral memories are updated comes from functional magnetic resonance imaging (fMRI) research. Specifically, the results of Sakaki, Niki, and Mather (2012) showed neurological differences between the updating of emotional and neutral memories. In this study, participants went through an initial learning phase where pictures (half negatively arousing, half neutral) were paired with neutral objects (e.g. a picture of a banana) or orienting tasks (e.g. answering the question "*have you seen similar scenes?*"). Then there was an updating phase where the previously learned pictures and a new set of emotional and neutral pictures were presented in one of two locations, followed by a picture-location test.

The rationale behind this paradigm was to determine if the original association of an item (i.e. a picture paired with an orienting task) would interfere with a new association to that item (i.e. a picture paired with a location). The level of interference could be assessed by comparing performance on the different item types to each other, and to the new items that did not have previous associations. Although there were no behavioural differences between the location memory accuracy of negatively arousing and neutral items, there were differences in the neurological activity during the updating phase. Specifically, they found that activation in the frontopolar orbito-frontal cortex (OFC) discriminated between old and new items when the stimuli were emotional, but not when the stimuli were neutral, which suggests that this brain area is involved in updating emotional (old) items. Furthermore, when the OFC was activated, it had negative connectivity with the medial temporal lobe (MTL), which includes the hippocampus, and this relationship was mediated by the amygdala. The authors concluded that in order for an emotional memory to be updated, the brain mechanisms responsible for protecting that memory must be suppressed, resulting in a difference in proactive interference between emotional and neutral memories.

Work conducted using another experimental paradigm lends support to the conclusions of the updating and emotion research. Using harbingers (cues that have a predictive values), Mather and Knight (2008; Experiment 1) presented participants with a neutral tone (harbinger) that repeatedly preceded pictures that were either neutral or negatively arousing. Participants were later asked to learn the pairing

of these harbinger sounds with digits. At test, the participants heard the tones and were asked to indicate which digit had been associated with the tone using a two alternative forced choice (2AFC). The results showed that the memory for the digits was better when they had been associated with a neutral harbinger than when they had been associated with an emotional harbinger. Mather and Knight (2008) interpreted this finding as indicating that there was stronger proactive interference for emotional memories than neutral memories.

These results as a whole (Mather & Knight, 2008; Novak & Mather, 2009; Sakaki et al., 2012) suggest that it may be more difficult to update or create new associations for emotional items than for neutral items. Mather (2009) concludes that this is because emotional items produce more proactive interference than neutral items. However, there are several reasons to think this conclusion may be premature.

First, in updating research, Novak and Mather (2009) found that when participants made location errors after an item changed locations, they were more likely to indicate the item's original location if the items were neutral than if they were emotional. This result is a clear case of proactive interference: the original location of the neutral picture interfered more with learning the new location than it did for emotional pictures. One common measure of the degree of proactive interference is the number of times participants erroneously recall previously learned information instead of information from the current context (e.g., an item from List 1 is recalled on a test for List 2 items, Wickens, 1970). Given that this pattern of proactive interference occurred more for neutral items than emotional items, this finding is inconsistent with the claim that emotional memories produce *more* proactive interference than neutral memories.

Second, when analyzing only the items for which the pre-change location memory was correct, participants were more likely to change their location response after the change trial (albeit to the incorrect location) for emotional items than for neutral items. The authors concluded that this was an indication that participants were more likely to notice that the location had changed for emotional items than for neutral items. As a result, they claimed that the updating impairment observed for emotional items was not due to the inability to notice a change, but rather due to an inability to learn new associations. I argue that this conclusion is premature given that noticing was not directly measured, and

this measure of performance may include additional cognitive processes that are not accounted for, such as poor initial encoding.

Third, recent research on the harbinger effect (Sakaki, Herrera, & Mather, 2013) found that the effect (that emotional harbingers were less likely to be associated to a subsequent item than a neutral harbinger) could be reversed if more attention is drawn towards the harbinger by increasing participants' awareness of the contingency (i.e., that it predicted emotionally arousing pictures; more about this topic will be discussed later). Put another way, they found that emotionally arousing information does not necessarily produce more interference in associative learning than neutral information. These results further limit the applicability of proactive interference as a comprehensive explanation of the emotion and updating results.

Finally, we (Karam-Zanders & Lane, 2013) found a pattern similar to the results obtained from the updating research in *item recognition memory*, in that memory for neutral information benefitted from multiple encounters to a greater degree than memory for emotional information. Yet, proactive interference is unlikely to have played a role in this finding. In updating research (Novak & Mather, 2009), all of the items on the test are previously studied (and thus are familiar) and the feature tested (a particular location) is associated with multiple items during the study phase. This discrimination becomes even more difficult after the location change trial, because of the association of pictures to previous locations. The stimuli in Karam-Zanders and Lane (2013) had no associated contextual information and the item recognition test did not require participants to discriminate previously studied items from other studied items (rather, they discriminated old from new, never studied items). Altogether, proactive interference does not appear to be a viable explanation of our results.

Despite the differences between the emotion and updating research and our studies, there is a similar pattern of results: neutral information benefits more from repetition than emotional information. Karam-Zanders and Lane (2013, Experiments 1 and 2) showed participants a series of pictures that were negatively arousing or neutral in nature. During the encoding phase, participants made an orienting task judgment (they determined whether the picture was easy or hard to describe, or whether or not the picture depicted something that could occur locally). One third of the pictures were repeated a second

time, another third were tested immediately, and the remaining pictures were only presented once. Forty-eight hours later, participants returned for an old/new recognition test.

The results of the delayed final test (Figure 1) showed that there was an emotionality advantage for the pictures that were presented once. Interestingly, there were no differences between neutral and emotional stimuli when the pictures were presented twice or studied once and tested once. In other words neutral information benefitted more from testing and repetition than emotional information. However, later experiments showed that this was the case only when participants completed the orienting task, promoting deep encoding. When participants simply viewed pictures at study, an emotionality advantage for once and twice studied items was found at the delayed test (though immediately tested emotional and neutral items were equivalent).

We concluded that the repeated presentations benefitted neutral stimuli more than emotional stimuli because they enhanced the neutral memory representations by creating separate unique representations (i.e. the contextual variability hypothesis, Jang & Huber, 2008; Pastotter, Schicker, Niedernhuber, & Bauml, 2010). This hypothesis states that testing allows the memory representation to be associated with the internal contexts (i.e. thoughts) surrounding the retrieval process, which leads to a more unique and distinguishable representation. We (Karam-Zanders & Lane, 2013) argued that there was more variability in the encounters of the neutral items than for emotional items, because emotional stimuli are more likely to trigger memories of previous encounters due to the emotion that is experienced and reinstated (Buchanan, 2007; Eich & Metcalfe, 1989; Mather, 2009; Talmi & Moscovitch, 2004). To relate this idea to the earlier store scenario, each time you see the gun, you will experience similar thoughts, feelings and internal contexts, whereas each experience with the phone would be more variable. Therefore, the memory representations for the emotional stimuli were less unique in part due to the reinstatement of the emotion during the second encounters, which lead to similar experienced contexts.

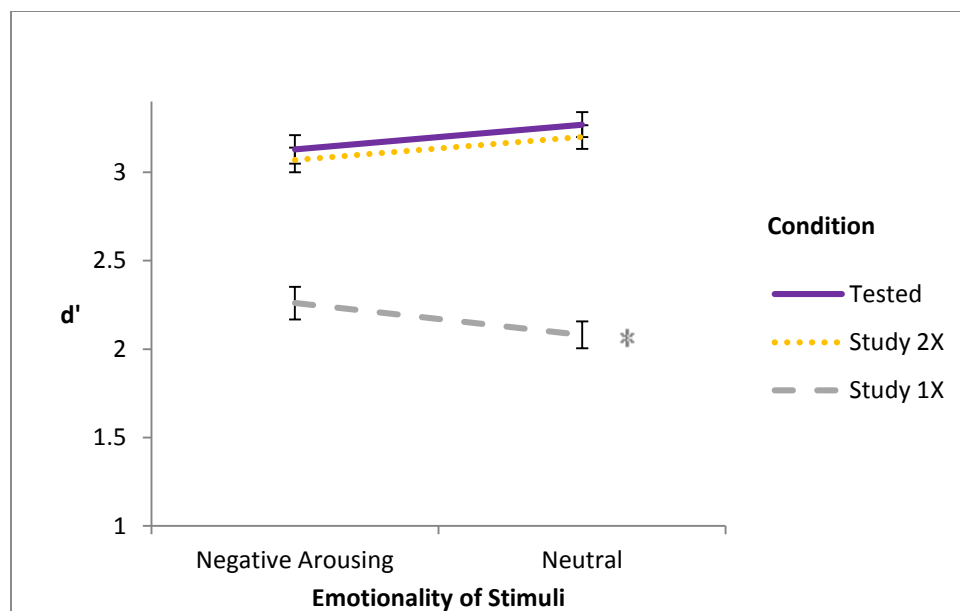


Figure 1. From Karam-Zanders and Lane (2013) Experiment 2. Results from the final recognition test 48 hours later after the items were either: studied twice, studied once, or studied once and tested. The dependent variable is d' which is a calculation of discriminability between old and new items. An asterisk denotes a significant difference between stimuli type.

I propose that the results in the updating literature (Novak & Mather, 2009) and work on the impact of emotional arousal on the testing effect (Karam-Zanders & Lane, 2013) reflect similar underlying processes, and therefore one unified mechanism should be able to explain both sets of results. Proactive interference cannot adequately explain the results found by Karam-Zanders and Lane (2013) and does not entirely explain the updating findings either (e.g. because it is inconsistent with some results). I argue that the recursive reminding hypothesis (Hintzman, 2004) is a better explanation of the findings. Although this hypothesis is not necessarily inconsistent with the proactive interference explanation, it provides a more specific description of the mechanisms by which people process repeated information, especially at re-encoding. In this paper, I attempted to use the recursive reminding hypothesis as a means to better understand the memory updating, and conducted experiments designed to influence the role of reminders in this task.

Recursive Reminders: An Alternative Explanation

A potential explanation for the way repetition differentially affects emotionally arousing and neutral memories is an extension of the *recursive reminding* hypothesis (Hintzman, 2004, 2010). According to this hypothesis, when an item is re-presented, the perceiver is reminded of the previous encounter. This reminding directs attention internally and consequently becomes imbedded in the

memory representation. Before I describe further details of the hypothesis, I will describe the circumstance that led to its development.

It was thought that making memory judgments relied on the strength of the memory representation, so that the stronger the memory, the more likely you will report to have remembered it. Hintzman (2004) conducted experiments to determine whether making judgments about how often something was presented (judgments of frequency, JoFs) and making judgments about whether you have seen an item before (a recognition task) relied on the same underlying memory process: strength of memory trace. He varied two dimensions of item presentation that should affect memory trace strength: frequency and duration. A series of names were presented to participants either 0, 1, 2, or 3 times. He also varied for how long the names were presented, either .5 or 2 seconds. Participants then performed both JoFs and old/new recognition judgments with a confidence rating (he used a 4-point recognition confidence rating, RCR, of “*sure new*”, “*maybe new*”, “*maybe old*”, and “*sure old*”). The RCR test was used so that he could plot receiver operating characteristic (ROC) curves⁵ on both judgment types for direct comparison.

Hintzman compared the qualities of the judgments for both tests in three separate ways. First, by using correlations between the two manipulations and the results of the tests he was able to calculate the amount of variance each manipulation accounted for in each test (by calculating r^2). The results showed that there was a difference in how the manipulations affected the judgments. Specifically, presentation frequency contributed to the majority of the variance of both judgments, but to a much greater extent for the JoFs ($r^2 = .945$) than for the RCRs ($r^2 = .806$), and presentation duration had less of an effect on JoFs ($r^2 = .038$) than RCRs ($r^2 = .125$). Second, when comparing old/new recognition discriminability⁶ between

⁵ An ROC curve plots hit rates (saying an old item is “old”) against false alarms (saying a new item is “old”) across biasing conditions, in this case, confidence (Wixted & Squire, 2008). It is a cumulative plot which means that it adds the hits versus false alarms over the biasing judgment, in this case high confidence in an item being new, then low confidence in an item being new, then low confidence in an item being old, then high confidence in an item being old. Or in the case of JoFs, items reported to have been presented 0, 1, 2, and 3 times.

⁶ Although there were discriminability differences between the judgment types as calculated by d' , there was also a difference in bias. Specifically, people were more conservative in the recognition judgments when making RCRs than when making JoFs. Therefore logistic d 's and A 's were conducted to account for the bias and the pattern of discriminability differences were still found between RCRs and JoFs.

the two judgment types, discriminability was stronger for RCR judgments than for JoF judgments. Third, the incremental z-ROC curves for the two judgments types were significantly different with respect to the slopes of the different presentation frequencies (f_s). In this variation of z-ROCs, the slopes indicate how different a representation is from the representation of an item with one less presentation. So the slope of an item presented once indicates how different its representation is from an item not presented, and so on. Hintzman found that for RCR judgments, the slopes of items presented once indicated that there was considerable variability between that representation and items not presented. The slopes of items presented twice and three times did not indicate much variability. In other words, the RCR judgments are strongly affected by whether an item was presented ($f = 1$) or not ($f = 0$), and not by how often an old item was presented ($f = 2$ and $f = 3$). On the other hand, the slopes for JoFs showed a different pattern. There was some variability in the slope of items presented once, however the largest variability was seen in $f = 2$, indicating that there was a considerable difference between the judgments made for items presented twice and those presented once.

These results led Hintzman (2004) to two conclusions. First, RCRs and JoFs do *not* rely on the same memory process. He argued for a dual-process account of the results (Yonelinas, 2002). Such an account states that memory judgments can be based on either familiarity (the sense that you have seen something before) or recollection (actually retrieving the learning experience). Given that the data did not support that the strength of the memory trace was relied upon to make both judgments, he concluded that recognition judgments rely on familiarity, and frequency judgments rely on recollection. The second conclusion is that there is something unique about the second presentation of an item (as was indicated by the variability of the incremental z-ROC slope in the JoF task for $f = 2$) above and beyond simply strengthening the memory trace (as was indicated by the lack of variability of the z-ROC slope in the RCR task for $f = 2$). He hypothesized that that unique contribution to the memory representation was the *reminding* of the previous encounter when an item is re-presented.

According to Hintzman (2004), each time an item is presented, it leaves a memory trace separate from other presentations in the item's memory representation. When an appropriate retrieval cue is presented, all memory traces of that item are activated in parallel. Based on his findings that something unique is occurring on the second presentation (compared to the first), he hypothesized that when an

item is presented a second time, its first presentation is spontaneously reactivated – it is reminding the perceiver of the item’s first presentation. This reminding experience (and all associated context) becomes embedded in the item’s memory representation, and the reminding depth grows with each encounter. Therefore, when a repeated item is presented, spontaneous reactivation occurs, and attention is directed internally towards the reminders, and away from the external stimulus. Although not all memory tests are sensitive to the effects of reminders (i.e. recognition tests), judgments of frequency are. The most informative frequency judgments are between items that were presented once (for which a memory representation exists) and items that were presented twice (memory representation that includes a reminding).

Consider a real world example of recursive reminding. Imagine you walk to your car in the parking lot and when it is in view you remember that there was a flyer on the windshield the day before (*spontaneous reactivation of reminding*). Your attention would be focused internally, perhaps remembering the flyer was promoting a new frozen yogurt store with a coupon, and that you want to go there this weekend. The next day when you see your car in the parking lot, you remember the flyer *and* that you are going to get the new frozen yogurt this weekend with that coupon (*spontaneous reactivation of the recursive reminding*). Because you are thinking about your internal thoughts, you might not see a bicyclist ride by in front you, as you might had you not had the spontaneous reactivation of the frozen yogurt flyer. This scenario illustrates how recursive reminders become embedded into a memory representation (in this case, of your car in the parking lot), and how being cued by the stimulus can reactivate those reminders, which draws attention internally.

One important characteristic of the memory representation in how it is affected by reminders is contextual variability between presentations (Hintzman, 2004, 2010). According to Hintzman (2004), reminders can be affected by study trial similarity in that the more similar each repetition context is to one another (i.e. if the encoding tasks are the same versus different), the more of an effective reminder it is (as estimated by higher JoFs for study trials with similar study contexts compared to those with different study contexts, Hintzman & Stern, 1978). In other words, the less contextual variability between the encounters with the same stimulus, the more reminders occur. Back to our flyer on the car example, if you park your car in the same parking spot each day, then you are more likely to be reminded of

yesterday's flyer when you see your car than if you parked it in a spot across the parking lot because of the similarity among presentation contexts.

Recursive Reminding and Emotional Arousal

It is possible to extend this hypothesis to emotional items by asking whether reminders in memory representations for repeated negatively arousing stimuli are stronger than for repeated neutral stimuli. Specifically, are re-presentations of emotional items more likely to spontaneously activate memory traces of previous presentations, leading to better encoding of the reminding into the memory trace as compared to re-presentations of neutral stimuli? If so, then perhaps the recursive reminding hypothesis can explain the differences in the benefits of repetition between emotionally arousing and neutral stimuli. Specifically, when emotional stimuli are re-presented, people are more likely to be reminded of the previous presentation leading to greater internally focused attention, than when the stimuli is neutral. If so, this would result in less attention directed at the external emotional stimulus and therefore less learning from the repetition as compared to neutral stimuli.

One possible explanation for a difference is that emotional items are processed more similarly across repetitions than is the case for neutral items. When we (Karam-Zanders & Lane, 2013) found that testing benefitted subsequent memory for neutral information more than emotionally arousing information, one of the explanations for the data was based on the contextual variability hypothesis (Jang & Huber, 2008; Pastotter et al., 2010). We argued that our data showed that neutral items benefitted more from testing because these items were more variable with respect to their internal contexts during the repetitions than was the case for emotional items (e.g., because the overlap of the emotion experienced when re-encountering the emotional items; Buchanan, 2007; Eich & Metcalfe, 1989; Mather, 2009; Talmi & Moscovitch, 2004). While variability in presentations appears to help recognition memory, it also leads to less reminding of previous memory traces (Hintzman & Stern, 1978).

For example, returning to the car in the parking lot scenario, imagine a negatively arousing version: as you approach your car in the parking lot you remember that you were mugged the day before as you were entering your car. You begin to feel the emotions you felt during that experience (*emotion reinstatement*). Perhaps your palms get sweaty and you remember that you were not able to reach for your cell phone in time. So you tell yourself to always have your phone in your hand. As you approach

your car the next day you remember the mugging and re-experience the emotions *and* you check your hand to make sure you are holding your phone. Now imagine that in both of those scenarios your car had been scratched while you were at work (*change in the external stimulus*). In which situation (the neutral flyer, or the emotional mugging) would cause more attention to be directed internally so that you do not notice the scratch on your car? Now imagine that the day after your car was damaged, police come to your office and inform you that they had footage of the hit and run on your car and ask you to file a report. In which of those two scenarios would you better remember the scratch on your car? I suggest that the spontaneous reactivation of the memory representation of the mugging scenario will be more engaging and processed more similarly than the flyer scenario. As a result, you would be less likely to notice that there was a scratch on your car, and have a worse memory representation for that scratch in the emotional scenario than in the neutral scenario.

Preliminary Experiment

In order to determine if reminders in emotional memories are stronger (i.e., more likely to be reinstated during re-presentation) than in neutral memories, I conducted an experiment that assessed judgments of frequency (JoFs) for emotional and neutral stimuli. In this experiment, 61 participants saw a series of 192 pictures (half were negatively arousing and half were neutral) 0, 1, 2, or 3 times, at a rate of 1 picture per second. At test, participants saw all the pictures and indicated how many times they had seen each picture (Figure 2). Overall, participants responded with significantly higher frequency judgments for emotional items ($M = 1.68$) than for neutral items ($M = 1.22$). Relative to actual frequency, judgments for the neutral stimuli were underestimated, whereas the judgments for the emotional items were more calibrated. The pattern of results for items shown once (for which a memory representation exists) and those shown twice (a memory representation that includes an embedded reminding), a key comparison according to Hintzman (2004), was different for emotional and neutral stimuli. Specifically, a significant interaction was obtained such that the discrepancy between the frequency judgments for emotional and neutral items was larger for items presented twice (effect size, $\eta^2 = .68$), than for those presented once (effect size, $\eta^2 = .51$). This finding supports the notion that the reminders of emotional memories are stronger than those of neutral memories.

Further support for the possibility that the difference in updating between emotional and neutral stimuli is due to a difference in their reminders comes from correlation data. The obtained frequency judgments correlated with the arousal ($r = .58$) and valence ($r = -.51$) ratings provided by the creators of the pictorial stimuli (Lang, Bradley, & Cuthbert, 2008). Thus, the more arousing and the more negative the valence of a picture, the higher the frequency judgment. This paralleled correlations that Novak and Mather (2009) found between updating, and the arousal and valence of the items. Taken together, these correlations suggest that recursive reminding could be a mediating factor between emotional information and updating of those memory representations.

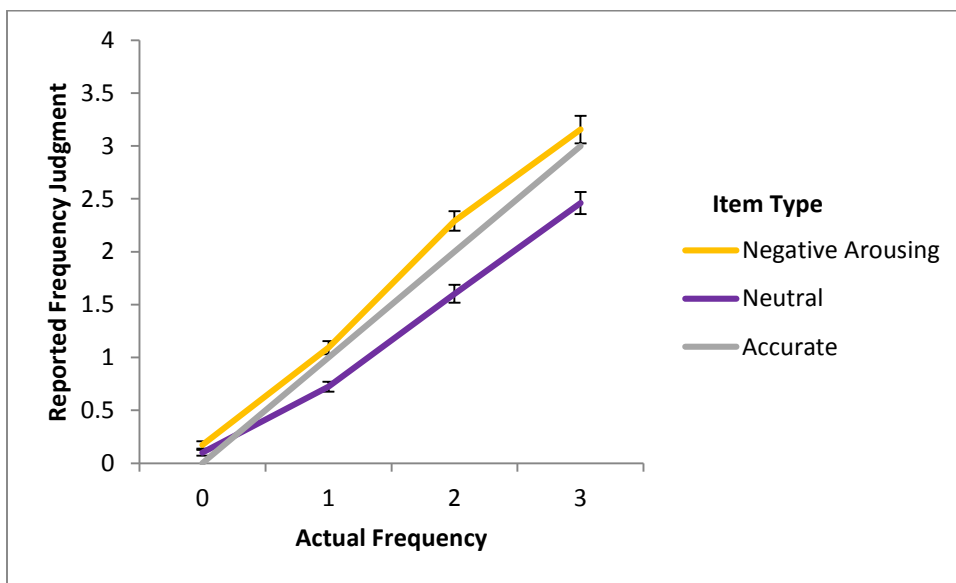


Figure 2. Results of the judgment of frequency test based on the actual frequency of presentation in the preliminary experiment. A line has been drawn to indicate perfectly calibrated performance.

Although the recursive reminding hypothesis has not yet been applied to study why emotional and neutral items differ in their repetition effects, the results of the preliminary experiment give reason to think that repetition of emotional items may differ from neutral items in the degree to which people are reminded of previous encounters. As a result, those memory representations may attract more internally directed attention resulting in insufficient externally directed attention necessary to learn from the stimulus. Therefore the direction of attention is mediating the relationship between emotion and memory updating.

Applying the Recursive Reminding Hypothesis to Memory Updating

In order to better understand differences in updating, it is important to first understand all of the steps involved in the updating process. Wahleim and Jacoby (2013) point out that in order to accurately remember that changes occurred to paired associates, one not only needs to encode the new pair, but also the old pair and the fact that they noticed a change when a change occurs. In their experiments, Wahleim and Jacoby (2013) employed a proactive interference paradigm⁷ that included pairs of words that were repeated across trials (A-B, A-B), changed across trials (A-B, A-D) and unique across trials (control pairs; A-B, C-D). On the final test, participants were asked to report the most recent target (B, D, D, respectively) that was associated with the test cue (A, A, C, respectively). This paradigm somewhat parallels the updating framework (i.e., the unchanged and changed item-location pairs) and adds an important control condition. According to Wahleim and Jacoby (2013), in order to accurately update information in the A-B, A-D condition, one needs to encode “noticing” into the memory representation. That way, when it is time for the test, being cued by item A will trigger the memory representation for A that includes its associations with paired items B and D, and noticing that A’s association had changed. The fact that B and D are encoded temporally provides the information necessary to respond correctly with D. The findings from this study suggest that a failure to correctly update memory is due to a failure at the *noticing* phase, highlighting the importance of awareness of change during associative learning.

In Figure 3, I have outlined the processes involved for successful memory updating to occur based on reading the recursive reminding hypothesis literature (Hintzman, 2004). Successful memory updating is measured as retrieval of the most recent memory representation when cued. In order for this to occur, the stimulus must first be encoded into memory by creating a representation. When the stimulus is encountered again, the cue *triggers* the spontaneous reactivation of the memory representation. While the memory representation is activated and the stimulus is present, one needs to *compare* them to determine if they match. This involves allocating attention internally *and* externally. If the external stimulus does not match the internal representation, then the observer needs to *notice* that there is a discrepancy.

⁷ Wahleim and Jacoby (2013) discuss proactive interference as an *empirical outcome*, not as a *theoretical mechanism*, and contrast it with proactive facilitation. In their experiment, when people noticed a change, proactive facilitation occurred (an earlier association *helped* memory for the later association), however when people did not notice a change, proactive interference occurred (an earlier association *harmed* memory for the later association).

The act of noticing needs to be encoded into the existing memory representation (Wahlheim & Jacoby, 2013). Once the discrepancy is noticed, the observer needs to *learn* from the external stimulus by allocating attention to the features that differ from the current memory representation, and creating a new memory trace that has the current information. At retrieval, the cue *triggers* the memory representation that has memory traces for both representations and the noticing of a difference between the presentations, and the correct information will be retrieved thus leading to successful memory *updating*. Given this framework for successful updating, it can be seen that any impairment in updating can be due to a failure at any of the stages. This conception allows for a determination for identifying a stage or stages where emotional and neutral memory representations differ.

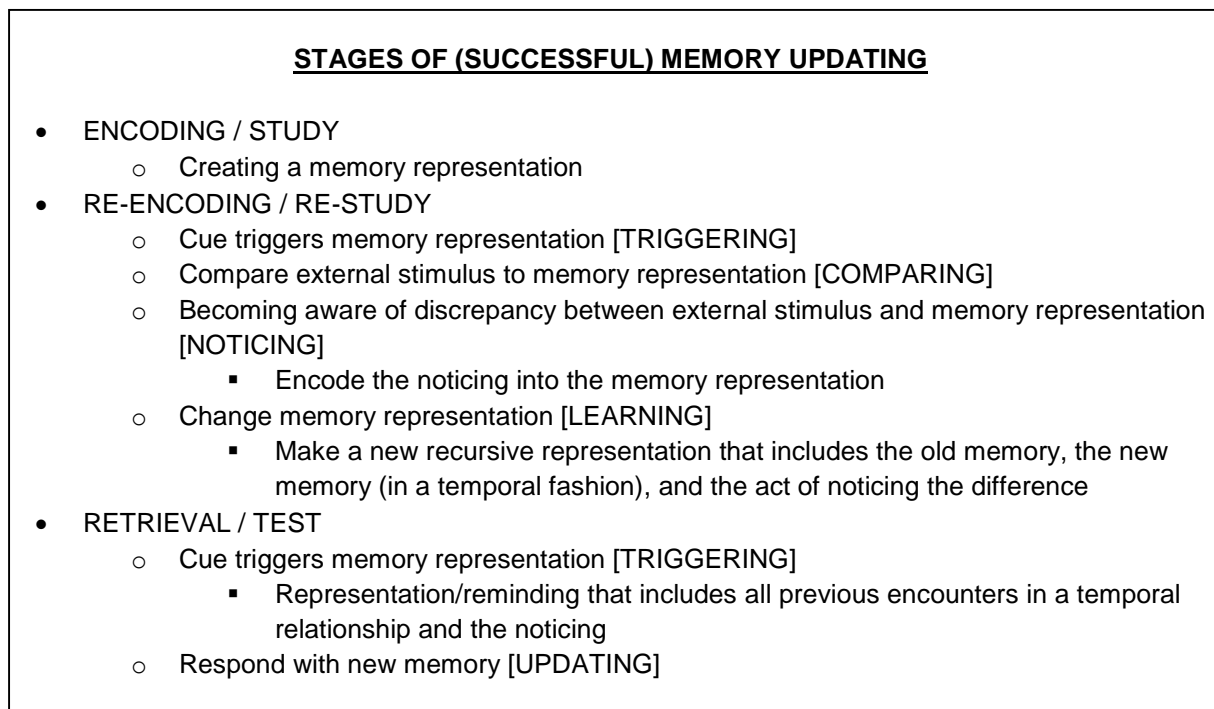


Figure 3. Schema of the phases involved in correct memory updating separated by stages of cognitive processing. Failure in any of the phases can hinder accurate updating. Terms used in the square brackets represent the associated stages as discussed in the document. This schema can be used to describe both types of updating: correcting an inaccurate memory representation and adapting to a change in the stimulus.

According to Novak and Mather (2009) the lack of updating of emotional memories is a failure during the learning phase due to interference from previous encounters with the stimuli. They arrived at this conclusion because they claim that emotional changes were *more* likely to be noticed than neutral changes, but were *less* likely to be updated. The authors assumed that there was a difference in noticing based on statistics that were calculated post hoc. Specifically, when conditionalized on correct pre-

change location judgments, the likelihood of changing a response post-change was considered to be a measure of noticing. However, these statistics do not necessarily measure *noticing* given that they were calculated post hoc and not measured during the noticing phase. Also, changing your previous answer does not necessarily mean that noticing a discrepancy occurred; perhaps the initial binding was poorly encoded.

In the following experiment, I overtly measured noticing during its occurrence to obtain an accurate measure of noticing. I did so in such a way intended to promote *comparison*. By promoting the comparison process, it was presumed to encourage the participant to focus on both the external stimulus and the internal memory representation. This is important because I hypothesized that people are worse at noticing differences between emotional stimuli and their memory representations than is the case for neutral stimuli because attention is more likely to be focused internally during re-representation of emotional stimuli. As a result of this direction of attention manipulation, I expected that the benefits of repetition for neutral and emotional stimuli will be equated, and so would memory updating.

Support for this expectation comes from a recent investigation of the harbinger effect (Sakaki et al., 2013), which demonstrated that the effect is not as straightforward as it was previously assumed. Their experiments showed that the harbinger effect, that neutral harbingers are more easily associated to new items than emotional harbingers, can actually be reversed when the participant is aware of the contingencies. In other words, when participants are aware that a harbinger is predictive of the outcome, emotional harbingers are more easily associated with a new item than neutral harbingers. The authors explain that awareness of contingency affects the way people process the information at encoding. Specifically, when aware, attention is focused on the harbinger and away from the outcome compared to when they are unaware of the contingency. As a result, the arousal experienced during encoding becomes integrated into the memory representation of the harbinger. Thus, the improved ability to form new associations to the emotional harbinger is a function of intentional encoding (as predicted by the arousal-biased competition model, Mather & Sutherland, 2011). Given this finding, I expected that changing the way people process the stimuli during re-encoding would affect the way the memory representations were updated.

In the following study, I explored the recursive reminding hypothesis as an explanation for previous findings in the repetition and emotion literature by attempting to influence the way attention is allocated during re-presentations of the stimuli. The proactive interference explanation (Mather, 2009; Novak & Mather, 2009) assumes that errors in updating emotional memories are due to a failure in the learning phase of updating. I hypothesize that these differences in the updating of different item types is a result of the way information is attended at re-presentation (comparing and noticing). Therefore by directing attention more towards the external stimulus and away from the internal representation I expect to increase the updating of emotional stimuli.

Experiment 1

For this study, I replicated the updating paradigm used in Novak and Mather's (2009) Experiment 2 with two major changes: confidence judgments were made during test trials and noticing judgments were made during study trials in one condition. This procedure was chosen in order to examine not only the updating of a location change in memory, but also repeat errors, which indicate failures to update recalled location errors to the correct associations. I assessed confidence in location judgments at each test. This measure was used to provide a clearer understanding of how people are assessing their memory for location, and whether that assessment can affect subsequent learning as measured by their behavior on the following test. Given the previous literature on beliefs about memory processes (Kensinger, 2009; Magnussen et al., 2006), flashbulb memories (Talarico & Rubin, 2003), and meta-memory judgments (Phelps & Sharot, 2008; Zimmerman & Kelley, 2010), I expected that participants would rate their confidence in emotional location judgments higher than in neutral location judgments. I also expected that the relationship between confidence and accuracy would be stronger for neutral items than emotional items. These results would support the idea that people do not notice changes to an emotional stimulus because they believe they have already learned it well and therefore do not pay attention to it.

In addition to the confidence judgments, half of participants made noticing judgments during study trials (the Noticing condition) and half did not (the Control condition). The purpose of this judgment was two-fold. First, it was used to assess noticing at the time noticing was occurring, and second, it was intended to promote a comparison between participants' internal memory representation and the external stimulus in an attempt to influence where attention was allocated. In order to answer the noticing question, the participant must compare the properties of the external stimulus to the memory representation for that item. This manipulation is presumed to direct where the attention was allocated during study, both externally and internally. By increasing attention to the external aspects of the emotional pictures, this was expected to equate the updating for emotional and neutral items.

Method

Participants.

This was a 2 (stimuli type) X 2 (condition) mixed design where the stimuli type was manipulated within-subjects and the condition was between-subjects. A power analysis was computed using G*Power (Erdfelder, Faul, & Buchner, 1996) to determine the ideal sample size in order to determine a two-way mixed model interaction with a small effect size of $f = .176$ (which is equivalent to a $\eta^2 = .03$) and it determined that a total sample size of 108 was needed to achieve .80 statistical power. One hundred twenty-six people participated in this study however the data of 18 people were not used in the analyses because of experimenter comments⁸ ($n = 10$) and performance indicating they were not exerting effort in the task ($n = 8$). For the latter group, I discarded the data of people whose accuracy on Tests 3 and 5 were more than two standard deviations below the mean. These two tests were chosen because performance was generally very high by the time they reached Test 3, and bounced back up on Test 5 after the change of half the items on the fourth trial. Therefore, the cut off for Test 3 was 70.3% correct and 54.7% correct for Test 5. After accounting for the discarded data, 108 participants were included in this study, 54 in each condition. Twenty-nine participants were male and 79 were female. The mean age was 19.29 years old with the ages ranging from 16 to 27 years. Participants received credit toward their psychology course in exchange for participating.

Materials.

The experiment was programmed and administered on computers using EPrime™ 2. The stimuli consisted of 64 pictures from the International Affective Picture System (IAPS; Lang et al., 2008). This database is comprised of 700 pictures, which participants have previously rated on dimensions such as arousal and valence in a norming study. Valence was measured by a scale that ranged from negative (*unhappy, annoyed, unsatisfied, melancholic, despaired, bored*) to positive (*happy, pleased, satisfied, contented, hopeful*). Arousal was measured by a scale that ranged from unaroused (*relaxed, calm, sluggish, dull, sleepy, unaroused*) to aroused (*excited, frenzied, jittery, wide-awake, aroused*). Half of the

⁸ Nine participants looked away from the screen during study phases and missed the presentation of items. Some of them closed their eyes, looked down, or looked at the computer screens of other participants. The data from the tenth participant was discarded because he or she accidentally began a study phase before the instructions were completed.

pictures used in this study were negative in valence and high in arousal and half were neutral in valence and low in arousal. Two independent samples t-tests demonstrated that the negatively arousing and the neutral pictures significantly differed in valence, $t(62) = 15.656, p < .001$, with negatively arousing pictures rated as more negative ($M = 2.56$) than the neutral pictures ($M = 5.81$). The pictures also differed in arousal, $t(62) = 11.192, p < .001$, with negatively arousing pictures rated as more arousing ($M = 6.00$) than the neutral pictures ($M = 3.91$). Given that half of the pictures changed location on the change block, there were two counterbalanced versions. Specifically, pictures were divided into two sets: one served as the unchanged items and one as the changed items, and this was counterbalanced across the experiment. The two sets of pictures were equivalent in valence and arousal, and independent t-tests ensured that there were no statistically significant differences between picture sets (all t s $< .1$, and all p s $> .95$). The pictures were presented on the computer screen in one of 9 locations on a 3 X 3 grid.

Procedure.

The procedure was designed to replicate and extend Experiment 2 of Novak and Mather's (2009) updating paradigm. When all of the participants scheduled for the session arrived, the experiment began with the administration of the informed consent form, which included a warning of the disturbing nature of some of the stimuli. The participants were then presented instructions for the task on the computer and read out loud by the experimenter. The procedure followed a study-test, study-test (STST) format for 5 blocks, where each block contained one study block and one test block. On each study block, the pictures were presented in one of the 8 outer locations on the grid for 3 seconds, with an intervening blank screen (inter-stimulus interval, ISI) for 2 seconds. After all 64 pictures were studied in random locations, there was a test block. Each studied picture was presented in the middle of the grid, and the participant indicated in which of the 8 locations that picture was previously presented by pressing a number from 1-8 associated with each location. They also indicated their confidence in the location judgment by responding to a 7-point Likert scale of confidence, where 1 represented "*not at all confident*" and 7 represented "*highly confident*" (similar to that used in Kim et al., 2012, Experiment 2). After all of the picture-location associations were tested, another study-test block began. Each sequence of items in the study and test blocks was presented in random order. Starting on the second block, the participants in the noticing condition made a noticing judgment for each picture during the study blocks. Specifically, they

were asked “*is this picture in the same location as you remember it?*” and they were instructed to answer “yes” or “no” by pressing designated keys on the keyboard during the ISI. The control group never made this judgment. This STST pattern continued for a total of 5 blocks. On Block 4, half of the pictures of each type changed locations (the *change block*) during the study trial, and Block 5 was exactly the same as Block 4. Instructions for the task were provided before the experiment began, and, for the noticing condition, additional instructions about the noticing judgments were provided between the first and second blocks. All participants were aware that the purpose was to remember the item-location association and that at some point items could change locations, and therefore their task on each test was to report the most recent location where the picture was most recently presented. After the experiment was completed, the participants were asked demographic and post-experiment questions (Appendix B). When all participants in a session finished, they were thanked and debriefed.

Results

There are four major groups of statistical analyses that were performed: those related to Novak and Mather’s (2009) updating errors; those concerning the Noticing judgments; confidence judgments; and exploratory analyses including post-experiment questions. Within the results section, I will discuss a priori predictions inspired by the recursive reminding hypothesis and the obtained results. Figure 4 depicts the overall performance collapsed across both conditions.



Figure 4. The overall accuracy across test, between stimuli type and collapsed across conditions. Performance is calculated as the proportion of location errors made.

Updating Errors.

According to Novak and Mather (2009), there are two types of updating errors that can occur in this paradigm and those were the dependent variables measured in this section: *repeat errors* in Blocks 2 and 3, and *change errors* for the changed items in Block 4. For both types of errors, I predicted a main effect of condition in that the noticing manipulation should decrease updating errors as compared to the control condition, because promoting the process of comparing should lead participants to improve their noticing of discrepancies between where the picture is located and where they remember the picture being located. I also predicted a significant interaction because I expected to replicate Novak and Mather's (2009) finding of higher repeat errors for emotional locations than neutral locations in the Control condition, however, if the noticing manipulation is effective, it should equalize the updating errors for locations of emotional and neutral pictures.

Repeat Errors. Repeat errors are the proportion of location errors made at test during Blocks 1 or 2 that were repeated on tests in Blocks 2 and 3. A 2 (stimuli type) X 2 (condition) mixed ANOVA was conducted on the repeat errors, with stimuli type as the within-subjects variable and condition as the between-subjects variable. The results of the ANOVA (Figure 5) showed that there was a main effect of stimuli type, $F(1, 106) = 23.951, p < .001, \eta^2 = .184$, indicating that participants made more repeat errors to negatively arousing pictures ($M = .149, SE = .011$) than to neutral pictures ($M = .083, SE = .009$), consistent with findings of Novak and Mather (2009). Unexpectedly there was no significant main effect of condition, $F(1, 106) = 2.201, p = .141, \eta^2 = .020$, nor was there a significant interaction, $F(1, 106) = .572, p = .451, \eta^2 = .005$. Thus, there was evidence of impaired updating for location memory for emotionally arousing pictures relative to neutral pictures, but the noticing manipulation did not have the intended effect of reducing this differential impairment.

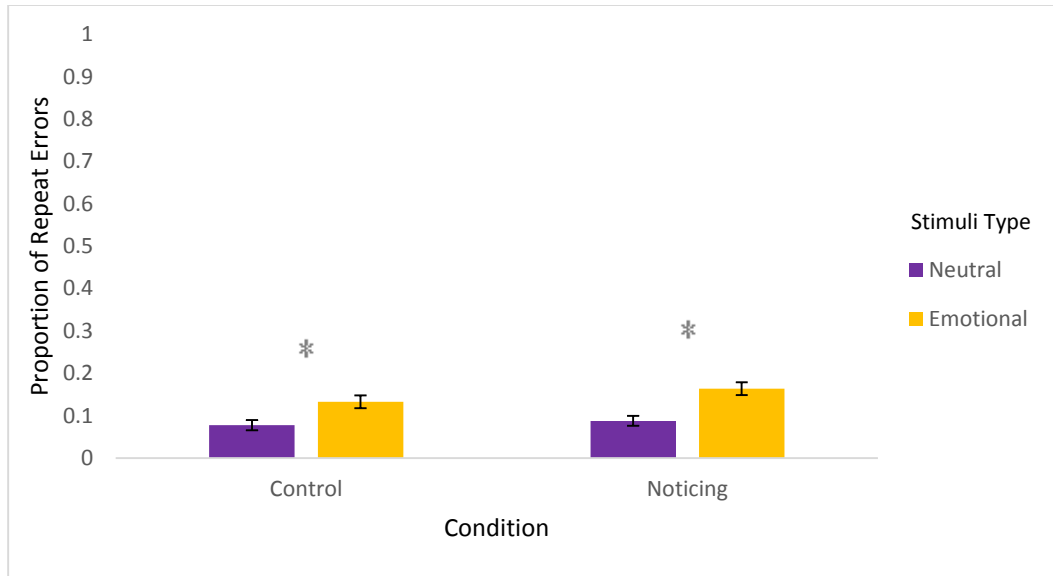


Figure 5. The obtained results for *repeat errors* (errors made on Tests 1 and 2 that were repeated on Tests 2 and 3) in Experiment 1 based on condition and stimuli type. An asterisk denotes a significant difference between stimuli types.

Change Errors. Novak and Mather (2009) compared location recall accuracy on the change blocks by comparing performance on the pre-change block (Test 3) and the post-change block (Test 4). They found a difference in performance between the stimuli types on Test 4 but not on Test 3, indicating a stimuli difference in updating. I repeated the same analysis and included the condition manipulation resulting in a 2 (stimuli type) X 2 (test block) X 2 (condition) mixed ANOVA (refer to Figure 6). The effect of the condition manipulation was not statistically significant, $F(1, 106) = .010, p = .922, \eta^2 < .001$, however there was a significant main effect of emotion, $F(1, 106) = 48.199, p < .001, \eta^2 = .313$, and a significant main effect of testing block, $F(1, 106) = 337.083, p < .001, \eta^2 = .761$. Across both tests participants made more location errors for the negatively arousing items ($M = .174, SE = .008$) than for the neutral items ($M = .139, SE = .008$), and across item type, there were fewer errors on the third test ($M = .081, SE = .010$) than on the fourth test ($M = .231, SE = .010$). There was no significant interaction between emotion and testing block, $F(1,106) = 1.771, p = .186, \eta^2 = .016$, which fails to replicate the previous findings of Novak and Mather (2009). In other words, location errors were elevated in emotionally arousing pictures relative to the neutral pictures, both before and after the change block, and therefore there was no difference in change updating between stimuli type. This surprising finding (or lack thereof) will be discussed in detail in the general discussion. Furthermore, it can be concluded that

requiring participants to make a noticing judgment did not affect updating errors generally, nor differentially based on stimuli type.

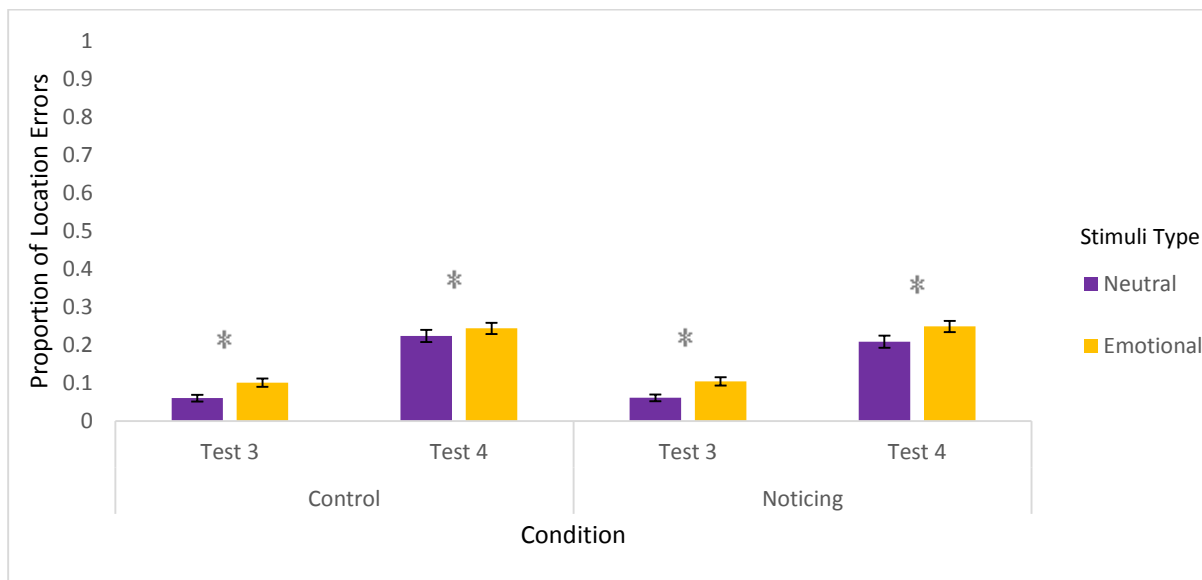


Figure 6. The results for *change errors* made on Block 4 compared to the location errors made on Test 3 in Experiment 1 based on condition and stimuli type. An asterisk denotes a significant difference between stimuli types.

Noticing Judgments.

These analyses were only performed on the results of the participants in the noticing condition (participants in the control condition did not make these judgments) and were designed to contrast noticing accuracy for emotional and neutral items. There are two kinds of noticing that could occur that map onto the two kinds of updating errors (repeat and change). Participants can notice that their memory representation is wrong or that the item has changed locations. The noticing judgments were made in response to the question “*Is this picture in the same location as you remember it?*” If the location at study trial is different from how they remember it (either because they misremembered the previous location as indicated by the previous test or the location has changed) then the correct answer is “*no*”. This will be considered accurate noticing because this is the situation where comparing the external stimulus to the internal representation should indicate a difference. The accuracy of detecting a discrepancy was calculated by comparing the study location for any given block (S_n) to the location judgments made on the test for the previous block (T_{n-1}). Given that noticing a discrepancy can only occur when $S_n \neq T_{n-1}$, noticing accuracy will be constrained to those trials and calculated as the proportion of trials for which the participant replies “*no*”. I expected that the noticing manipulation would equate the stimuli types in

noticing which would contradict Novak and Mather's (2009) argument that changes to emotional stimuli were noticed more than changes to neutral stimuli. The results indicated that there was not a significant difference between emotional and neutral stimuli in noticing an error on the previous test whether that test was Test 1, $t(53) = .769, p = .445$, or Test 2, $t(37) = 1.522, p = .136$. Also, there was no significant difference in noticing a picture had changed location based on whether the item was emotional or neutral, $t(53) = 1.258, p = .214$. All means and standard errors are presented in Table 1.

Table 1. Proportion of correct noticing of previous errors and location changes based on stimuli type. Standard errors are in parentheses.

	Neutral	Emotional
Previous error on T1	.52 (.02)	.54 (.02)
Previous error on T2	.61 (.03)	.55 (.04)
Location Change	.48 (.03)	.47 (.03)

Novak and Mather (2009) claimed that emotional changes were noticed more, but updated less, than neutral changes; therefore they should predict the relationship between noticing a previous error and repeating that error would be nonexistent or even positive for emotional items. I conducted separate 2 (stimuli type) by 2 (noticing of previous error) within-subjects one-way ANOVAs for each test – one for noticing errors made on Test 1 that were repeated on Test 2 and one for noticing errors made on Test 2 that were repeated on Test 3. The results of the first ANOVA showed that there was a main effect of stimuli type $F(1, 53) = 12.402, p = .001, \eta^2 = .190$, indicating that participants were more likely to repeat an emotional error ($M = .063, SE = .007$) than they were to repeat a neutral error ($M = .035, SE = .005$). There was no significant main effect of noticing previous error, $F(1, 53) = .061, p = .806, \eta^2 = .001$, nor was there a significant interaction, $F(1, 53) = 1.052, p = .310, \eta^2 = .019$. The results of the second ANOVA (refer to Figure 7) whereby I looked at the relationship between noticing a previous error made on Test 2 and repeating that error on Test 3 showed a different pattern of results. The ANOVA again yielded a main effect of stimuli type, $F(1, 50) = 12.939, p = .001, \eta^2 = .206$ demonstrating that participants repeated emotional errors ($M = .053, SE = .008$) more often than neutral errors ($M = .023, SE = .004$). This analysis also yielded a significant interaction, $F(1, 50) = 10.206, p = .002, \eta^2 = .170$. Follow-up dependent samples t-tests showed that participants were more likely to repeat and error when they did not notice they made the error ($M = .075, SE = .007$) than when they did notice the error ($M = .035, SE = .013$), $t(53) = 2.822, p = .007$. The opposite however was true for neutral items in that participants were

more likely to repeat an error when they *did* notice the previous error ($M = .032$, $SE = .006$) than when they did not ($M = .013$, $SE = .005$), $t(50) = 2.371$, $p = .022$. Although these effects are significant, the actual occurrence of repeating errors is small and therefore should be interpreted with a caution. The take home message from these analyses is that noticing a previous error, as measured in this experiment, does not translate into avoiding the error again in the future.

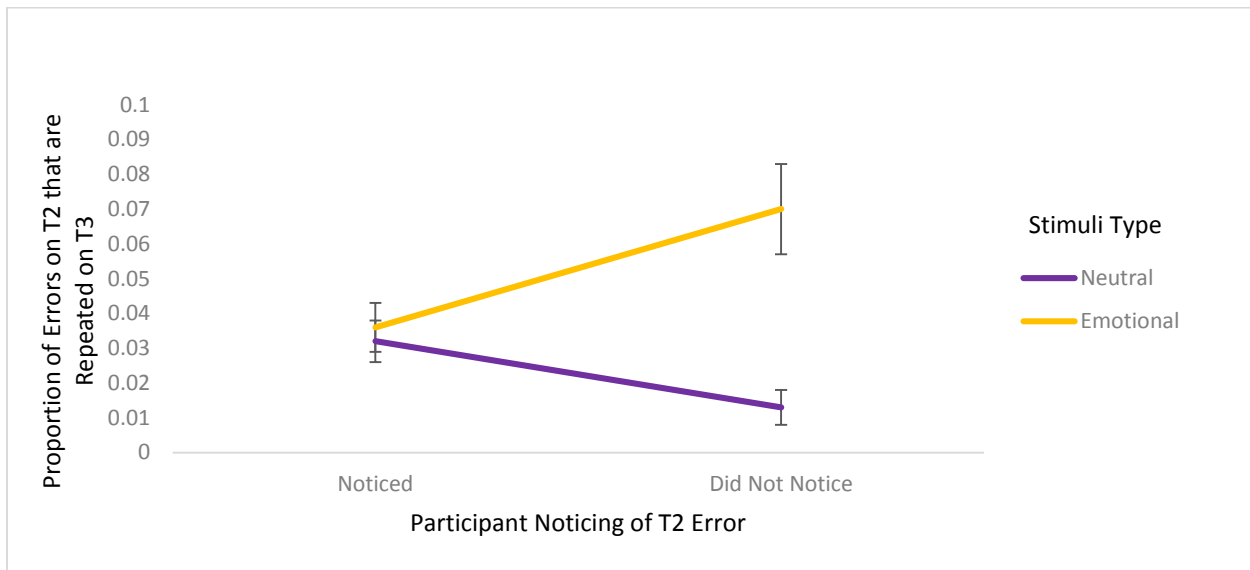


Figure 7. The proportion of previous errors that were repeated based on whether the participant noticed the previous error or not.

I also analyzed noticing of location changes in Block 4 by calculating the same accurate noticing variable, but only for *changed items* on Block 4. I did not expect a significant dependent samples t-test between the stimuli types and in fact there was no significant difference, $t(53) = 1.258$, $p = .214$ (means and standards errors are reported in Table 1).

Along with the noticing measure I obtained in this study I explored the noticing calculations Novak and Mather (2009) conducted in order to gain insight in to what was actually being measured in their experiment. They determined that analyzing the “proportion of errors after the switch that involved a change in the location response, only for those correctly recalled in Blocks 2 and 3” (p. 950) would provide a measure of noticing with the reasoning that participants would only change their correct location judgment if they noticed that the location had changed. In order to recreate their noticing measure, I examined items that were changed in Block 4 that they had answered correctly in Blocks 2 and 3, and computed the proportion of items in which a reported location was neither the item’s location on Blocks 3

nor 4. The dependent t-test showed that there was no significant difference between their calculations of change noticing between emotional ($M = .178, SE = .010$) and neutral ($M = .157, SE = .010$)⁹ items, $t(107) = 1.665, p = .099$. Taken together, the findings from the noticing analyses contradicted both Novak and Mather's and the current hypotheses by not finding any difference in noticing between emotional and neutral discrepancies.

Confidence Judgments at Test.

Confidence in location judgments was measured on a scale of 1 to 7 where 1 represents "not at all confident" and 7 represents "highly confident". A series of dependent t-tests were conducted on the confidence judgments to determine differences in confidence between the location judgments of emotional and neutral items. Overall on all tests, participants were more confident in the location judgments for the neutral pictures than the emotional pictures (see Table 2), $t_s(108) > 1.990, p_s < .05$. I also separated the confidence ratings according to whether the location judgment

Table 2. Mean confidence ratings on location judgments based on a 7-point scale. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli type.

	Neutral	Emotional
Test 1*	4.486 (.098)	4.745 (.092)
Test 2*	6.169 (.074)	6.104 (.077)
Test 3*	6.603 (.061)	6.509 (.063)
Test 4*	5.872 (.089)	5.792 (.089)
Test 5*	6.298 (.083)	6.226 (.087)

was accurate (Table 3) or inaccurate (Table 4). The results showed that when the location judgments were correct, participants indicated higher confidence in those judgments if they were for neutral stimuli than for emotional stimuli (significant differences were obtained for Test 3, 4, and 5 ($t_s(107) > 2.409, p_s < .034$). Thus, participants appear to be learning that they are more accurate on neutral items as the study-test trials progress. The opposite pattern was found for the location errors. Specifically, participants had significantly higher confidence in location errors for emotional items than in neutral items on Tests 1 and 2 ($t_s(107) > 4.283, p_s < .001$), but not for subsequent tests. Although all the above results are statistically significant, it is important to note that the numerical difference of confidence ratings are modest. Not only were participants more confident in emotional location errors, but they were also more confident in

⁹ Novak and Mather's calculations were that participants "noticed" emotional changes 46% of the time and 29% of neutral item location changes, which is higher than the rates I calculated for the current data.

emotional repeat errors. Specifically, participants were more confident in emotional errors repeated from Test 1 to Test 2 ($M = 5.428$, $SE = .234$) than in neutral repeat errors ($M = 4.535$, $SE = .259$), $t(51) = 3.369$, $p = .001$ ¹⁰. Overall, confidence was highly correlated with test accuracy (see Table 5 for all Pearson correlations; all $ps < .001$).

Table 3. Mean confidence ratings on accurate location judgments based on a 7-point scale. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli type.

	Neutral	Emotional
Test 1	5.612 (.079)	5.651 (.083)
Test 2	6.427 (.065)	6.385 (.062)
Test 3*	6.690 (.054)	6.617 (.056)
Test 4*	6.181 (.084)	6.109 (.086)
Test 5*	6.445 (.076)	6.381 (.079)

Table 4. Mean confidence ratings on inaccurate location judgments based on a 7-point scale. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli type.

	Neutral	Emotional
Test 1* (n = 108)	3.115 (.105)	3.810 (.102)
Test 2* (n = 103)	4.378 (.134)	4.924 (.131)
Test 3 (n = 69)	5.247 (.187)	5.373 (.170)
Test 4 (n = 105)	4.628 (.124)	4.758 (.121)
Test 5 (n = 86)	4.884 (.166)	4.994 (.162)

Table 5. Pearson r correlations between confidence and accuracy based on stimuli type. All correlations were significant $p < .001$.

	Neutral	Emotional
Test 1	0.669	0.466
Test 2	0.588	0.623
Test 3	0.546	0.571
Test 4	0.340	0.353
Test 5	0.430	0.468

Post Experiment Questions.

After the experiment portion was completed, the participants were asked several questions about their experience in the experiment. For most of the questions there was no difference between the two conditions ($ts(106) < 1.850$, $ps > .067$) and therefore their responses were collapsed across condition and are reported for informational purposes. Participants were asked to report the level of negative

¹⁰ The pattern was also true for errors made on Test 2 that were repeated on Test 3 however there was not enough power to detect a difference in the analysis ($n = 33$).

emotions they felt as elicited by the pictures. Table 6 shows their mean ratings on a scale of 1 to 5. A one-way repeated-measures ANOVA yielded a significant main effect of emotion, $F(3, 321) = 96.608, p < .001$. A Bonferroni post-hoc analysis showed that participants felt significantly more disgust and sadness from the pictures than they did anger or fear.

Participants were also asked to answer two questions about their performance during the experiment. They were asked to rate their accuracy on the tests as to whether they were more accurate on emotional, neutral or equal items. The results (Table 7) showed that participants believed that they were either equally accurate or more accurate on the emotional items. What is interesting is not only that the location tests showed people were more accurate on the neutral items, but also when assessed on an item level participants were more confident overall on the neutral items than the emotional items. This difference in meta-memory on an item level compared to an item type level will be discussed in the general discussion.

Table 6. Mean rating of experienced emotions elicited by the pictures used in the experiment. Standard errors are in parentheses.

Anger	2.16 (.119)
Disgust	3.55 (.116)
Fear	1.96 (.111)
Sadness	3.46 (.125)

Table 7. Percentage of responses to the question “*My location judgments were more accurate for:*”

Emotional	48.1
Neutral	6.5
Equal	45.4

Another question asked participants to indicate their ability to notice a change (Table 8). The results again showed that participants thought they were either equally accurate at noticing changes or more accurate at noticing emotional changes, when in reality they were more accurate on the test after the switch for the neutral items than for emotional items.

Table 8. Percentage of responses to the question “*I was more accurate at noticing a change for:*”

Emotional	51.9
Neutral	7.4
Equal	40.7

There were two post-experiment questions for which the responses significantly differed according to condition. Both were questions regarding the design of the experiment. The first question

(Table 9) asked them to indicate which type of picture was presented more often: emotional or neutral (keep in mind that they were presented equally often). The results showed that the pattern of judgments made by participants in the Control condition differed significantly from those in the Noticing condition ($\chi^2(2) = 7.272, p = .026$). Examination of the distribution of the responses in the two conditions reveals that more participants in the Control condition chose the correct option than participants in the Noticing condition. In both conditions, the majority of errors involved claiming that the emotional pictures had been presented more often.

Table 9. Percentage of responses to the question “*Throughout the experiment, which type of picture was presented more often?*” separated by condition. The + sign denotes the correct answer.

	Control	Noticing
Emotional	27.8	46.3
Neutral	9.3	16.7
Both equally+	63.0	37.0

The second question (Table 10) that yielded differences between the groups was when the participants were asked to indicate how many times the pictures changed locations during the experiment. Although the large majority of participants gave an incorrect response (anything more than *once*), it again showed that the participants in the Control condition ($M = 2.83, SE = .094$) were more accurate than participants in the Noticing condition ($M = 3.17, SE = .126$) in that their errors were closer to reality ($t(106) = 2.116, p = .037; \chi^2(3) = 15.964, p = .001$).

Table 10. Percentage of responses to the question “*On how many trials did the pictures change location?*” separated by condition. The + sign denotes the correct answer.

	Control	Noticing
1+	0.0	3.7
2	33.3	24.1
3	50.0	24.1
4	16.7	48.1

Discussion

The noticing manipulation was designed to lead participants to focus more attention toward the external stimulus (the picture) rather than their internal representation of the previous presentation (reminding). Thus, the goal was to shift where attention was allocated. The hypothesis was that this type of judgment would improve *comparing*, resulting in equivalent levels of memory updating between emotional and neutral stimuli. The results of Experiment 1 did not support this hypothesis. In short, the

noticing manipulation did not affect memory updating, nor did it seem to affect overall allocation of attention, for either stimulus type. At the very least this indicates that simply asking people to assess the veracity of their memories compared to the external state was not enough for them to actually assess their memories AND make a change in their memory representation. Wahlheim and Jacoby (2013) stated that in order for correct updating to occur, the original pairing, the noticing, and the new pairing all need to be encoded into the memory representation in a temporal manner. The fact that the manipulation did not have an effect on memory accuracy could be due to one of two possibilities: the manipulation was not strong enough to actually promote noticing, or the manipulation had no effect on encoding the act of noticing into the memory representation. Either way, the manipulation did not ultimately affect memory updating.

Experiment 1 provided an opportunity to attempt to replicate the findings of Novak and Mather (2009) with a large sample of participants, and there were a number of similarities and differences in results. First, consistent with their results, participants had better associative memory for neutral stimuli than for emotional stimuli. This finding was also consistent with previous research that has shown impaired associative memory for emotional information compared to neutral information (Kensinger, 2009; Mather, 2007) especially on an immediate test (Jones et al, 1987; Pierce & Kensinger, 2011). However, these findings were not moderated by block type (before or after the location change). I did not replicate Novak and Mather's (2009) finding that there was a difference in updating a location change between emotional and neutral items. To be specific, I did not find equivalent location memory on the trial before the change, but did find the neutral advantage after half the items changed locations. Thus, although there was a general associative decrement for emotionally arousing pictures, this type of updating was not differentially impaired. This point and further comparison between the current experiments and Novak and Mather's will be discussed in depth in the general discussion. Finally, the increased rate of repeat errors (continuing to provide a previously incorrect test location for a picture after a restudy opportunity) for emotional pictures relative to neutral pictures was replicated. Thus, updating of this specific type was impaired for emotionally arousing pictures.

The addition of a confidence measure for location memory was informative, as participants differed in the confidence they had in their accurate and erroneous location memories as a function of

stimuli type. The fact that location errors of emotional items were rated with higher confidence and were more likely to be repeated suggests that perhaps these errors are based on features that are not strongly associated with memory fidelity. This finding supports previous research conducted on emotion and meta-memory discussed in the introduction (Kenisinger, 2009; Magnussen et al., 2006; Phelps & Sharot, 2008; Talarico & Rubin, 2003; Zimmerman & Kelley, 2010). This experiment has shown that obtaining confidence measures is important for understanding the underlying differences between memory for emotional and neutral information, and will be further explored in Experiment 2.

Experiment 2

The manipulation in Experiment 1 was expected to equate updating for emotional and neutral memory representations by directing attention externally to the stimulus, therefore overriding the default emphasis on internally directed attention for emotional items. However, this was not effective. Although I expected this manipulation to promote comparing and noticing, the success of those processes depended on the participants' ability to accurately compare, notice, learn and update. Therefore, Experiment 2 was designed to eliminate the need to make comparisons, and make noticing simpler by alerting participants when a picture was in a different location than they last claimed (Feedback condition) or when an item changed location (Warning condition). By doing this, I expected to engender an awareness similar to that found in Sakaki et al. (2013). The researchers were able to reverse the previously found harbinger effect (where cues predicting the presentation of emotional stimuli were less able to bind to new associates than neutral harbingers) by making participants aware of the contingencies of the harbingers. I therefore expected that providing alerts to location discrepancies would result in similar awareness and thus similar reversal in updating such that emotional memories would be better updated than neutral memories.

Furthermore, the arousal-biased competition model (Mather & Sutherland, 2011) claims that binding is enhanced by emotion when it is intentional. Given that the manipulations in Experiment 2 provide explicit information regarding a change in location information, the intention to bind the stimulus to its perceived location should be strong, and memory should be enhanced when the stimulus is emotional. In this situation, it should be less likely that attention is directed internally because assessing the existing memory representation was unnecessary; all the information the participant needs to perform well is in the external environment. This design was assumed to be a stronger test of the mechanism behind the "interference" experienced in the previous updating research (Novak & Mather, 2009). If the predicted reversal occurs, this would highlight the fact that interference effects are not irreversible due to strong memory representation, but rather a matter of attention allocation that is flexible.

The alerts in this experiment will not only serve as a warning that something has changed (as in the Warning condition), but will also provide feedback on the location tests in the Feedback condition. This is an important distinction because of the increased repeat errors for emotional locations compared to neutral locations that were found in Experiment 1. I expect that providing feedback about previous

errors will directly affect repeat errors, especially for emotional stimuli. Support for this hypothesis comes from the findings from Finn, Roediger, and Rosenzweig (2012). In these studies, participants were presented with a pair of Swahili – English words and were given a cued – recall test. If the participant correctly recalls the target English word (Experiment 1), they were presented with a picture that was either negative, neutral or positive immediately after the successful retrieval. They found that performance on a final cued-recall test was best when initial retrievals were immediately presented with a negative picture. The authors concluded that the negative picture facilitated the reconsolidation of the association of the word pairs. In Experiment 2, they examined how emotion affects reconsolidation if the retrieval attempt was unsuccessful but correct feedback was provided. The results showed that negative pictures had a beneficial effect on later associative memory if they were presented immediately after an unsuccessful retrieval attempt, more so than neutral or blank screens. They also found that this was especially so for commission errors (when the participants provided an answer that was incorrect) compared to an omission error (when the participant did not provide an answer, responding with the “I don’t know” option). The authors concluded that this could be related to the hypercorrection effect.

Research has shown that judgments with higher confidence are more likely to change when given feedback than lower confidence judgments (*the hypercorrection effect*, Butterfield & Metcalfe, 2001). The underlying mechanism for this phenomenon is not clear but it could be due to two possible reasons. One potential reason this occurs could be that it is easier to correct a highly confident memory because it is more familiar and therefore more information is known about it, which means that less needs to be relearned as compared to a memory associated with less confidence (Finn et al., 2012; Butterfield & Metcalfe, 2001). So in the context of the current experiments, if an item is well-remembered, it would be easier to relearn its correct location than if the item was less remembered and therefore the item and the location need to be relearned. Another potential explanation of the hypercorrection effect has to do with surprise. Perhaps the feedback that one was wrong about his highly confident memory is so unexpected that more attention is allocated to the feedback itself compared to the situation where the feedback is not surprising, as would be the case with a low confident memory (Butterfield & Metcalfe, 2001).

Given that Experiment 2 provided feedback on memory accuracy I expected to find the hypercorrection effect. Overall, I expected that feedback on memory accuracy would decrease repeat

errors and warning of location changes would decrease change errors. Experiment 1 results showed that emotional errors were rated with more confidence than neutral errors. Because of this, I expected that hypercorrection from feedback would occur more for location errors for emotional stimuli than for neutral location errors.

Method

Participants.

This was a 2 (stimuli type) X 3 (condition) mixed design, where stimuli type (emotion, neutral) was manipulated within-subjects and condition (warning, feedback, control) was between-subjects. A power analysis was computed to determine the sample size needed to determine a within-between interaction with a small effect size of $f = .176$ (which is equivalent to a $\eta^2 = .03$) and it determined that a total sample size of 129 was needed to achieve .80 statistical power. One hundred fifty-three people participated in this study, however the data of 20 people were discarded from the analyses because of experimenter comments¹¹ ($n = 7$) and performance indicating they were not effortful on the tests ($n = 13$) using the same criteria as used in Experiment 1. For the latter group, I discarded the data of people whose accuracy on Tests 3 and 5 were more than two standard deviations below the mean. The cut off points were coincidentally equivalent to the cut off points in Experiment 1: 70.3% correct for Test 3 and 54.7% correct for Test 5. After accounting for the discarded data, 133 participants were included in this study, 45 in the Warning condition, and 44 participants in each the Feedback and Control conditions. Ninety-one of the participants were female and 42 were male. The mean age was 19.59 years old with the ages ranging from 17 to 33 years. Participants received credit toward their psychology course in exchange for their participation.

Materials.

The experiment was programmed and administered on computers using EPrime™ 2. The stimuli were the same as those used in Experiment 1. The only difference from Experiment 1 was that there was

¹¹ Three of the participants looked away for extended periods of time during the study phases. The computer or program malfunctioned during the running of three other participants. The data of the seventh participant was discarded because he or she repeatedly checked his or her phone and was texting during the experiment despite instructions not to do so.

a red border around the picture during the study phase, denoting an alert, when: 1) the picture changed location as in the Warning condition, or 2) that the participant responded incorrectly on the previous test for this item in the Feedback condition. This border was presented for the entire time the picture was on the screen.

Procedure.

The procedure replicated Experiment 1 with some slight changes: there were no noticing judgments at study, and two types of alerts were provided. Participants received an alert regarding either the accuracy of their location judgments (they were given feedback during the study trials if they were incorrect in the previous test beginning on Block 2; *Feedback* group), when the item changed locations (only on Block 4; *Warning* group), or they received no alert (*Control* group). All alerts occurred exclusively during the study trials in order to ensure that any changes that occurred to the memory representation happened during re-encoding. This also served to minimize the need to focus attention internally, as a comparison was not necessary in order to accurately update a memory in this situation. An alert occurred for the Feedback group if $S_n \neq T_{n-1}$ and it was in the form of a red border around the item during a study trial (S_n) which denoted that they chose the wrong location for that item during the previous test (T_{n-1}). As for the Warning group, an alert (the same red border) occurred for location changes during Block 4 as a warning that an item had changed location from previous study blocks. Participants still made confidence judgments during each test, as all other aspects of the procedure used in Experiment 1 remained the same.

Results

Three major groups of statistical analyses were performed: updating errors, confidence judgments, and exploratory analyses including post-experiment questions. Figure 8 depicts the overall performance collapsed across all three conditions.

Updating Errors.

These were calculated in the same manner as Experiment 1 and repeat errors and change errors were analyzed.

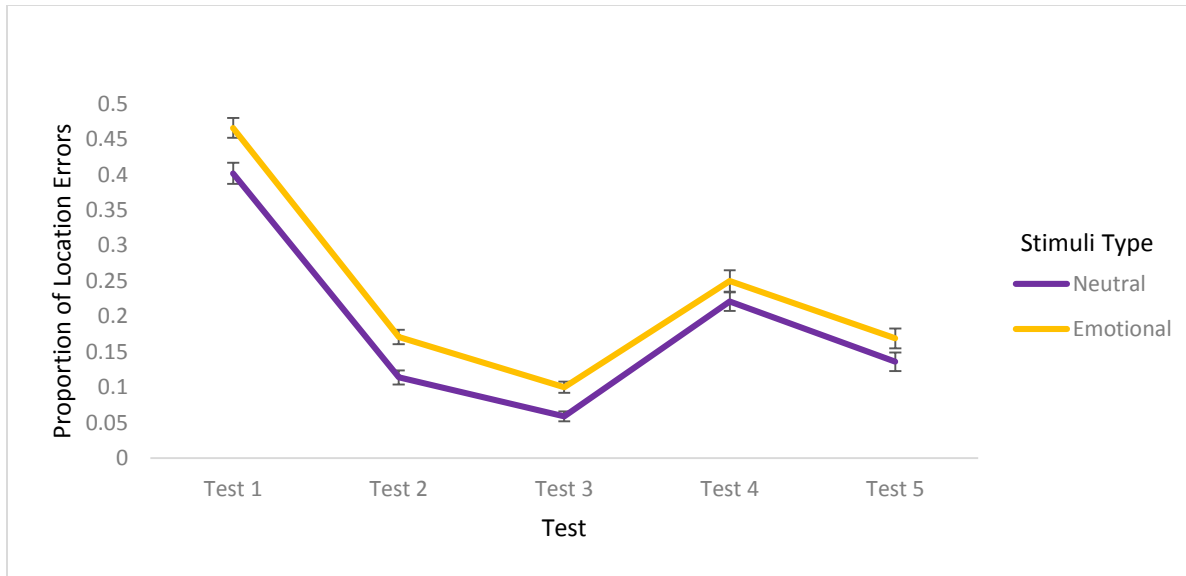


Figure 8. The overall accuracy across test, between stimuli type and collapsed across conditions. Performance is calculated as the proportion of location errors made.

Repeat Errors. A 2 (stimuli type) X 3 (condition) ANOVA was conducted to determine if there were any differences in repeat errors (see Figure 9). I predicted that the Feedback group would yield fewer repeat errors than the Warning and Control groups. I also expected to find an interaction, such that Warning and Control conditions would replicate the pattern found in Experiment 1 (and Novak and Mather, 2009), and that the Feedback condition would eliminate and even reverse the pattern. The ANOVA yielded a significant main effect of condition $F(2, 130) = 4.059, p = .020, \eta_p^2 = .059$, and the Bonferroni post-hoc test ($p = .016$) showed that participants in the Feedback condition made fewer repeat errors ($M = .081, SE = .012$) than participants in the Warning condition ($M = .128, SE = .012$) as predicted. Participants in the Control condition ($M = .110, SE = .012$) were not significantly different than the experimental conditions in terms of repeat errors. As in Experiment 1, there was a significant main effect of stimuli type $F(1, 130) = 65.698, p < .001, \eta_p^2 = .336$, in that there were more repeat errors for emotional pictures ($M = .149, SE = .010$) than for neutral pictures ($M = .063, SE = .007$). Thus, updating errors of this type were greater for emotional pictures. There was also a significant interaction ($F(2, 130) = 4.139, p = .018, \eta_p^2 = .060$) that showed that the difference between emotional and neutral repeat errors were smaller (but still significant) for those in the Feedback condition than in the Warning and Control conditions. Simple main effect one-way ANOVAs for each stimuli type revealed that there was no difference between the conditions on the repeat errors of neutral stimuli, $F(2, 130) = .626, p = .536, \eta_p^2 =$

.010, but there was a significant difference on the repeat errors of the emotional stimuli, $F(2, 130) = 5.676$, $p = .004$, $\eta^2 = .080$. Specifically, the repeat errors of the emotional pictures were lower for participants in the Feedback condition ($M = .102$, $SE = .018$) than for those in the Warning ($M = .182$, $SE = .017$) and Control ($M = .164$, $SE = .018$) conditions. These results indicated that feedback reduced repeat errors of emotional stimuli, but not for neutral stimuli.

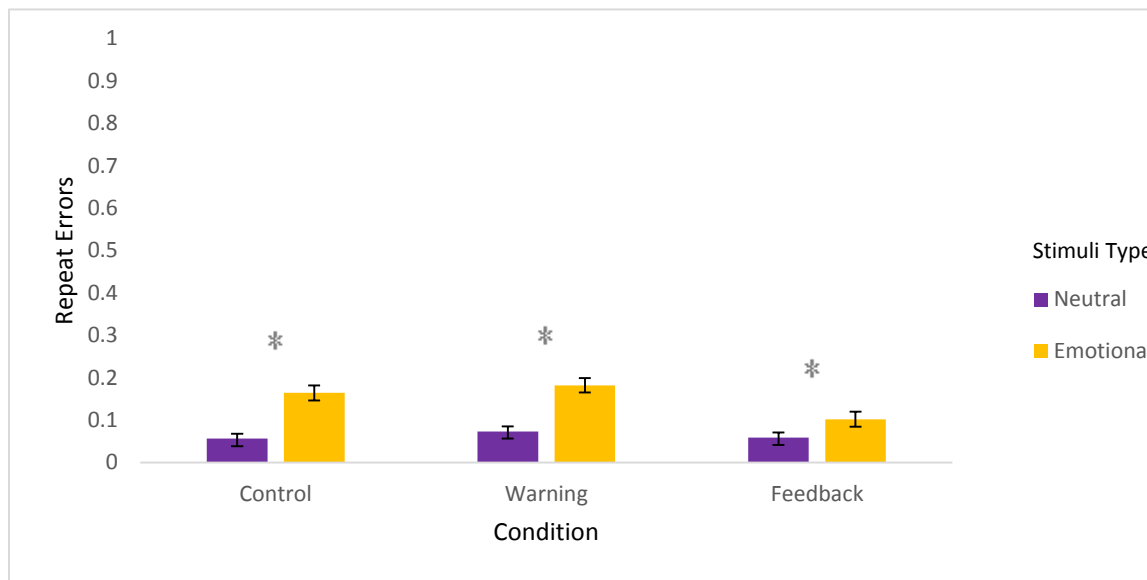


Figure 9. The obtained results for *repeat errors* (errors made on Tests 1 and 2 that were repeated on Tests 2 and 3) in Experiment 2 based on condition and stimuli type. An asterisk denotes a significant difference between stimuli types.

I separated the collapsed repeat errors by test and analyzed the errors made on Test 2 that were repeated in Test 3 only in order to assess learning over time as a result of the corrective feedback (see Figure 10). This analysis showed a significant main effect of stimuli type, $F(1, 100) = 15.769$, $p < .001$, $\eta^2 = .136$, whereby there are significantly more emotional repeat errors ($M = .255$, $SE = .022$) than neutral repeat errors ($M = .146$, $SE = .022$). There was also a main effect of condition, $F(2, 100) = 4.166$, $p = .018$, $\eta^2 = .077$. Bonferroni post hoc tests showed that participants in the Warning condition ($M = .258$, $SE = .030$) made more repeat errors than participants in the Feedback condition ($M = .138$, $SE = .029$), $p = .015$. Repeat errors made by participants in the Control condition ($M = .206$, $SE = .030$) was not significantly different from either experimental condition. There was also a marginal interaction found, $F(2, 100) = 2.855$, $p = .062$, $\eta^2 = .054$. Despite the marginal interaction, I conducted a priori comparisons based on the hypothesis that feedback would eliminate (or even reverse) the increased repeat errors for

emotional items compared to neutral items. Planned dependent samples t-tests showed that there was a significant difference between repeat errors for emotional and neutral stimuli in the Warning ($t(33) = 3.271, p = .003$) and Control ($t(33) = 2.752, p = .010$) conditions, but not in the Feedback condition ($t(34) = .542, p = .591$). Although the pattern did not reverse for the Feedback condition as I had predicted, it did reduce the difference such that there was no longer a differential enhancement of errors to emotional items. Altogether, the predictions regarding the effect of feedback were largely confirmed.

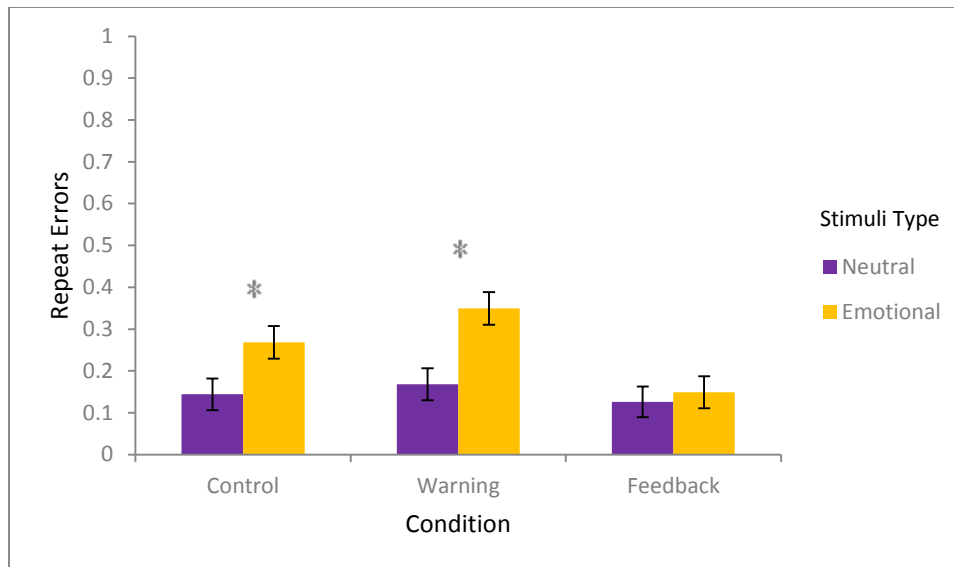


Figure 10. The obtained results for *repeat errors* (errors on Test 2 that were repeated on Test 3) in Experiment 2 based on condition and stimuli type. An asterisk denotes a significant difference between stimuli types.

Change Errors. In order to assess memory updating based on change errors, I conducted a similar analysis to the one used in Experiment 1. I conducted a 2 (emotion) X 2 (test block) X 3 (condition) mixed design ANOVA with emotion and test block as within-subjects variables and condition as a between-subjects variable (see Figure 11). I expected this test would show a significant main effect of condition so that the Feedback and Control conditions would yield more change errors than the Warning condition. I also expected a significant interaction in that there would be more change errors for emotional stimuli than neutral stimuli in the Feedback and Control conditions, whereas the pattern would be reversed in the Warning condition. This was based on the fact that Sakaki et al. (2013) found this reversal pattern when people were aware of the contingency which affected the way attention was allocated at re-encoding. I expected to find the same pattern in this situation where the change was alerted, and therefore attention would have been allocated externally with no need to focus attention internally. The results of the analysis

yielded a significant main effect of stimuli type, $F(1, 130) = 62.923$, $p < .001$, $\eta^2 = .326$, indicating that across both tests participants made more location errors on emotional

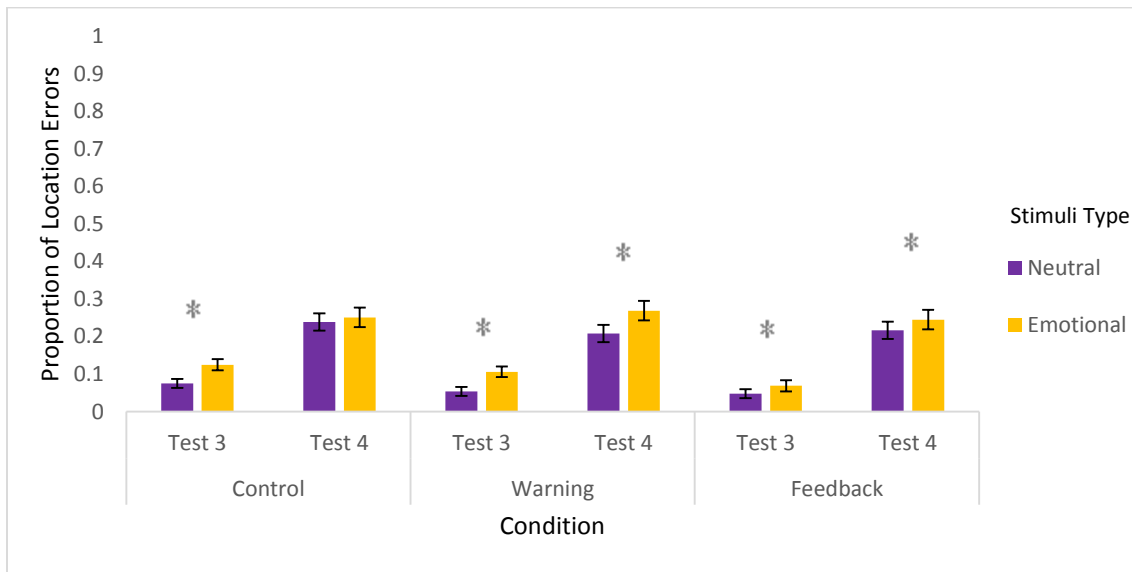


Figure 11. The results for *change errors* made on Block 4 compared to the pattern of location errors made on Test 3 in Experiment 2 based on condition and stimuli type. An asterisk denotes a significant difference between stimuli types.

pictures ($M = .177$, $SE = .140$) than on neutral pictures ($M = .140$, $SE = .009$). There was also a significant main effect of test, $F(1, 130) = 251.540$, $p < .001$, $\eta^2 = .659$, indicating that across stimuli type participants made fewer errors on Test 3 ($M = .079$, $SE = .007$) than on Test 4 ($M = .238$, $SE = .014$). The ANOVA also yielded a significant interaction between stimuli type and condition, $F(2, 130) = 4.180$, $p = .017$, $\eta^2 = .060$. Follow-up dependent samples t-tests showed that participants made more errors on emotional locations in Test 3 and 4 than neutral location errors in all three conditions ($t_s > 3.662$, $p_s < .002$), however by looking at the effect sizes of those differences it can be concluded that the difference was larger for the Warning condition ($\eta^2 = .469$) than the Control ($\eta^2 = .240$) and Feedback ($\eta^2 = .238$) conditions. The lack of a stimuli type by test interaction (or a three way interaction) again revealed that emotional arousal did not differentially impair updating with respect to changed locations. Instead, location memory for emotional pictures was worse than for neutral before and after the change block. This finding replicates the results of Experiment 1, but does not replicate the findings of Novak and Mather (2009). This difference will be discussed in the general discussion section.

Confidence Judgments.

Confidence in location judgments was measured on each test. Similar to Experiment 1, there were significant differences in confidence between stimuli types on each test (Table 11), $t_s(132) > 1.999$, $p_s < .049$ showing that participants had more confidence in their location judgments of emotional items than neutral items on Test 1, however the reverse was true for the

Table 11. Mean confidence ratings on location judgments based on a 7-point scale. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli type.

	Neutral	Emotional
Test 1*	4.740 (.087)	4.983 (.074)
Test 2*	6.330 (.054)	6.267 (.058)
Test 3*	6.677 (.040)	6.601 (.046)
Test 4*	5.923 (.081)	5.801 (.086)
Test 5*	6.252 (.082)	6.181 (.083)

remaining tests. This pattern was also found for accurate location judgments (Table 12), $t_s(132) > 2.292$, $p_s < .024$. On the other hand, participants had more confidence in emotional location errors than neutral errors (Table 13) for Test 1 and 2, $t(132) = 9.306$, $p < .001$, and $t(102) = 4.797$, $p < .001$, respectively. Similar to Experiment 1, there were significant positive correlations between confidence and accuracy on all tests for both item types (Table 14).

Table 12. Mean confidence ratings on accurate location judgments based on a 7-point scale. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli type.

	Neutral	Emotional
Test 1*	5.687 (.066)	5.787 (.060)
Test 2*	6.571 (.040)	6.499 (.046)
Test 3*	6.759 (.035)	6.711 (.038)
Test 4*	6.185 (.077)	6.071 (.081)
Test 5*	6.387 (.075)	6.338 (.079)

Table 13. Mean confidence ratings on inaccurate location judgments based on a 7-point scale. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli type.

	Neutral	Emotional
Test 1* (n = 133)	3.350 (.092)	4.035 (.089)
Test 2* (n = 103)	4.499 (.138)	5.113 (.109)
Test 3 (n = 70)	5.017 (.179)	5.272 (.154)
Test 4 (n = 121)	4.794 (.113)	4.910 (.111)
Test 5 (n = 97)	5.095 (.146)	5.079 (.144)

Table 14. Pearson r correlations between confidence and accuracy based on stimuli type. All correlations were significant $p < .001$.

	Neutral	Emotional
Test 1	0.669	0.466
Test 2	0.588	0.623
Test 3	0.546	0.571
Test 4	0.340	0.353
Test 5	0.430	0.468

Given that it was expected that the Feedback condition would affect the confidence participants would have in their location judgments, I conducted a 2 (stimuli type) X 5 (test) X 3 (condition) mixed ANOVA on overall confidence judgments. The results are depicted in Figure 12. Expectedly, there was a significant main effect of test, $F(4, 520) = 207.687, p < .001, \eta^2 = .615$, indicating that confidence significantly increased from Test 1 ($M = 4.861, SE = .077$) to Test 2 ($M = 6.299, SE = .054$) to Test 3 ($M = 6.639, SE = .042$) and then significantly decreased on Test 4 ($M = 5.862, SE = .083$) which is when half of the items changed location, and then significantly increased again on Test 5 ($M = 6.216, SE = .082$; which is statistically equal to Test 2). Although there was no significant main effect of stimuli type, $F(1, 130) = .809, p = .370, \eta^2 = .006$, it was involved in 3 significant interactions. Stimuli type significantly interacted with test, $F(4, 520) = 26.158, p < .001, \eta^2 = .168$, and with condition, $F(2, 130) = 6.637, p = .002, \eta^2 = .093$. Finally there was a three-way interaction between stimuli type, test, and condition, $F(8, 520) = 2.443, p = .013, \eta^2 = .036$.

The stimuli type by test interaction was reflected in Figure 12 indicating that emotional location judgments were rated with higher confidence than neutral location judgments on the first test and that pattern reversed for the remainder of the tests. This pattern was true for each of the conditions, explaining some of the effect of the three-way interaction. I conducted separate 2 (stimuli type) X 5 (test) within subjects ANOVAs for each condition. All three ANOVAs yielded a significant interaction between stimuli type and test ($F_s > 6.057, p_s < .001$), however the effect size was larger for the Control condition ($\eta^2 = .286$) than the Warning ($\eta^2 = .121$) and Feedback ($\eta^2 = .154$) conditions likely reflecting the larger discrepancy between confidence in stimuli types on the first test.

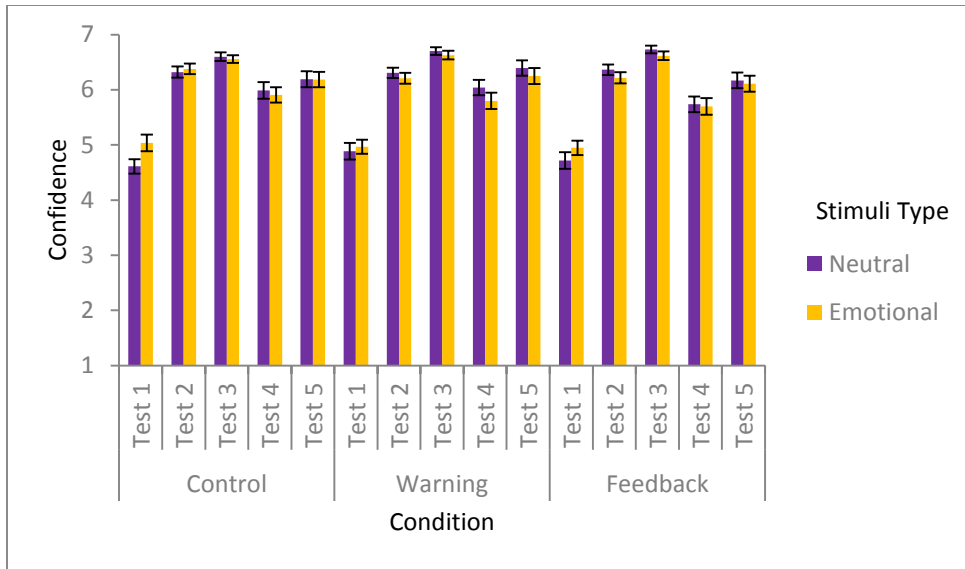


Figure 12. Mean confidence ratings on location judgments based on a 7-point scale based on the condition and test.

The ANOVAs also showed a main effect of stimuli types for the Warning ($F(1, 44) = 9.230, p = .004, \eta^2 = .173$) and Control ($F(1, 43) = 6.456, p = .015, \eta^2 = .131$) conditions but not for the Feedback condition ($F(1, 43) = .457, p = .503, \eta^2 = .011$), refer to Table 15. These results suggest that, as I predicted, feedback equalized confidence ratings for emotional and neutral location judgments.

Table 15. Mean rating of confidence in location judgments separated by condition. Standard errors are in parentheses. An asterisk denotes a significant difference between stimuli types.

	Neutral	Emotional
Control *	5.942 (.095)	6.0131 (.099)
Warning *	6.067 (.094)	5.970 (.098)
Feedback	5.943 (.095)	5.918 (.099)

I not only expected that feedback would affect overall confidence ratings, but I also expected that confidence would impact how people corrected their errors. Butterfield & Metcalfe (2001) found that when participants had high confidence in their memory errors and received feedback, they were better able to correct these errors than when they had low confidence (hypercorrection effect). In their experiment, feedback was provided during the test phase, however it was provided during the re-representation phase in this study. I expected this to be a stronger effect of feedback because there is no reliance on remembering the feedback at the re-representation (as was the case in Butterfield & Metcalfe, 2001), because the correct item-location association was present during the feedback presentation. Therefore, I expected to find a similar pattern in that confidence on location judgments will have a relationship with

updating errors. Specifically, the higher the confidence for location errors, the fewer repeat errors participants in the Feedback group should make. Given that participants in Experiment 1 rated emotional location errors with higher confidence than neutral location errors, this hypercorrection should be exacerbated for emotional items compared to neutral items.

To assess hypercorrection, I analyzed the proportion of location errors on Test 1 that were corrected on Test 2 by confidence in the original error only for the Feedback condition, as feedback is needed for hypercorrection to occur. I grouped the Test 1 errors as to whether confidence in those errors were low (given a rating of 1 – 3 on the confidence scale) or high (given a rating of 5-7 on the confidence scale). I used a 2 (emotion) X 2 (confidence level) within subjects design ANOVA. Given the need to conditionalize performance to calculate this dependent variable, a total of 33 participants in the Feedback condition¹² were included in the analysis. The results (refer to Figure 13) showed that there was a marginal main effect of emotion, $F(1, 32) = 3.890, p < .057, \eta^2 = .108$, indicating that, neutral location errors ($M = .836, SE = .032$) were corrected more often than emotional location judgments ($M = .767, SE = .036$) from Test 1 to Test 2. There was a significant interaction between emotion and confidence level, $F(1, 32) = 8.780, p = .006, \eta^2 = .215$. Given that hypercorrection effects are characterized by the correction of highly confident errors when given feedback (more so than errors with low confidence), I conducted two dependent-samples t-tests: high versus low confident errors separated by stimuli type. The results showed that there was no significant difference in hypercorrection of emotional errors based on the level confidence in those errors, $t(39) = 1.418, p = .164$. On the other hand, I did find the standard hypercorrection effect for neutral items so that participants were more likely to correct errors they had high confidence in than errors they had low confidence in, $t(36) = 2.907, p = .006$.

Overall, the results of the hypercorrection analyses showed that participants hypercorrected (were more likely to correct their high confidence errors than low confidence errors) neutral errors more than emotional errors (where they were slightly more likely to correct low confident errors than high confident errors) which was the opposite of what I predicted.

¹² The data of 11 participants were not included in the analyses because either: their confidence levels in Test 1 errors were moderate (a judgment of “4”), or they did not have both low and high confident errors on Test 1.

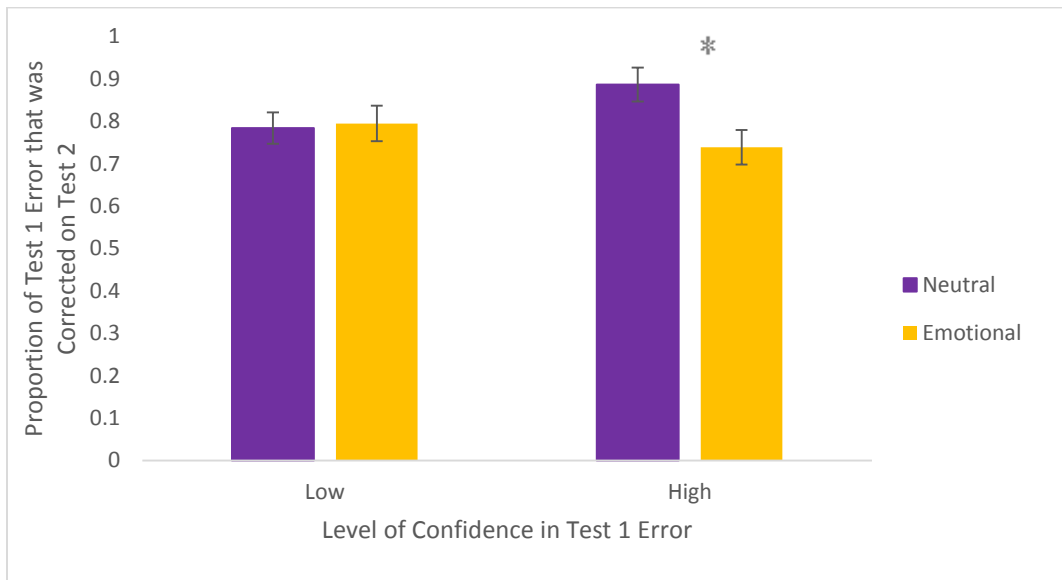


Figure 13. Hypercorrection analyses in the Feedback condition (n = 33). The proportion of errors on Test 1 that were corrected on Test 2 based on stimuli type and level of confidence in the Test 1 error. An asterisk denotes a significant difference between stimuli types.

Another potential way to look at the relationship between confidence and errors is to correlate the confidence in errors on one test and the probability of repeating that error on the next test. I analyzed those correlations based on test (Test 1 to Test 2 and Test 2 to Test 3) and condition. Table 16 shows the Pearson *r* correlations between confidence in Test 1 errors and the probability of repeating errors on Test 2. There were two significant correlations: one for the neutral items in the Control condition, $r(44) = -.399$, $p = .007$ indicating that the more confident in the Test 1 errors, the less likely they will repeat the error (this reflects the hypercorrection calculations above). There was also a correlation indicating that for people in the Warning condition, $r(45) = .331$, $p = .026$, the higher their confidence in emotional location errors on Test 1, the more likely they will repeat those errors on Test 2.

Table 16. Pearson *r* correlations between confidence on Test 1 location errors and probability of repeating those errors on Test 2. An asterisk denotes a significant correlation.

	Neutral	Emotional
Control	-0.399*	0.175*
Warning	-0.115	0.331*
Feedback	-0.050	-0.083

I conducted the same analyses for confidence in Test 2 errors and repeating those errors on Test 3 and those results are depicted in Table 17. The more confident people were in the emotional location errors

on Test 2, the more likely they were to repeat them, but only for participants in the Control ($r(42) = .444$, $p = .003$) and the Warning ($r(44) = .406$, $p = .006$) conditions. Taken together, I conclude that feedback eliminates the relationship between confidence and errors.

Table 17. Pearson r correlations between confidence on Test 2 location errors and probability of repeating those errors on Test 3. An asterisk denotes a significant correlation.

	Neutral	Emotional
Control	0.180	0.444*
Warning	-0.031	0.406*
Feedback	-0.091	-0.046

Post Experiment Questions.

After the experiment portion was completed, the participants were asked several questions about their experience in the experiment. For most of the questions there was no difference between the three conditions ($F_s(2, 130) < 1.787$, $p_s > .171$) and therefore their responses were collapsed across condition and are reported for informational purposes. Participants were asked to report the level of negative emotions they felt were elicited by the negatively arousing pictures. Table 18 shows their mean ratings on a scale of 1 to 5. A one-way repeated-measures ANOVA yielded a significant main effect of emotion, $F(3, 396) = 114.522$, $p < .001$. A Bonferroni post-hoc analysis showed that participants felt significantly more disgust and sadness from the pictures than they did anger or fear ($p < .001$), replicating Experiment 1.

Table 18. Mean rating of experienced emotions elicited by the pictures used in the experiment. Standard errors are in parentheses.

Anger	2.20
Disgust	3.62
Fear	2.19
Sadness	3.61

Participants were also asked to answer two questions about their performance on the tests. They were asked to rate their accuracy on the tests as to whether they were more accurate on emotional, neutral or equal items. The results (Table 19) showed that participants believed that they were either equally accurate or more accurate on the emotional items. What is interesting is not only that the tests showed people were more accurate on the neutral items, but also when assessed on an item level participants were more confident overall on the neutral items than the emotional items. This was also found in Experiment 1 and will be discussed in the general discussion section.

Table 19. Percentage of responses to the question “*My location judgments were more accurate for:*”

Emotional	46.6
Neutral	4.5
Equal	48.9

Another question asked them to indicate their ability to notice a change (Table 20). The results again showed that participants thought they were either equally accurate at noticing changes for both stimulus types or more accurate at noticing emotional changes, when in reality they were more accurate on the test after the switch for the neutral items than for emotional items.

Table 20. Percentage of responses to the question “*I was more accurate at noticing a change for:*”

Emotional	45.9
Neutral	12.0
Equal	42.1

There were two post-experiment questions whereby the responses were significantly different based on the condition the participants were in, both of which were questions regarding the design of the experiment. The first question (Table 21) asked them to indicate on which trial the pictures started changing locations. The results showed that, unsurprisingly, participants in the Warning condition were more accurate than those in Control and Noticing conditions ($F(2, 130) = 11.098, p < .001; \chi^2(6) = 27.243, p < .001$).

Table 21. Percentage of responses to the question “*On which trial did the pictures start changing location?*” broken up by condition. The asterisk denotes the correct answer.

	Control	Warning	Feedback
2nd	18.2	0.0	4.5
3rd	61.4	37.8	61.4
4th*	18.2	62.2	34.1
5th	2.3	0.0	0.0

The second question (Table 22) that yielded differences between the groups was when the participants were asked to indicate how many times the pictures changed locations during the experiment. It again showed that the participants in the Warning condition were more accurate than participants in the Control and Feedback conditions ($F(2, 130) = 15.074, p < .001; \chi^2(6) = 30.460, p < .001$).

Table 22. Percentage of responses to the question “*On how many trials did the pictures change location?*” broken up by condition. The + sign denotes the correct answer.

	Control	Warning	Feedback
1+	2.3	42.2	11.4
2	47.7	40.0	47.7
3	36.4	17.8	34.1
4	13.6	0.0	6.8

Given the nature of the design, it is not surprising that participants in the Warning condition were more accurate on these questions as they were made fully aware of when and how often a change had occurred. Essentially these two questions served as manipulation checks in that the Warning participants should have been more aware of the information asked than the other two conditions.

Discussion

The results from Experiment 2 replicated many of the findings from Experiment 1, including the failure to observe a difference between emotional and neutral pictures with respect to change errors (Novak & Mather, 2009). The results also replicated the finding that repeat errors were higher for emotional than neutral items, and that these errors were endorsed with higher confidence. Furthermore, Experiment 2 also provides the first evidence that this difference can be reduced. Specifically, providing feedback benefitted location memory more for emotional pictures more than neutral pictures. Participants in the Feedback condition reduced the repetition of their location errors for emotional items over time. Providing feedback also equalized the confidence participants had in their location judgments across stimuli type. Although the confidence participants had in emotional location errors did not directly affect how they corrected those errors after being provided with feedback, it may have still had an effect on errors overall, and I will discuss this in the general discussion.

General Discussion

Summary of Findings

Patterns Observed in Both Experiments.

In Experiments 1 and 2, participants had, overall, better location memory for neutral items than emotional items. This supports previous findings in the literature that have shown that associative memory for emotional items is worse than for neutral items (Kensinger, 2009; Jones et al., 1987; Mather, 2007; Pierce & Kensinger, 2011). In both experiments, I also replicated Novak and Mather's (2009) finding that mis-bindings of emotional items to their locations were more likely to be repeated (i.e., repeat errors) than mis-bindings of neutral items and locations. However, I did not replicate the finding that there was a difference between item types in memory updating when pictures changed locations on the critical fourth block. For reasons I discuss below, there may be reason to question the robustness of this previous finding.

Participants in both experiments were more confident in their memories of neutral picture locations than in emotional picture locations after the first block. This increased confidence was appropriate, as participants appeared to learn over time that accuracy was better for neutral than emotional pictures. However, there was also evidence that subjective experience was not always accurate. Participants were more confident in their location errors to emotional pictures than to neutral items on the first two tests.

Experiment 1 Findings.

Experiment 1 used a noticing manipulation to direct more attention externally during re-presentation of stimuli in order to affect the comparison and noticing phases of the updating process. The noticing manipulation (asking people if they noticed a discrepancy between what they see and what they remembered) did not affect memory updating (overall or differentially across stimuli type), inconsistent with the prediction. Furthermore, the noticing measure also revealed that people were just as likely to notice discrepancies in locations for emotional and neutral items. This contradicts Novak and Mather's argument that people notice emotional changes more but fail to update them. This also contradicts the current paper's hypothesis that people notice changes to emotional items less (due to the internal direction of attention during emotional reminders) than for neutral items. Despite the lack of difference in

noticing between item types, the data do not rule out the possibility that there may be differences in the encoding of noticing into the memory representation (which has been argued to be necessary for the updating process; Wahlheim & Jacoby, 2013). More specifically, in order to correctly update a memory representation one needs to encode the original memory, the new memory, and the noticing that it has changed. Although the first experiment showed that people are noticing emotional and neutral discrepancies equally often, it is possible that people may encode noticing into their memory representations differentially for emotional and neutral items.

Experiment 2 Findings.

Experiment 2 was designed to eliminate the need to compare (and thereby eliminating the need to actively notice) the external stimulus and the internal representation by alerting participants when an item changed location, or when they had been wrong about an item's location on the previous test (providing feedback). The alert (warning) did not improve performance, but the feedback manipulation did. Specifically, feedback helped participants correct emotional location errors more than neutral location errors (repeat errors). Feedback also reduced the confidence participants had in emotional errors more than for the neutral errors. Providing feedback eliminated the overconfidence participants reported in their emotional repeat errors.

Explaining the Obtained Results

Emotion and Feedback.

Out of the three experimental conditions in these experiments (Noticing, Warning, and Feedback), providing feedback was the only manipulation that had an effect on memory performance and on confidence, and this effect was stronger for emotional items than for neutral items. A possible explanation of this finding is that feedback affected the way participants evaluated properties of their memory representations. This explanation is consistent with work by Lane, Roussel, Villa, and Morita (2007). In their third experiment, they examined the role of feedback on source memory accuracy. Participants in the study first viewed a video of a home burglary and car chase. Afterwards, participants answered a questionnaire that contained accurate and inaccurate information about the video. After a 10 minute delay, participants were given a source test. On the test, participants were presented with items they had encountered during the experiment and their task was to indicate the source of the information:

from the video only, the questionnaire only, both the video and the questionnaire, or not previously presented. Participants received two source tests: a training test and a critical test. Each test contained half of the total set of test items (i.e., they were different items on each test). During the training test, 1/3 of the participants simply took the test (the control condition), 1/3 received correct feedback about the accuracy of their responses (correct feedback condition), and 1/3 received partially incorrect feedback (incorrect feedback condition). During the critical test, none of the groups received feedback. On the critical test, participants in the correct feedback condition were significantly more accurate than participants in the control condition, and those who received incorrect feedback were worst of all. The authors concluded that accurate feedback on the first half of the test helped participants learn to use better diagnostic cues when evaluating their memories and therefore increased memory accuracy.

Although feedback was somewhat different in format than in Lane et al. (2007), the beneficial meta-cognitive adjustments resulting from feedback also appear to occur in the current experiment. Participants who received feedback appeared better able to assess memory accuracy than those who did not because they learned to not simply rely on the sense of familiarity of the item. This was especially true for emotional items. It is possible that emotionally arousing items benefitted more than neutral items because people initially assessed their memories of the former using less diagnostic criteria, such as confidence derived from familiarity of the item as opposed to recollection of the contextual information (e.g., Phelps & Sharot, 2008). Given that feedback had an effect on confidence ratings, it appears that participants who received feedback assessed their memories differently when making location judgments than people who did not receive feedback. Feedback appears to have promoted reliance on informative information (recollection of location memory) as opposed to readily available information (familiarity of the item). This point can be supported by the fact that there was no longer a positive correlation between confidence and location errors in the Feedback condition, but there was in the other conditions. Given that corrective feedback was provided during the study trials, it is not completely clear if the impact of feedback occurred during the re-encoding or retrieval stages of memory. Either way Feedback participants appeared better able to change how they evaluated their emotional memories. This is consistent with the conclusions of Phelps and Sharot (2008) that people base their confidence judgments for emotional memory accuracy on activation that is not informative of accuracy. If it is possible to lead

people to ignore reliance on uninformative information when making location memory judgments, then it is also possible to lead people to make confidence judgment on informative information as well. Overall, providing feedback benefitted emotional memories more than neutral memories.

Emotion and Meta-memory.

As was discussed in the introduction, meta-memory judgments of emotional information rely on different neural processes (Phelps & Sharot, 2008) than meta-memory judgments of neutral information (i.e. activation in the amygdala versus the posterior parahippocampus, respectively). Interestingly, the results from the current studies also show that emotion impacts the information we use to make meta-cognitive judgments. In both experiments, I found that participants rated their confidence differently when asked at an item level (after making each location judgment) than when asked at a global level (when asked which types of items they remembered best overall on the post-experiment questionnaire). In general, participants expressed higher confidence in their neutral item memories than their emotional item memories, particularly after the first block. However, when asked to rate their memory accuracy overall, participants claimed they performed better when remembering the location of emotional items than neutral items. Why would this be the case? According to Koriat, Bjork, Sheffer, and Bar (2004), *experience-based* meta-cognitive judgments are based on subjective aspects of the experience of remembering, such as fluency with which an item is retrieved, while *theory-based* meta-cognitive judgments are based on people's beliefs (lay theories) about which types of information are likely to be best remembered (see also Lane & Karam-Zanders, 2013, for a review of this distinction). The pattern of results suggests that when asked about their confidence at an item level, participants relied on *experience-based* meta-cognitive judgments, and they were largely accurate when indicating they had remembered the locations of neutral items better than emotional items. This is seen most clearly in the lowering of confidence for emotional location memories after the initial tests. On the other hand, when asked about their global performance, they relied on *theory-based* meta-cognitive judgments. People generally believe that emotion enhances memory (Kensinger, 2009) and it is likely this type of knowledge that many participants used when judging erroneously that they had remembered the locations of emotional items best. It is particularly interesting that when participants were asked to make this global

meta-cognitive judgment, they did not rely on the experience they just had in making confidence judgments multiple times during the experiment.

Current Experiments versus Novak and Mather (2009)

Before I discuss how the results from these experiments relate to previous research in the literature, I would first like to compare and contrast the current experiments with those of Novak and Mather (2009). The experiments discussed here were specifically designed to examine the memory updating findings of Novak and Mather (2009). For that reason, it is important to compare the two sets of experiments (particularly Exp. 2 in their study). As discussed above, one major issue is that the current experiments did not replicate a key finding of a neutral picture advantage for updating location changes on the critical change trial in any of the five conditions. In Novak and Mather, participants had equivalent location errors on Test 3 for emotional and neutral pictures, but better performance for neutral than emotional pictures on Test 4. I found that participants showed better performance for neutral pictures across both tests. One difference to consider between our studies is that their sample size was considerably smaller: they had 18 participants; whereas I did not find this pattern in any of the 5 conditions in these experiments, with a total sample size of 241 (see a comparison of performance in Novak and Mather's Experiment 2 and the control condition in Experiment 1¹³ in Table 23). Thus, it is possible that this effect may not be robust. In fact, Mather and colleagues have not replicated this particular finding in other memory updating experiments (see e.g., Sakaki et al., 2011).

Table 23. Comparison of location test errors from Novak and Mather (2009) Experiment 2 with the current Control condition from Experiment 1. Standard errors are in parentheses.

	Novak & Mather, 2009 (n = 18)		Exp #1 Control Condition (n = 54)	
	Neutral	Emotional	Neutral	Emotional
Test 1	0.474 (.027)	0.471 (.025)	0.429 (.021)	0.488 (.019)
Test 2	0.160 (.025)	0.154 (.016)	0.116 (.012)	0.167 (.013)
Test 3	0.050 (.008)	0.066 (.013)	0.060 (.009)	0.101 (.009)
Test 4	0.198 (.015)	0.253 (.015)	0.224 (.017)	0.244 (.013)
Test 5	0.077 (.014)	0.125 (.014)	0.130 (.015)	0.140 (.015)

¹³ This Control condition was used because there was a neutral advantage on the change trial whereas one was not obtained in the Control condition of Experiment 2

Before coming to this conclusion, it is appropriate to consider other features. Remember that Novak and Mather (2009) found that performance for emotional and neutral items did not significantly differ on Test 3, but did on Test 4. For the current experiment, one can ask whether the change error effect is obtained in participants who have equivalent performance on emotionally arousing and neutral pictures prior to the change block. To do this, I analyzed the data from the Experiment 1 Control condition only for those participants who had equal location errors on Test 3 between stimuli type (overall $M = .051$, $SE = .014$). A total of 19 participants who met this criterion were analyzed using a dependent t-test to compare the location errors on Test 4. The results showed that those participants did not significantly differ with respect in their location errors to emotional ($M = .240$, $SE = .027$) and neutral ($M = .216$, $SE = .033$) pictures, $t(18) = 1.204$, $p = .244$. Thus, even in this sub-sample, there was no evidence of differentially greater change errors for emotionally arousing than neutral pictures. The lack of change updating differences between stimuli type was not simply due to the failure to obtain similar performance on the pre-change test.

Another potential difference between our studies involves the stimuli set. Although there is overlap between Novak and Mather's picture set and the one used in these experiments, they reported that the mean valence and arousal levels of their emotional and neutral stimuli were somewhat more extreme than the current stimuli set, see Table 24 for a comparison of arousal and valence means for both stimuli sets. Thus, it is possible that this difference could be responsible for the failure to obtain increased change

Table 24. Arousal and valence means obtained from the norming experiments on the pictures used in the current experiments (taken from Lang et al., 2008) and those in Novak and Mather (2009) separated for neutral and emotional sets.

	Current Experiments		Novak & Mather	
	Arousal	Valence	Arousal	Valence
Neutral	3.91	5.81	1.77	5.61
Emotional	6.00	2.56	7.36	1.88

errors for emotionally arousing pictures. Yet, there are reasons to think this might not be the case.

Although there are mean differences in stimuli characteristics, some of the variability might be a function

of the differences between their norming study (conducted with 3 participants¹⁴) and the IAPS norming study that was used to characterize the pictures in this study (conducted with 100 participants). Therefore, it is possible that the data from their norming study was more extreme than that of the IAPS. I also compared a subset of the pictures used in Novak and Mather with those used in the present study. Not only was there was overlap between the sets, but non-overlapping pictures were highly similar with respect to content and visual detail¹⁵. Thus, I would argue that our stimuli sets are not in fact substantially different, and any differences between them are unlikely to explain the conflicting results.

The results of the current experiments did replicate the pattern of repeat errors obtained in Novak and Mather (2009), and overall accuracy rates were quite similar. Therefore, the only difference between the current results and Novak and Mather's is that I found location errors were higher for emotional than neutral pictures on the 3rd test and they did not (although even in their study, they were nominally higher, see Table 23). In fact, this finding was not obtained in Novak and Mather's first experiment either. In their first experiment, the locations of items never changed, and therefore the first 3 blocks are exactly the same as in the current experiment. To visually compare performance in the experiments, I constructed Figure 14. It depicts location errors for both of Novak and Mather's experiments (top and middle panels). I also collapsed across the control conditions in the first two experiments (N=98; bottom panel). Comparing performance on the first three tests across the three panels, you can see performance is similar in their first experiment and in the current experiments, but their second experiment shows a different pattern. Note the pattern for this second experiment was also not replicated in another study from their lab (Sakaki et al., 2011). Furthermore, given the small sample of her second experiment (n = 18) and the large sample size used in the current studies, I would argue that the weight of evidence casts doubt on the

¹⁴ Novak and Mather also used pictures from the IAPS database. However, they also created some new pictures by creating emotional or neutral versions of existing pictures, which is why they conducted their own norming study.

¹⁵ Dr. Mather has most of her stimuli sets available online. Unfortunately, only 48 of the 64 pairs used in Novak and Mather are available (2009; the set she has online are from an earlier study, and only made up a subset of Novak and Mather's stimuli). I was unable to get access to these additional pictures for the current analyses. Because of this, I compared the stimuli set used in the current experiments with the available pictures. Altogether, 13 of the 48 negatively arousing pictures used in the Novak and Mather (2009) experiment overlapped with the current experiment. Only 2 of the 48 neutral pictures overlapped. However, the non-overlapping pictures from their set and the current experiment were highly similar with respect to content, visual detail, and other characteristics.

robustness of this finding (disproportionally increased updating errors for emotional than neutral pictures).

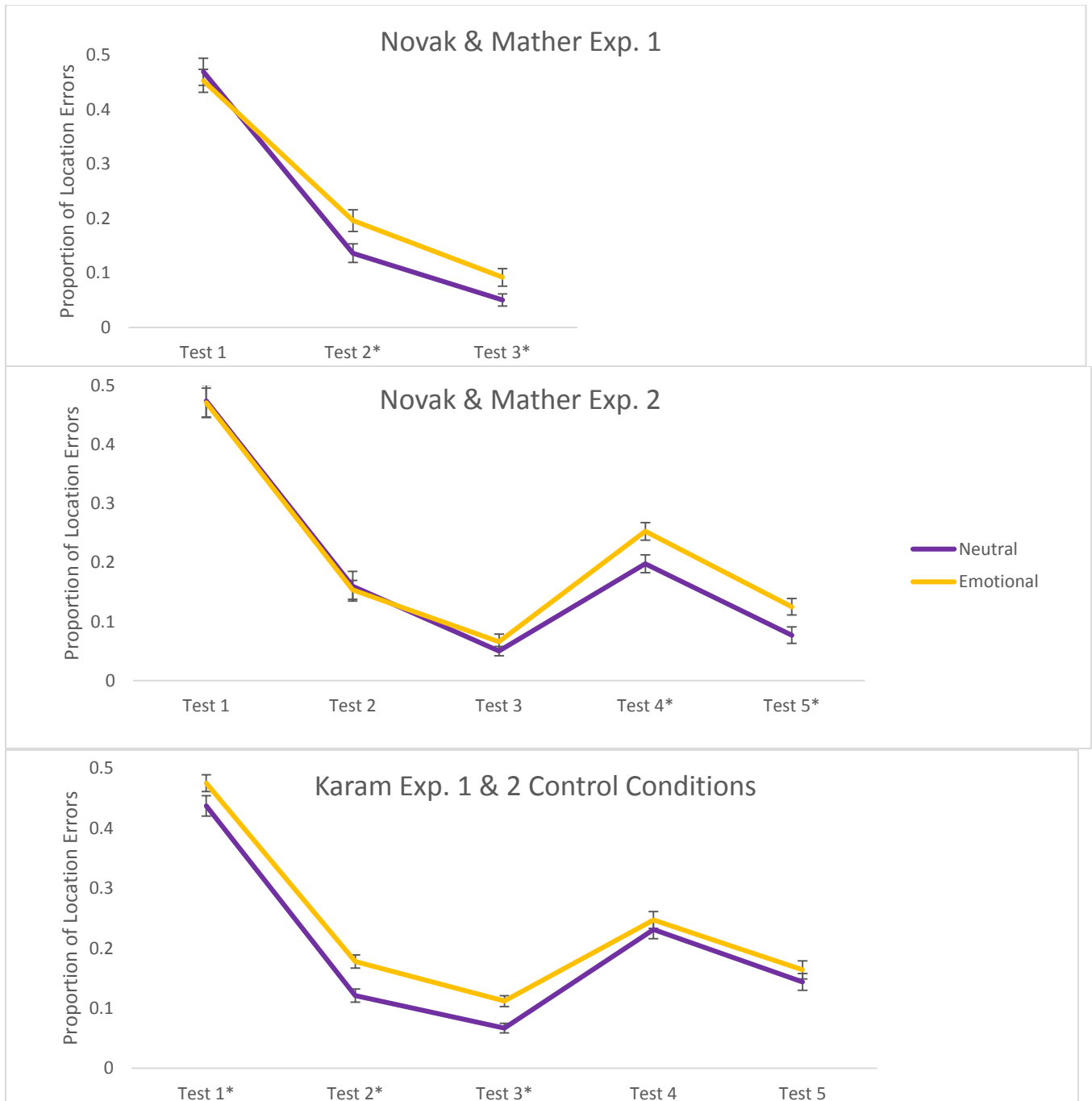


Figure 14. Proportion of location errors for Novak & Mather Experiment 1 (top panel; $n = 36$), Experiment 2 (middle panel; $n = 18$) and a combination of the two control conditions from the current Experiments 1 and 2 (bottom panel; $n = 98$). Procedure is identical in all three conditions in the first 3 tests. An asterisk denotes a significant difference between stimuli type.

Status of the Recursive Reminding Hypothesis

During the introduction to this paper, I presented an alternative to the proactive interference explanation of memory updating posited by Novak and Mather (2009). Specifically, I described how the recursive reminding hypothesis (Hintzman, 2004, 2010) might explain previous findings on the effect of emotional arousal on memory updating (Novak & Mather) and the testing effect (Karam-Zanders & Lane, 2013). This hypothesis was based on the assumption that people had more difficulty updating emotional memory representations than neutral representations. However, the results of the experiments did not replicate this previous finding. Specifically, I found that people are not differentially worse at updating location memory as a function of emotion. For that reason, the experiments were not a good a test of the hypothesis.

The data from the current experiments suggest that people have worse associative memory for emotional information than neutral information from the very first block, and that pattern is similar throughout the experiment, even when an item's location changes. This finding replicates previous literature (Jones et al., 1987; Kensinger, 2009; Mather, 2007; Pierce & Kensinger, 2011). In all 5 conditions in both experiments I found that people showed a similar ability to update emotional and neutral memories. Novak and Mather claimed that initial emotional representations interfere with changing the representation more so than neutral memories, yet I found no evidence of proactive interference being stronger for either types of memories.

Novak and Mather also argued that repeat errors (repeating the previously incorrect location) and change errors (not accurately reporting the new location) reflect the same underlying mechanism: poor memory updating. Although both processes do have similarities, such as: reflecting on the existing memory representation, acknowledging a difference between it and the state of the external stimulus, and thereby adjusting the representation to account for the difference; they also have important differences that the current experiments highlighted. None of the manipulations in the current experiments produced a difference on change updating between emotional and neutral information. All of the conditions in the current experiments, however, found differences in the repeat errors. I was also able identify

manipulations that affected repeat errors (Feedback condition), but not change errors (Warning condition).

What these findings suggest is that the two kinds of memory updating processes do not rely entirely on the same mechanisms. Repeat errors appear to occur more for emotional than neutral pictures at least partly because the former are held with more confidence. Thus, the mechanism appears meta-cognitive. People repeat their errors on subsequent tests because they are confident they are correct and may process the locations less deeply when they the pictures are re-presented. Feedback appears to have helped reduce this confidence in emotional item errors. On the other hand, accurate change updating does not require people to assess the accuracy of their previous memory in order to engage in the updating process. Whether a person feels as though they remember the location well or not is not a requisite to learning the *new* location of an item. Noticing that it has changed is. The noticing process is different for mis-binding updating (repeat errors) than from change updating. For the former, the person needs to assess the accuracy of their memory representation to know whether they need to correct that information, whereas this is not the case for the latter. The reason this distinction is so important is because of the meta-cognitive aspect.

Previous research (Phelps & Sharot, 2008; Talarico & Rubin, 2003; Zimmerman & Kelley, 2010) has shown that people make different meta-memory judgments for emotional and neutral information. Specifically, people believe that they *will* better remember (Zimmerman & Kelley, 2010) and that they *have* better remembered emotional information (Phelps & Sharot, 2008) compared to neutral information. Although people think they have better memory for information associated with emotional stimuli, that increased confidence is often not matched by increased accuracy. Phelps and Sharot (2008) hypothesize that people base confidence judgments for emotional memories on the activation of different brain areas (the amygdala) that are less related to accuracy, than they do for neutral memories (posterior parahippocampus). Essentially, the difference in corrective updating of mis-binding errors of emotional and neutral memories is based on the difference in meta-cognitive reliance. Change updating does not have this component and that is why there is no difference between stimuli type. That is also why the feedback manipulation in Experiment 2 had an effect on the repeat errors but not on the change errors.

Feedback encouraged the person to base the memory judgment on aspects indicative of memory accuracy of the peripheral information, not the sense of accuracy based on familiarity of the item.

The manipulations in the current experiments were motivated by the recursive reminding hypothesis, although not necessarily a good test of the hypothesis itself. One of the major reasons, as discussed above, was that change updating errors were not obtained. Instead, people were generally worse at remembering the location of an emotional item than a neutral item, and this did not increase further after a location change. On the other hand, there was a difference in how initial incorrect item-location bindings were corrected between emotional and neutral items, however this does not appear to be a result of where attention is allocated as I originally suspected (due to increased internally directed attention caused by strong reminders). Instead, as discussed above, repeat errors appear to increase for emotional items because of how those errors are subjectively experienced in memory.

Future Directions

Although the recursive reminding hypothesis may not be as useful as expected for understanding memory updating (for the reasons discussed above), it may still be useful to understanding the effects of emotion on repeated study or testing (e.g., Karam & Lane, 2013).

For example, the preliminary experiment showed that the accuracy of judgments of frequency were better for emotional than neutral repetitions, suggesting that there may be in fact a difference in reminders of emotional and neutral memory representations. Therefore future research should explore the potential effects of how attention is allocated during repetitions of emotional information compared to neutral information.

Furthermore, it may be fruitful to examine whether the recursive reminding hypothesis is equally useful for understanding associative memory (e.g., location), as it is for item memory.

The manipulations in these experiments were presumed to draw attention externally at different times to different degrees; although there was no direct measure of where attention was allocated. In the future it would be beneficial to include an item memory test. The current tests assess memory for the location of items, however attention could have been allocated externally but still not toward the location. Including an item memory test could give insight into where and how attention is being allocated.

Conclusions

We live in a dynamic ever-changing world. It is important for our memory system to be responsive and to be able change along with the world in order to navigate adequately through it. Understanding how people react to a changing world is important, especially if some factors affect our ability to learn such as the emotionality of an event. It is also important that we understand how people assess the accuracy of their own memories, and if those meta-cognitive processes can change. Accurate meta-memory judgments, such as confidence, are important to initiate future study. I hypothesize that the feedback in this experiment provided the participants with information indicating that they were misjudging the accuracy of their emotional memories, regardless of how confident they were. Therefore, the more insight we can gain into how we are affected by features of the situation, the more effectively we can assess the accuracy of our memories and the more likely we can overcome their effects.

References

- Buchanan, T. W. (2007). Retrieval of emotional memories. *Psychological Bulletin*, *133*, 761-779. doi:10.1037/0033-2909.133.5.761
- Burke, A., Heuer, F., & Reisberg, D. (1992). Remembering emotional events. *Memory & Cognition*, *20*, 277-290. doi:10.3758/BF03199665
- Butler, L. (2013). *The effects of emotional arousal on item and associative memory*. Unpublished Master's thesis, Louisiana State University.
- Butterfield, B. & Metcalfe, J. (2001). Errors committed with high confidence are hypercorrected. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 1491-1494. doi:10.1037/0278-7393.27.6.1491
- Cahill, L., Gorski, L., & Le, K. (2003). Enhanced human memory consolidation with post-learning stress: Interaction with the degree of arousal at encoding. *Learning & Memory*, *10*, 270-274. doi:10.1101/lm.62403
- Cahill, L., Haier, R. J., Fallon, J., Alkire, M. T., Tang, C., Keator, D., Wu, J., & McGaugh, J. (1996). Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Sciences of the United States of America*, *93*, 8016-8021.
- Christianson, S. & Loftus, E. F. (1991). Remembering emotional events: The fate of detailed information. *Cognition and Emotion*, *5*, 81-108. doi:10.1080/02699939108411027
- Clark-Foos, A. & Marsh, R. L. (2008). Recognition memory for valenced and arousing materials under conditions of divided attention. *Memory*, *16*, 530-537. doi:10.1080/09658210802007493
- Easterbrook, J. A. (1959). The effect of emotion on cue-utilization and the organization of behavior. *Psychological Review*, *66*, 183-201. doi:10.1037/h0047707
- Eich, E. & Metcalfe, J. (1989). Mood dependent memory for internal versus external events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*, 443-455. doi: 10.1037/0278-7393.15.3.443
- Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments & Computers*, *28*, 1-11. doi:10.3758/BF03203630
- Guillet, R. & Arndt, J. (2009). Taboo words: The effect of emotion on memory for peripheral information. *Memory & Cognition*, *37*, 866-879. doi: 10.3758/MC.37.6.866
- Finn, B., Roediger, H., & Rosenzweig, E. (2012). Reconsolidation from negative emotional pictures: Is successful retrieval required? *Memory & Cognition*, *40*, 1031-1045. doi:10.3758/s13421-012-0203-7
- Hintzman, D. L. (2010). How does repetition affect memory? Evidence from judgments of recency. *Memory & Cognition*, *38*, 102-115. doi: 10.3758/MC.38.1.102
- Hintzman, D. L. (2004). Judgment of frequency versus recognition confidence: Repetition and recursive reminding. *Memory & Cognition*, *32*, 336-350. doi: 10.3758/BF03196863
- Hintzman, D. L. & Stern, L. D. (1978). Contextual variability and memory for frequency. *Journal of Experimental Psychology: Human Learning and Memory*, *4*, 539-549. doi: 10.1037/0278-7393.4.5.539

- Jang, Y. & Huber, D. E. (2008). Context retrieval and context change in free recall: Recalling from long-term memory drives list isolation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*, 112-127. doi: 10.1037/0278-7393.34.1.112
- Johnson, M. K., Nolde, S. F., & De Leonardis, D. M. (1996). Emotional focus and source monitoring. *Journal of Memory and Language*, *35*, 135-156. doi: 10.1006/jmla.1996.0008
- Jones, E. B. & O'Gorman, J. G., & Byrne, B. (1987). Forgetting of word associates as a function of recall interval. *British Journal of Psychology*, *78*, 79-89. doi: 10.1111/j.2044-8295.1987.tb02227.x
- Karam-Zanders, T. & Lane, S. M. (2013). *Initial testing reduces the emotionality advantage*. Manuscript in preparation.
- Kensinger, E. A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences*, *15*, 241-251.
- Kensinger, E. A. (2007). Negative emotion enhances memory accuracy: Behavioral and Neuroimaging evidence. *Current Directions in Psychological Science*, *16*, 213-220. doi: 10.1111/j.1467-8721.2007.00506.x
- Kensinger, E. A. (2009). Remembering the details: Effects of emotion. *Emotion Review*, *1*, 99-113. doi:10.1177/1754073908100432
- 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 of the United States of America*, *101*, 3310-3315.
- Kessler, Y., & Oberauer, K. (2014). Working memory updating latency reflects the cost of switching between maintenance and updating modes of operation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, doi:10.1037/a0035545
- Kim, K., Yi, D., Raye, C. L., & Johnson, M. K. (2012). Negative effects of item repetition on source memory. *Memory & Cognition*, *40*, 889-901. doi: 10.3758/s13421-012-0196-2
- Koriat, A., Bjork, R. A., Sheffer, L., & Bar, S. K. (2004). Predicting one's own forgetting: The role of experience-based and theory-based processes. *Journal of Experimental Psychology: General*, *133*, 643-656. doi:10.1037/0096-3445.133.4.643
- LaBar, K.S. (2007). Beyond fear: Emotional memory mechanisms in the human brain. *Current Directions In Psychological Science*, *16*, 173-177. doi:10.1111/j.1467-8721.2007.00498.x
- LaBar, K. S. & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nature*, *7*, 54-64. doi:10.1038/nrn1825
- LaBar, K. S., & Phelps, E. A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science*, *9*, 490-493. doi: 10.1111/1467-9280.00090
- Lane, S. M. & Karam-Zanders, T. (2013). What do lay people believe about memory? In T. J. Perfect & D. S. Lindsay (Eds.), *The Sage Handbook of Applied Memory* (pp. 348-365). London: SAGE.
- Lane, S. M., Roussel, C. C., Villa, D., & Morita, S. K. (2007). Features and feedback: Enhancing metamnemonic knowledge at retrieval reduces source-monitoring errors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 1131-1142. doi:10.1037/0278-7393.33.6.1131

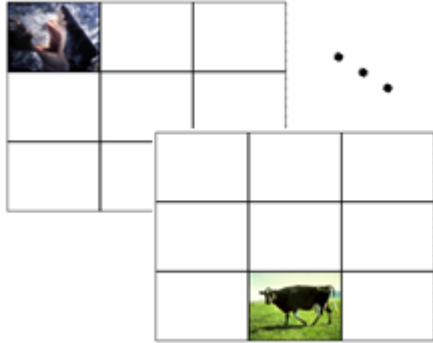
- Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8. University of Florida, Gainesville, FL.
- Levine, L. J. & Edelman, R. S. (2009). Emotion and memory narrowing: A review and goal-relevance approach. *Cognition and Emotion*, 23, 833-875. doi:10.1080/02699930902738863
- Magnussen, S., Andersson, J., Cornoldi, C., De Beni, R., Endestad, T., Goodman, G. S., & ... Zimmer, H. (2006). What people believe about memory. *Memory*, 14, 595-613. doi:10.1080/09658210600646716
- Mather, M. (2007). Emotional arousal and memory binding: An object-based framework. *Perspectives on Psychological Science*, 2, 33-52. doi:10.1111/j.1745-6916.2007.00028.x
- Mather, M. (2009). When emotion intensifies memory interference. *Psychology of Learning and Motivation*, 51, 101-120. doi:10.1016/S0079-7421(09)51003-1
- Mather, M. & Knight, M. (2008). The emotional harbinger effect: Poor context memory for cues that previously predicted something arousing. *Emotion*, 9, 850-860. doi: 10.1037/a0014087
- Mather, M. & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science*, 6, 114-133. doi: 10.1177/1745691611400234
- Novak, D. L. & Mather, M. (2009). The tenacious nature of memory binding for arousing negative items. *Memory & Cognition*, 37, 945-952. doi:10.3758/MC.37.7.945
- Pastotter, B., Schicker, S., Niedernhuber, J., & Bauml, K. H. T. (2010) Retrieval during learning facilitates subsequent memory encoding. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 37, 287-297. doi:10.1037/a0021801
- Pierce, B. H. & Kensinger, E. A. (2011). Effects of emotion on associative recognition: Valence and retention interval matter. *Emotion*, 11, 139-144. doi: 10.1037/a0021287
- Phelps, E. A., & Sharot, T. (2008). How (and why) emotion enhances the subjective sense of recollection. *Current Directions in Psychological Science*, 17, 147-152. doi:10.1111/j.1467-8721.2008.00565.x
- Reisberg, D. & Heuer, F. (2004). Memory for emotional events. In D. Reisberg & P. Hertel (Eds.), *Memory and Emotion*, 3-41. New York: Oxford University Press.
- Sakaki, M., Herrera, A. E., & Mather, M. (2013). *Association learning for emotional harbinger cues: When do previous emotional associations impair and when do they facilitate subsequent learning of new associations?* Manuscript in preparation.
- Sakaki, M., Niki, K., & Mather, M. (2012). Updating existing emotional memories involves the frontopolar/orbito-frontal cortex in ways that acquiring new emotional memories does not. *Journal of Neuroscience*, 21, 3498-3514. doi:10.1162/jocn_a_00057
- Sharot, T. & Yonelinas, A. P. (2007). Differential time-dependent effects of emotion on recollective experience and memory for contextual information. *Cognition*, 106, 538-547. doi:10.1016/j.cognition.2007.03.002
- Sison, J. G. & Mather, M. (2007). Does remembering emotional items impair recall of same-emotion items? *Psychonomic Bulletin & Review*, 14, 282-287. doi: 10.3758/BF03194065
- Stebly, N. M. (1992). A meta-analytic review of the weapon focus effect. *Law and Human Behavior*, 16, 413-424. doi: 10.1007/BF02352267

- Szmalec, A., Verbruggen, F., Vandierendonck, A., & Kemps, E. (2011). Control of interference during working memory updating. *Journal of Experimental Psychology: Human Perception and Performance*, 37, 137-151. doi:10.1037/a0020365
- Talarico, J. M., & Rubin, D. C. (2003). Confidence, not consistency, characterizes flashbulb memories. *Psychological Science*, 14, 455-461. doi:10.1111/1467-9280.02453
- Talmi, D. & Moscovitch, M. (2004). Can semantic relatedness explain the enhancement of memory for emotional words? *Memory & Cognition*, 32, 741-751. doi: 10.3758/BF03195864
- Treisman, A. (2006). How the deployment of attention determines what we see. *Visual Cognition*, 14, 411-443. doi:10.1080/13506280500195250
- Wahlheim, C. N. & Jacoby, L. L. (2013). Remembering change: The critical role of recursive reminders in proactive effects of memory. *Memory & Cognition*, 41, 1-15. doi: 10.3758/s13421-012-0246-9
- Wickens, D. D. (1970). Encoding categories of words: An empirical approach to meaning. *Psychological Review*, 77, 1-15. doi: 10.1037/h0028569
- Wixted, J. T., & Squire, L. R. (2008). Constructing receiver operating characteristics (ROCs) with experimental animals: Cautionary notes. *Learning & Memory*, 15, 687-690. doi:10.1101/lm.1077708
- Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, 46, 441-517. doi:10.1006/jmla.2002.2864
- Zimmerman, C. A., & Kelley, C. M. (2010). "I'll remember this!" Effects of emotionality on memory predictions versus memory performance. *Journal of Memory and Language*, 62, 240-253. doi:10.1016/j.jml.2009.11.004

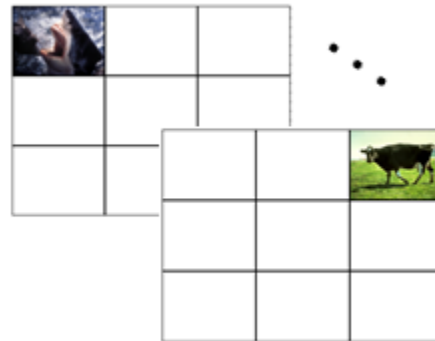
Appendix A: Novak & Mather (2009) Procedure

Schemata of the procedure for Novak and Mather (2009) Experiment 2. Pictures were presented in random order during the study phase in one of eight perimeter locations in a grid on the computer screen. After all the pictures were presented once, the test phase began. During the test phase, all pictures were presented in the middle of the grid. During the test, participants indicated the previous location of each picture by pressing a number associated with the eight locations. This study – test cycle continued until the participant correctly recalled all of the locations for two blocks in a row. The locations remained the same for all the pictures in the first 3 blocks. During the fourth block, half of the pictures changed locations. This location remained the same for the remainder of the blocks in the experiment.

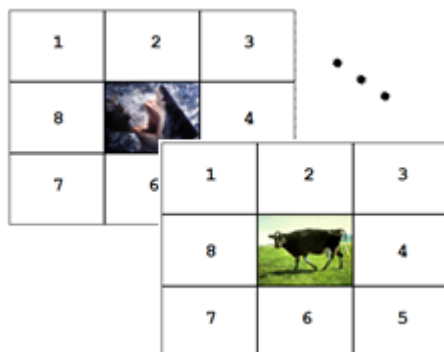
Study Phase (Blocks 1 – 3):
end):



Study Phase (Blocks 4 (change trial) – the



Test Phase (All Blocks):



Appendix B: Post-Experiment Questionnaire

Demographic questions:

Age

Gender

Emotional Experience questions:

The following set of questions has to do with how the emotionally arousing or disturbing pictures made you FEEL while you were viewing them. People sometimes feel a variety of emotions when they see pictures like the arousing ones shown in this experiment. We are interested in what you felt while looking at those pictures, and the extent of those feelings. Specifically you will be asked to indicate the extent you felt Anger, Fear, Sadness and Disgust.

How much ANGER did you feel when viewing the emotionally arousing pictures?

1-----2-----3-----4-----5

How much FEAR did you feel when viewing the emotionally arousing pictures?

1-----2-----3-----4-----5

How much SADNESS did you feel when viewing the emotionally arousing pictures?

1-----2-----3-----4-----5

How much DISGUST did you feel when viewing the emotionally arousing pictures?

1-----2-----3-----4-----5

Meta-memory questions:

On the test you just completed, some of the pictures you saw were Emotionally AROUSING or disturbing, and some were NEUTRAL (not emotionally arousing or disturbing). The next few questions use this distinction. If you are unclear as to what we mean by an Arousing or Neutral test item, please raise your hand right now and the experimenter will clarify that for you.

My location judgments were more accurate for

- 1 - Emotionally Arousing pictures
- 2 - Neutral pictures
- 3 - I was equally accurate for both types of pictures

In the experiment, some of the items changed location. I was more accurate at noticing a change for

- 1 - Emotionally Arousing pictures
- 2 - Neutral pictures
- 3 - I was equally accurate for both types of pictures

Experiment Design questions:

Throughout the experiment, which type of picture was presented more often?

- 1 - Emotionally Arousing pictures
- 2 - Neutral pictures
- 3 – Both types of pictures were shown an equal number of times

Throughout the experiment, which type of picture changed locations more often?

- 1 - Emotionally Arousing pictures
- 2 - Neutral pictures
- 3 – Both types of pictures changed an equal number of times

There were 5 cycles of study-test trials. On which trial did the pictures start to change location?

- 2 – the 2nd trial
- 3 – the 3rd trial
- 4 – the 4th trial
- 5 – the 5th trial

On how many trials did the pictures change location?

- 1
- 2
- 3
- 4 (on all the trials)

Your task was to remember the location of each picture. How did you accomplish this task? In other words, what strategy did you use to associate the picture with its location? Please be as detailed as possible. Press F12 when you have finished typing.

The Vita

Tanya Karam received her Bachelor's degree in Psychology at the University of Waterloo in Waterloo, Ontario, Canada. She went on to receive her Master's degree in Cognitive and Social Psychology at Ball State University in Muncie, Indiana, USA under the supervision of Dr. Kerri Pickel. Her interest in research and teaching continued to grow as she entered a Ph.D. program in Cognitive and Developmental Psychology at Louisiana State University in Baton Rouge, Louisiana, USA under the supervision of Dr. Sean Lane. She will receive her doctorate in May 2014 and plans to return to her hometown of Toronto, Ontario, Canada and continue to teach and research in the areas of cognition and social psychology.