When emotion intensifies memory interference

Mara Mather

University of Southern California

Oct. 12 version
In press, *Psychology of Learning and Motivation*, Volume 51

Abstract

Many of our most vivid memories are of emotional events; in research studies, emotional events or items are often more likely to be remembered than neutral events or items. However, as pointed out in this chapter, the same characteristics that make emotional information memorable can also make emotional information more subject to interference effects in memory. Thus, being reminded of some emotional memories can interfere with other memories evoking the same emotion, it can be more difficult to update one's memory of the context of an emotional item, it can be harder to learn a new association to something that was previously associated with an emotional item, and frequent re-exposure to a cue to a negative memory can increase forgetting of that negative memory.

Table of Contents

1. Introduction

"*Funes not only remembered every leaf on every tree of every wood, but even every one of the times he had perceived or imagined it."*

"He told me: I have more memories in myself alone than all men have had since the world was a world. And again: My dreams are like your vigils. And again, toward dawn: My memory, sir, is like a garbage disposal."

From "Funes the Memorious" by Jorge Luis Borges

To have a perfect memory for every instant of one's life may seem desirable. Yet, as Borges illustrated in his story *Funes the Memorious*, a mind that is incapable of forgetting would also be one that fails to distinguish minutia from core knowledge; one that is incapable of abstract thought. Thus, a key feature of memory is what is forgotten, or not even learned in the first place. Although the most noticeable factor that leads to forgetting is the passage of time, researchers have found that forgetting is not just a passive process. Information competes for mental resources and so newly learned information is vulnerable to interference from other mental activity (for reviews see Anderson, 2003; Wixted, 2004)}.

Much research attests to the fact that emotional events or stimuli are less likely to be forgotten than neutral events or stimuli (for reviews see Kensinger, 2004; Mather, 2004; Reisberg & Heuer, 2004). This memorial advantage is due to a number of factors, including that emotional stimuli grab attention, that we tend to think and talk more about emotional events than neutral events, and that a brain region that responds to emotionally arousing stimuli (the amygdala) modulates memory consolidation activity in the hippocampus, a brain region that plays a key role in acquiring new memories.

Because of its dominance in attention and memory, it is not surprising that emotional information should be more likely to interfere with other information in memory than neutral information. This competitive advantage of emotional information has been demonstrated in many studies (for a review see Mather, 2007). However, some recent findings suggest that, in some cases, the emotional nature of a stimulus make it the **object** of more interference than it might otherwise face, leading it (or information linked to it) to be more likely to be forgotten than if the stimulus were neutral. Unlike Funes the Memorious's memory, normal memory processes are selective. This chapter will touch upon some of the interference or inhibition paradigms and findings that are relevant for emotional memory and review how emotional material may sometimes be more subject to interference.

2. Interference From Being Part of an Emotional Category

Having learned a list of related items (e.g., sleep, bed, rest, awake, tired, dream, wake, snooze, etc.), people are worse at recalling a particular half of the items from the list if they are shown a list of the other items on the memory test than a control group that is not shown any items from the list (Bäuml & Kuhbandner, 2003). Similar part-set cueing effects have been demonstrated many times under a variety of circumstances (e.g., Marsh et al., 2004; Roediger, 1973; Rundus, 1973; Slamecka, 1968; Watkins, 1975). Findings of inhibition from part-set cueing are intriguing because they contrast with the idea that memory retrieval is facilitated by the activation of associated items, and many researchers have devoted effort to explaining the mechanisms of this "persisting enigma in memory research" (Nickerson, 1984).

Related to the part-set cueing effect is the finding that the repeated retrieval of a subset of items from a list can lead to forgetting of the nonretrieved items (Anderson et al., 2000; Anderson et al., 1994). In a typical retrieval practice experiment, participants learn lists of category-exemplar pairs (e.g., fruit-orange, drinks-scotch, fruit-banana). Then they are prompted to retrieve half of the exemplars from half of the categories with the aid of cued stem recall tests (e.g., fruit-or___). A retrieval-induced forgetting effect is demonstrated in the final cued recall test by reduced recall of unpracticed items from practiced categories relative to unpracticed items from unpracticed categories.

Both the part-set cueing effect and the retrieval-induced forgetting effect reveal that being part of a category can reduce a memory's chance of being recalled if other memories from that category have been retrieved more frequently or are activated first during a memory retrieval attempt. These category-based interference effects suggest that emotional memories may suffer from competition with memories that evoke similar emotions. For instance, reminding someone of a negative memory may make them less likely to retrieve as many other negative memories as if they had not been reminded of that memory.

In order to see this type of interference along emotional lines, a necessary prerequisite is that emotions act as organizing principles in memory. Otherwise, activation of a memory that elicits a particular emotion would not activate other memories that also evoke that emotion, and there would be no need to resolve competition among emotionally similar memories. Relevant to this issue, some researchers have argued that that emotions activate associated information within an associative network/spreading activation model of memory (e.g., Bower, 1981; Ingram, 1984; Niedenthal et al., 1999) and there is evidence that emotional cues facilitate retrieval of memories with similar emotional qualities (e.g., Schulkind & Woldorf, 2005). These models and findings of memory activation along emotional lines suggest that there may also be memory interference along emotional lines.

Recent findings support this possibility of interference due to the emotional category of memories. One study examined retrieval-induced forgetting for autobiographical memories generated from cue words (Barnier et al., 2004).

Participants first generated memories in response to nine category cue words, of which three were negative (horrified, sickness, tragedy), three were neutral (hardworking, patient, polite) and three were positive (entertaining, excitement, happy). Participants were also asked to generate a unique personal cue word for each memory that would remind them of the memory. In a subsequent retrieval-practice phase, participants were asked to retrieve their previously generated memory in response to a category cue word/personal cue pair (e.g., hardworking - exams) three times. The experimenter gave them the cues to complete this retrieval for half of the memories generated for one negative, one neutral and one positive category. On the final test, participants were shown all nine category cue words again and were asked to recall all the memories associated with each word. As would be expected from previous studies using category-exemplar word pairs such as fruit-orange, participants were more likely to later recall the memories that they had practiced retrieving than memories from unpracticed categories. In addition, they showed the standard retrieval-induced forgetting effect, as they were less likely to retrieve unpracticed memories from practiced categories than unpracticed memories from unpracticed categories. The novel finding was that retrieval-induced forgetting was greater for memories from emotional categories than for memories from neutral categories.

This finding of greater retrieval-induced forgetting for emotional memories suggests that the competition among memories from the same emotional category may require greater inhibition at retrieval than is necessary to resolve competition among memories from a neutral category. However, it is not clear whether the emotional nature of the memories was the key factor or whether the autobiographical memories generated in response to the different cue words differed on other dimensions.

Another experiment that showed that interference can occur based on emotional category membership used words with either positive or negative valence (Ferraro & King, 2004). In this study, participants received four trials, each consisting of a 3-word triad of either positive or negative words. On each trial, they studied the words and then, after a distractor task, recalled them. For half of the participants, all four trials had words of the same valence. As expected, they showed proactive interference, with worse recall on each subsequent trial that had the same valence for the word triad. For the other participants, the words switched valence on the fourth trial. These participants showed a robust release from proactive interference, with recall that was numerically even higher than their first trial (see also Wickens & Clark, 1968). Thus, the proactive interference occurred along emotional lines, with interference seen only if the words were from the same emotional valence category as the words in the previous trials.

Interference based on membership in an emotional category was also seen in a paradigm in which participants learned a few critical lists (one list consisted of tools, another of diseases and another of curse words) and many filler lists that were also categorized (Smith & Moynan, 2008). After the learning

phase, participants either did unrelated tasks or a retrieval-biasing procedure in which they were repeatedly exposed to the filler lists but not the critical lists. Then they were asked to recall all the list names (e.g., tools) from the first learning phase. Participants showed a high level of forgetting for the critical list names, with 40% higher recall of the critical list names in the control condition. The rate of forgetting was similar for the emotional and non-emotional list names.

An important question is whether the interference effects in the studies reviewed above occurred along emotional lines only because the experimental structure highlighted the emotional nature of the memories, or whether memories from similar emotional categories would spontaneously interfere with each other, even if there were no external cues to use emotional categories. Sison and Mather (2007) used a modified part-set cueing design to examine whether the organization of information along emotional lines is an automatic process that always occurs in response to emotional stimuli or whether the categorical structures that lead to competition among same-category items vary depending upon the most salient organizational scheme at the time. Participants were shown a series of pictures. Each picture belonged to one of four categories: amusing animals, amusing people, fear-inducing animals or fear-inducing people. Thus, each picture could be categorized based on whether it contained people or animals or whether it evoked amusement or fear.

After the initial slideshow presenting the pictures, participants in some conditions were cued to retrieve one picture at a time, all of which were from the same category (e.g., all the amusing people). They were shown a word describing the picture (e.g., “clowns”) and asked to visualize the picture that matched the phrase and then to press a key when they had succeeded. After they pressed the key, the corresponding picture was shown. Ten minutes after this reminder phase, participants were asked to list as many of the pictures from the slide show as they could.

Unlike most part-set cueing or retrieval-induced forgetting paradigms, participants were not reminded of the categories on either the retrieval practice or the final memory test (they were not asked to recall the pictures separately by category and the categories were not used as retrieval cues). Instead, the only explicit statement that the pictures could be categorized was in the initial instructions. In the actor-salient condition, part of the instructions stated that participants would view pictures of animals or people, whereas in the emotion-salient condition, the instructions instead stated that participants would view pictures depicting amusement or fear.

As shown in Figure 1, Sison and Mather found a part-set cueing effect both for pictures from the same actor category (e.g., fear-related people) and for pictures from the same emotion category (e.g., amusing animals). The emotion effect reveals that pictures that elicit the same emotion as pictures that were recently reactivated are subject to interference, even if the topic of the picture is otherwise from another category (e.g., people vs. animals). But a second key finding is that these impairments in memory for items from the same category

depended on which category was mentioned in the instructions. This suggests that which categories are most likely to influence memory competition are flexible, and the degree to which being from the same emotion category will lead to competition among memories will depend on whether the emotional similarity is salient.

Sison and Mather's findings suggest that the emotional nature of memories does not have a special status in determining which memories will interfere with each other, but can act like other categories (see also Smith & Moynan, 2008). Furthermore, the way that memories are categorized, and therefore the degree to which one memory will compete with another one during retrieval, is flexible and context dependent. This ad hoc nature of emotional categories is consistent with Barrett's (2006) proposal that the experience of emotion is itself an act of categorization that is based on prior experience and shaped by the current situation.

3. Proactive Interference for Emotional Items

Having learned an association between two things (such as that Emily lives in Portland) it is usually more difficult to learn a new, competing association (such as that Emily now lives in Seattle). Many studies have demonstrated this type of proactive interference using "AB-AC" paired-associate cued recall designs, in which participants first learn one set of cue-response pairings (AB) and then learn another set (AC). These participants do worse on a test for the AC pairs than other participants who are asked to learn entirely new associations in the second list (CD).

The ability to resolve proactive interference may contribute to many higher cognitive functions, especially working memory (Jonides & Nee, 2006). Prefrontal brain regions, in particular the left ventrolateral prefrontal cortex, play a role in resolving proactive interference (Nee et al., 2007). In addition, reliable individual differences in the ability to inhibit or suppress irrelevant information influence working memory capacity (Barrett et al., 2004; Conway & Engle, 1994).

In at least some models of proactive interference, the probability of recall is based on both the relative and the absolute strength of an item (e.g., Altmann & Gray, 2002; Mensink & Raaijmakers, 1988). This assumption leads to an interesting prediction regarding emotional associations, as recent evidence indicates that emotional items tend to yield stronger memory binding for their intrinsic features than neutral items do (Mather, 2007). Because of stronger proactive interference, people may have a harder time learning new associations with emotional items than new associations with neutral items.

Novak and Mather (under review) tested this possibility by having participants learn the association between pictures and their locations on the screen. In their first experiment, participants studied a series of 72 pictures, each shown in one of eight locations on the computer screen (none were shown in the center location). Half of the pictures were emotionally arousing (and negative)

and half were more neutral. After the study phase, participants were shown each picture again in the middle of the screen and asked to indicate which location it had been shown in previously. They repeated this study-test cycle until they achieved perfect performance in two successive rounds. In the first round, there was no significant difference in picture-location memory accuracy (although location accuracy was slightly higher for the emotional pictures). However, after the first round, accuracy was significantly higher for the neutral pictures than for the arousing pictures. Further examination of the errors on the repeat rounds revealed that participants were more likely to repeat an initial location error again for arousing pictures than for neutral pictures (despite having seen the picture in the correct location again).

The finding that initial picture-location errors were more persistent for the arousing pictures suggested that, when associations change over time, participants might have more difficulty updating associations to arousing items than to neutral items. To test this, in the second experiment Novak and Mather changed the locations of half of the pictures on the fourth round of viewing the series of pictures. At the start of the study, participants were informed that some pictures might change locations in one of the rounds and that at the end of each viewing cycle they should report the most recent locations of the pictures. By the end of the third round, participants had learned the locations of most of the pictures. Among those pictures that they had correctly indicated its location on Round 3, participants were less likely to correctly indicate the changed locations of arousing pictures than neutral pictures on Round 4.

One surprising aspect of these data was that the difference between location memory for arousing and neutral pictures in Round 4 was not driven by a failure to notice the change in location. In fact, participants were slightly less likely to erroneously repeat the location from Round 3 for arousing pictures than for neutral pictures. Instead, their impaired performance for arousing pictures was driven by errors in which they responded with a different location than either the one the picture had been in for Rounds 1-3 (and that they had accurately recalled on Round 3) or the one it had been in for Round 4. This pattern suggests that participants noticed when arousing pictures changed locations – but they were less able to effectively bind the new locations to arousing pictures than they were for neutral pictures. This is an intriguing finding, as it argues against the possibility that the worse performance for new associations with emotional items is due to simple source errors in which people recall the initial association to the emotional item and assume it was the most recent association. Instead, participants seem to have more difficulty learning new associations to emotional items, even when they are aware that the original association is no longer current.

4. Impaired Associations to Emotional Harbingers

The role of memory strength in proactive interference leads to another interesting possibility with regards to emotional associations. Do people have a harder time learning new associations to cues that previously were associated with emotional items, because those emotional associations are more vividly recalled and are therefore more interfering than neutral associations? For instance, having learned to associate a particular phone ring sound with emotionally arousing phone calls, people might have a harder time remembering associated contextual details the next time the phone rings than if the phone were associated with neutral phone calls.

A series of experiments by Mather and Knight (in press) is consistent with this idea that learning associations with emotional items interferes more with learning subsequent associations than learning associations with neutral items. Mather and Knight examined how well people can learn new associations to cues that previously predicted emotional or neutral pictures. For instance, in their first experiment, Mather and Knight first asked participants to indicate as quickly as they could whether pictures shown on the computer screen were negative or neutral. Each picture was preceded by a neutral tone sequence (Figure 2A). Each tone sequence was played before multiple pictures, but always preceded pictures of the same type. Thus, some tones were emotional harbinger cues and others were neutral harbinger cues.

In the second phase of the experiment, participants were asked to learn the association between each of the tone sequences and a digit shown on the screen (Figure 2B). Next, they were given a memory test for the tone-digit associations (Figure 2C). Participants were worse at remembering which digit had been associated with emotional harbinger tones than neutral harbinger tones. A follow-up experiment indicated that this impairment for emotional harbinger associations was also seen for tones that previously predicted positive arousing pictures. Thus, the emotional harbinger effect is consistent across arousing stimuli, regardless of valence.

In subsequent experiments, Mather and Knight replicated the emotional harbinger effect using visual harbinger cues (neutral faces) rather than the auditory tones. They investigated whether attentional narrowing could account for the findings. In other words, did the memory impairments occur because participants focused their attention onto cues that previously predicted something emotionally arousing, making it less likely they would learn other information presented at the same time? The findings indicated that memory narrowing could not account for the impaired memory for information associated with emotional harbingers. For instance, in Experiment 3, the new associations that participants were asked to learn to the neutral face harbinger cues were hats. The neutral face harbinger cue was shown either wearing the hat, or on the other side of the screen from the hat. In both conditions, participants were worse at learning which hat had been associated with neutral faces that had previously predicted emotional pictures than the hat-face association for faces that had previously predicted neutral pictures. Also arguing against an attentional narrowing

hypotheses were findings from Experiment 4, in which memory was impaired not only for external associations with emotional harbingers (digits shown near the face cues) but also for intrinsic associations (the locations of the faces).

The finding that location memory was worse for faces that previously predicted emotionally arousing pictures than for faces that previously predicted neutral pictures contrasts with findings that location memory is better for pictures that are themselves emotionally arousing than for pictures that are more neutral (Mather et al., under review; Mather & Nesmith, 2008). Thus, in Experiment 5, Mather and Knight tested whether, in the same paradigm, participants would have impaired location memory for emotional harbingers compared with neutral harbingers but enhanced location memory for inherently emotional pictures compared with neutral pictures. Like Experiments 3 and 4, in this experiment, participants started with a learning phase in which they saw a neutral face followed by a picture on each trial. They had to rate whether the picture was negative or neutral. Each neutral face appeared multiple times, always predicting the same type of picture. In the next phase, these neutral and emotional harbinger face cues were shown in different locations on the screen and participants were asked to learn the face-location pairings. Interspersed with these harbinger cue faces were new faces that were themselves either emotionally arousing (e.g., a woman with a black eye) or neutral (e.g., other participants saw the same woman without the black eye). Participants were then tested for their memory of all the face-location pairings.

There was a significant interaction, such that participants were worse at remembering the locations for emotional harbinger faces than for neutral harbinger faces, but better at remembering the locations for inherently emotional new faces than for neutral new faces. Furthermore, there was a significant main effect, with participants remembering the locations of the new faces better than the locations of the harbinger faces which had each been seen many times before during the cue learning phase (always in the center of the screen, in a location not used during the face-location association phase).

These findings suggest that when a face is inherently arousing, people tend to have better location memory for it, as seen in our previous studies (Mather et al., under review; Mather & Nesmith, 2008). However, when a face was previously associated with an emotionally arousing picture rather than a neutral picture, this previous emotional association makes it more difficult to learn a new and quite different association (the current location of the face). The main effect in which learning the locations of the harbinger faces was more difficult than learning the locations of the new faces suggests that proactive interference plays a role, even though the nature of the information being associated is different in the initial phase (faces with pictures) and the subsequent phase (faces with locations). Furthermore, this suggests that the reason that learning new associations to emotional harbingers is more difficult than learning new associations to neutral harbingers is because the initial emotional associations create more proactive interference than the initial neutral associations.

The emotional harbinger effect from Mather and Knight's (in press) study and the impaired emotional updating effect from Novak and Mather's (under review) study may reflect a general phenomenon, in which making an initial association that involves an emotionally arousing element makes it more difficult to learn new associations to any component of the original association. This would have important implications in everyday life, as it would mean that associations with emotional events are less likely to be updated or corrected when new information is available.

One interesting question is whether this emotional harbinger effect is related to the more general memory phenomenon in which additional study is more beneficial for previously studied items that have mostly been forgotten than for previously studied items that are remembered well at the time of relearning. For instance, increasing the spacing between two study sessions increases the retention of the material. In their new theory of disuse, Bjork and Bjork (1992) argue that the more accessible an item is at a given point, the less it will benefit from relearning opportunities (e.g., Storm et al., 2008). Memories for emotional items will tend to be more accessible than memories for neutral items, and therefore relearning should be less effective for the emotional items. Particularly intriguing is the indication that relearning will not only be impaired for the item itself, but for associations with that item (Mather & Knight, in press; Novak & Mather, under review).

5. The Intentional Suppression of Emotional Memories

This chapter has already reviewed a number of ways in which emotional memories are more subject to forgetting and interference than neutral memories. However, one key factor not yet discussed is that emotional memories are more likely to evoke the desire to forget or remember than neutral memories. Unpleasant memories, such as the embarrassing thing one said during a meeting, can trigger a negative mood, just as pleasant memories can trigger a positive mood. Retrieving positive memories while avoiding reactivation of negative memories is one way to help regulate emotions (e.g., Rusting & DeHart, 2000; Sakaki, 2004). For instance, simply asking people to rate their emotions every page or so when they filled out a survey about their memories for their health and well-being years earlier made them remember their past in a more positive light and led them to be in a better mood after they completed the questionnaire than when they started, unlike the control participants who were not asked to rate their emotions (Kennedy et al., 2004). Likewise, asking people to think about how they feel about choices just after they make them can lead them to show more of a choice-supportive bias later when they recall the attributes of the choice options, attributing more positive features to their chosen option and more negative features to the rejected option (Mather & Johnson, 2000). In general, people are more likely to remember positive autobiographical events than negative ones, and negative feelings associated with events fade

faster than positive feelings (Walker et al., 2003). Coping mechanisms that minimize the impact of negative events seem to contribute to the advantage for pleasant memories (Taylor, 1991).

The notion that the desire to forget an unpleasant memory could somehow contribute to it being forgotten goes back to Freud's concept of repression, in which mental processes "strive towards gaining pleasure; psychical activity draws back from any event which might arouse unpleasure" (Freud, 2003, p. 68). Despite its extensive history, the concept of memory repression is still controversial (Brewin, 2007; Erdelyi, 2006 and associated commentaries). Some psychologists believe that amnesia for traumatic events is not uncommon (Arrigo & Pezdek, 1997; Gleaves et al., 2004) whereas others are skeptical that emotionally charged memories tend to be repressed (Schacter, 2001) or that anything beyond normal forgetting mechanisms are needed to account for forgotten episodes of trauma (Kihlstrom et al., 2005).

One reason that experimental psychologists have been skeptical of the notion of repression is that it has been difficult to demonstrate repression in controlled laboratory studies. Recently, however, Anderson and Green (2001) provided an experimental task that they argued demonstrated repression. In their study, participants first learned to say an associated word whenever they saw its cue word (e.g., see "ordeal," say "roach"). In the subsequent "think/no-think" phase, they saw some of the cue words printed in green and some in red, and were asked to respond with the associate for the green cues but to not respond to the red cues. Furthermore, for the red cues, participants were asked not to even let the associated word come to mind—they were supposed to avoid thinking about it. The more frequently participants saw a cue word in red during this phase, the less likely they were to recall it later when shown the cue word or a word stem completion such as "insect-r____." This procedure may serve as an analogue to real-life situations in which people encounter something or someone associated with an unpleasant memory but use cognitive control mechanisms to avoid thinking about the associated memory.

Several studies followed up these findings using emotional stimuli, to see if people are more or less likely to suppress emotional associates than neutral associates. One study found that when repeatedly shown faces and asked either to think or not to think of a word or picture previously associated with each face, participants showed larger facilitation and inhibition of associated items that were negative than of items that were neutral (Depue et al., 2006). However, another study using word pairs with neutral cues and emotional response words found that facilitation and inhibition were less effective for unpleasant words than for pleasant words (Marx et al., 2008), whereas other studies have found no differences in the effects of trying not to think about positive and negative stimuli for non-depressed participants (Hertel & Gerstle, 2003; Joormann et al., 2005). Thus, although these studies do not yield clear conclusions about whether it is easier or harder to suppress positive, negative or neutral associations, they suggest that trying not to think of emotional associations has similar effects as

trying not to think of neutral associations, leading people to be more likely to forget them later.

This ability to intentionally forget emotional stimuli has also been demonstrated using directed forgetting paradigms, in which participants are presented with two lists of words and instructed to forget one of the lists but remember the other one (Myers & Derakshan, 2004; Power et al., 2000; Wessel & Merckelbach, 2006). At least among non-depressed college students, telling them to forget a list of negative words is just as effective as telling them to forget a list of neutral words; in both cases, they are more likely to forget those words than control participants not given the forget instructions, with very similar forgetting rates for negative and neutral words (Wessel & Merckelbach, 2006).

Although the studies reviewed above reveal that telling people not to think about an emotional item or set of items decreases the likelihood they will recall that item or set later, none of them attempt to measure what people do without explicit instructions. To examine whether people spontaneously try to suppress negative memories more than positive or neutral memories, Mather and Mangold (in preparation) designed a procedure with a similar structure to Anderson and Green's (2001) think/no-think procedure, but without any explicit instructions to think or not think about associations to the cues. In the first phase of the study, participants were asked to learn the association between faces and pictures. They learned the face-picture associations in lists of nine items. All of the faces were neutral, and the pictures were either neutral, positive or negative. After being shown each face-picture pair once, participants were shown each face and asked to recall the associated picture. After they gave an answer, they were shown the actual associated picture and then another face in the list. They repeated the test for the nine pairs until they remembered all of the pictures correctly. In this fashion, participants learned four lists of face-picture pairs.

The next phase of the study was designed to simulate the undirected nature of everyday re-exposures to memory cues. Participants saw some of the faces again, but were not instructed about whether or not to think about the associated pictures. Instead, they were shown each face on the screen for a few seconds, then the face disappeared, replaced by a question about it (e.g., "Would you like to go out for a drink with the person in the picture?"). Thus, participants were free to reactivate their memories of the associated picture while they looked at a face cue, or to avoid thinking about the association. During this re-exposure phase, one third of the faces were shown once, one third were shown six times (each time followed by a different randomly selected question), and one third were not shown.

Next, participants were shown each face from the original face-picture association-learning phase and asked to recall which picture it had been associated with. Since some of the faces had been seen during the re-exposure phase and some had not, this test provided a measure of how seeing the face again affected memory for what it had originally been associated with. In general, participants were less likely to recall pictures associated with faces shown six

times in the re-exposure phase than pictures associated with faces shown only once or not at all. Thus, frequent re-exposure to faces interfered with memory for previous associations to the faces. Presumably, re-exposure impaired memory for previous associations at least in part because of retroactive interference from new associations to the questions.

However, the main effect of re-exposure was qualified by a significant interaction of picture valence, number of re-exposures and participant gender. Males recalled fewer associated negative pictures with repeated re-exposure to the face cues but did not show this decrease in memory for neutral pictures. In contrast, females did not show this selective diminishment of negative associations with repeated re-exposure to the face cues.

Another question of interest in this study was whether depression status would predict the degree to which people spontaneously suppress negative memories. Previous studies have examined how effectively depressed participants forget associated items or whole lists when asked to do so (Hertel & Gerstle, 2003; Hertel & Mahan, 2008; Joormann et al., 2005; Power et al., 2000). Depressed participants sometimes show impairments in the ability to suppress information when asked to (Hertel & Gerstle, 2003; Power et al., 2000). However, these studies did not examine spontaneous engagement in suppression or enhancement of memories.

Categorizing participants by whether they were above or below the average score on a depression scale in Mather and Mangold's study revealed that females with above average depression scores had better memory for the negative associations to repeatedly re-exposed face cues than did females with below average depression scores or males with above average scores. Thus, females experiencing higher levels of depressed mood were less likely than other participants to successfully suppress negative associations with repeated re-exposure to reminders of those negative memories.

These individual differences based on participant sex and depression levels are consistent with research showing that, in response to a sad or depressed mood, women are about as likely to ruminate about their feelings as they are to try to distract themselves, whereas men are more likely to try to distract themselves from the negative mood (Nolen-Hoeksema et al., 1993). Females' greater tendency to ruminate rather than distracting themselves in response to feeling down about something seems to be one reason that women experience more depression than men do (Nolen-Hoeksema & Jackson, 2001; Treynor et al., 2003). The results from Mather and Mangold's study suggest that sex differences in the likelihood of spontaneously suppressing negative associations to cues may contribute to females' greater risk for depression.

6. Concluding Remarks

Inhibition is a key component of a functioning memory system. In this chapter, I reviewed findings that demonstrate that the emotional response that

some information evokes can make it more subject to interference. This emotion-based susceptibility to interference can happen for a variety of reasons.

First, emotional responses to information can serve as an organizational principle in memory, leading items that evoke similar responses to be categorized together. Most memories have the potential of being categorized in multiple ways. For instance, memory for a picture of clowns could be categorized as something involving people, something amusing, or something seen during the experiment session. Many previous studies have demonstrated that when some members of a category are retrieved, non-retrieved members of the category are less likely to be recalled later than if no category members had been retrieved (for a review see Nickerson, 1984). Emotional categories create interference as do these other types of categories in memory (Barnier et al., 2004; Sison & Mather, 2007; Smith & Moynan, 2008). However, being part of both a semantic and an emotional category does not automatically increase the amount of interference a memory is subject to. Instead, interference happens along emotional or semantic lines depending on which type of categorization scheme is most salient to the rememberer (Sison & Mather, 2007).

Second, I reviewed findings that suggest that emotion can increase proactive interference because of the initial strength of memories for emotional information. Novak and Mather found that it was harder for participants to learn a new location of a picture previously seen in another location if that picture was emotional than if it was neutral. Thus, memory binding that helps create associations among features of an object is more resistant to updating for emotional objects than for non-emotional objects. Furthermore, findings from Mather and Knight's (in press) series of experiments suggests that this impaired memory updating for emotional associations is a surprisingly general phenomena that extends to neutral items that were previously associated with emotional items (emotional harbingers) and leads to impaired new learning of associations that have no overlap or similarity to the original memory representation. For instance, participants were worse at learning which digit was associated with emotional harbinger sounds (sounds that previously preceded emotional pictures) than with neutral harbinger sounds (sounds that previously preceded neutral pictures) even though no numbers had been included in the original learning phase. This intriguing set of findings suggests that people will be less likely to learn any type of new association to something once it has been associated with something emotional.

Cognitive aspects of emotional memories, such as being associated with other similar memories and stronger initial memory representations, are not the only factors relevant for memory interference. Emotional memories are more likely to tap into people's hopes, desires and fears. To maintain positive moods or curtail negative moods, people should aim to remember happy events and forget disturbing ones. Thus, people may be more likely to try to suppress emotionally negative memories than neutral or positive ones. Findings described in this chapter suggest that there are individual differences in how likely people are to

spontaneously suppress negative associations (Mather & Mangold, in preparation). Repeated exposure to faces previously associated with negative pictures impaired males' ability to remember the original face-picture associations more than it impaired females' ability to remember the original associations. Furthermore, females with above-average scores on a depression scale were the least likely to show selective forgetting of the negative associations. This pattern fits with previous research indicating that females are less effective at suppressing intrusive negative thoughts (Nolen-Hoeksema et al., 2008). It also provides an example of how, because of their evocative content, negative memories may be more likely to be the target of memory suppression attempts. One important question for future research is whether depressed females are less likely to try to suppress negative associations or whether they are as likely to try to do so, but are less effective at it. Research with older adults indicates that they use cognitive resources to enhance processing of positive information but to diminish it for negative information—but that when fewer cognitive resources are available, they can no longer selectively favor positive over negative information (Knight et al., 2007; Mather & Knight, 2005). Similarly, depressed females may desire to avoid dwelling on negative memories, but to be ineffective at doing so because of cognitive control deficits associated with depression (e.g., Hertel, 2000; Hertel, 2007).

Emotional events have a special status in memory. They attract greater attention that enhances initial perceptual binding of various features (Mather, 2007). Emotional memories tend to be more long lasting both because they elicit more memory rehearsal and retellings and because emotional events evoke amygdala activity that enhances hippocampal consolidation processes (Canli et al., 2000; McGaugh, 2000). However, as outlined in this chapter, some of the very same reasons that emotional events are more memorable can lead them to be more subject to memory interference or suppression.

7. References

Altmann, E. M., & Gray, W. D. (2002). Forgetting to remember: The functional relationship of decay and interference. *Psychological Science, 13*, 27-33.

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language, 49*, 415-445.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychonomic Bulletin & Review, 7*, 522-530.

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

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

Arrigo, J. M., & Pezdek, K. (1997). Lessons from the study of psychogenic amnesia. *Current Directions in Psychological Science, 6*, 148-152.

Barnier, A., Hung, L., & Conway, M. (2004). Retrieval-induced forgetting of emotional and unemotional autobiographical memories. *Cognition & Emotion, 18*, 457-477.

Barrett, L. F. (2006). Solving the emotion paradox: Categorization and the experience of emotion. *Personality and Social Psychology Review, 10*, 20-46.

Barrett, L. F., Tugade, M. M., & Engle, R. W. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin, 130*, 553-573.

Bäuml, K. H., & Kuhbandner, C. (2003). Retrieval-induced forgetting and part-list cueing in associatively structured lists. *Memory and Cognition, 31*, 1188-1197.

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. F. Healy, S. M. Kosslyn & R. M. Shiffrin (Eds.), *Essays in honor of William K. Estes* (Vol. 2, pp. 35-67). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bower, G. H. (1981). Mood and memory. *American Psychologist, 36*, 129-148.

Brewin, C. R. (2007). Autobiographical memory for trauma: Update on four controversies. *Memory, 15*, 227-248.

Canli, T., Zhao, Z., Brewer, J. B., Gabrieli, J. D. E., & Cahill, L. (2000). Event-related activation in the human amygdala associates with later memory for individual emotional response. *Journal of Neuroscience, 20*, RC99.

Conway, A. R. A., & Engle, R. W. (1994). Working memory and retrieval: A resource-dependent inhibition model. *Journal of Experimental Psychology: General, 123*, 354-373.

Depue, B. E., Banich, M. T., & Curran, T. (2006). Suppression of emotional and nonemotional content in memory: Effects of repetition on cognitive control. *Psychological Science, 17*, 441-447.

Erdelyi, M. H. (2006). The unified theory of repression. *Behavioral and Brain Sciences, 29*, 499-+.

Ferraro, F. R., & King, B. (2004). Release from proactive interference with positive and negative words. *The Psychological Record, 54*, 199-206.

Freud, S. (2003). Formulations on the two principles of mental functioning. In R. Steiner (Ed.), *Unconscious Phantasy* (pp. 67-76). London: Karnac.

Gleaves, D. H., Smith, S. M., Butler, L. D., & Spiegel, D. (2004). False and recovered memories in the laboratory and clinic: A review of experimental and clinical evidence. *Clinical Psychology: Science and Practice, 11*, 3-28.

Hertel, P. (2000). The cognitive-initiative account of depression-related impairments in memory. In D. L. Medin (Ed.), *The Psychology of Learning and Motivation* (Vol. 39, pp. 47-71). San Diego: Academic Press.

Hertel, P., & Mahan, A. (2008). Depression-related differences in learning and forgetting responses to unrelated cues. *Acta Psychologica, 127*, 636-644.

Hertel, P. T. (2007). Impairments in inhibition or cognitive control in psychological disorders. *Applied & Preventive Psychology, 12*, 149-153.

Hertel, P. T., & Gerstle, M. (2003). Depressive deficits in forgetting. *Psychological Science, 14*, 573-578.

Ingram, R. E. (1984). Information processing and feedback: Effects of mood and information favorability on the cognitive processing of personally relevant information. *Cognitive Therapy and Research, 8*, 371-385.

Jonides, J., & Nee, D. E. (2006). Brain mechanisms of proactive interference in working memory. *Neuroscience, 139*, 181-193.

Joormann, J., Hertel, P. T., Brozovich, F., & Gotlib, I. H. (2005). Remembering the good, forgetting the bad: Intentional forgetting of emotional material in depression. *Journal of Abnormal Psychology, 114*, 640-648.

Kennedy, Q., Mather, M., & Carstensen, L. L. (2004). The role of motivation in the age-related positivity effect in autobiographical memory. *Psychological Science, 15*, 208-214.

Kensinger, E. A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences, 15*, 241-251.

Kihlstrom, J. F., McNally, R. J., Loftus, E. F., & Pope, H. G. (2005). The problem of child sexual abuse (letter to the editor). *Science, 309*, 1182-1183.

Knight, M., Seymour, T. L., Gaunt, J., Baker, C., Nesmith, K., & Mather, M. (2007). Aging and goal-directed emotional attention: Distraction reverses emotional biases. *Emotion, 7*, 705-714.

Marsh, E. J., Dolan, P. O., Balota, D. A., & Roediger, H. L. (2004). Part-set cuing effects in younger and older adults. *Psychology and Aging, 19*, 134-144.

Marx, B. P., Marshall, P. J., & Castro, F. (2008). The moderating effects of stimulus valence and arousal on memory suppression. *Emotion, 8*, 199-207.

Mather, M. (2004). Aging and emotional memory. In D. Reisberg & P. Hertel (Eds.), *Memory and Emotion* (pp. 272-307). London: Oxford University Press.

Mather, M. (2007). Emotional arousal and memory binding: An object-based framework. *Perspectives on Psychological Science, 2*, 33-52.

Mather, M., Gorlick, M., & Nesmith, K. (under review). The limits of arousal's memory impairing effects on nearby information.

Mather, M., & Johnson, M. K. (2000). Choice-supportive source monitoring: Do our decisions seem better to us as we age? *Psychology and Aging, 15*, 596-606.

Mather, M., & Knight, M. (2005). Goal-directed memory: The role of cognitive control in older adults' emotional memory. *Psychology and Aging, 20*, 554-570.

Mather, M., & Knight, M. (in press). The emotional harbinger effect: Poor context memory for cues that previously predicted something arousing. *Emotion*.

Mather, M., & Mangold, S. (in preparation). When repeated reminders lead to forgetting: Sex differences in the spontaneous suppression of negative associations.

Mather, M., & Nesmith, K. (2008). Arousal-enhanced location memory for pictures. *Journal of Memory and Language, 58*, 449-464.

McGaugh, J. L. (2000). Memory: A century of consolidation. *Science, 287*, 248-251.

Mensink, G. J., & Raaijmakers, J. G. W. (1988). A model for interference and forgetting. *Psychological Review, 95*, 434-455.

Myers, L., & Derakshan, N. (2004). To forget or not to forget: What do repressors forget and when do they forget? *Cognition & Emotion, 18*, 495-511.

Nee, D. E., Jonides, J., & Berman, M. G. (2007). Neural mechanisms of proactive interference resolution. *NeuroImage, 38*, 740-751.

Nickerson, R. S. (1984). Retrieval inhibition from part-set cuing: A persisting enigma in memory research. *Memory and Cognition, 12*, 531-552.

Niedenthal, P. M., Halberstadt, J. B., & Innes-Ker, A. H. (1999). Emotional response categorization. *Psychological Review, 106*, 337-361.

Nolen-Hoeksema, S., & Jackson, B. (2001). Mediators of the gender difference in rumination. *Psychology of Women Quarterly, 25*, 37-47.

Nolen-Hoeksema, S., Morrow, J., & Fredrickson, B. L. (1993). Response styles and the duration of episodes of depressed mood. *Journal of Abnormal Psychology, 102*, 20-28.

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on Psychological Science, 3*, 400-424.

Novak, D. L., & Mather, M. (under review). The tenacious nature of memory binding for arousing items.

Power, M. J., Dalgleish, T., Claudio, V., Tata, P., & Kentish, J. (2000). The directed forgetting task: application to emotionally valent material. *Journal of Affective Disorders, 57*, 147-157.

Reisberg, D., & Heuer, F. (2004). Memory for emotional events. In D. Reisberg & P. Hertel (Eds.), *Memory and Emotion* (pp. 3-41). N.Y.: Oxford University Press.

Roediger, H. L. (1973). Inhibition in Recall from Cueing with Recall Targets. *Journal of Verbal Learning and Verbal Behavior, 12*, 644-657.

Rundus, D. (1973). Negative effects of using list items as recall cues. *Journal of Verbal Learning & Verbal Behavior, 12*, 43-50.

Rusting, C. L., & DeHart, T. (2000). Retrieving positive memories to regulate negative mood: Consequences for mood-congruent memory. *Journal of Personality and Social Psychology, 78*, 737-752.

Sakaki, M. (2004). Effects of self-complexity on mood-incongruent recall. *Japanese Psychological Research, 46*, 127-134.

Schacter, D. L. (2001). Suppression of unwanted memories: repression revisited? *Lancet, 357*, 1724-1725.

Schulkind, M. D., & Woldorf, G. M. (2005). Emotional organization of autobiographical memory. *Memory and Cognition, 33*, 1025-1035.

Sison, J. A. G., & Mather, M. (2007). Does remembering emotional items impair recall of same-emotion items? *Psychonomic Bulletin & Review, 14*, 282-287.

Slamecka, N. J. (1968). An examination of trace storage in free recall. *Journal of Experimental Psychology, 76*, 504-513.

Smith, S. M., & Moynan, S. C. (2008). Forgetting and recovering the unforgettable. *Psychological Science, 19*, 462-468.

Storm, B. C., Bjork, E. L., & Bjork, R. A. (2008). Accelerated relearning after retrieval-induced forgetting: The benefit of being forgotten. *Journal Of Experimental Psychology-Learning Memory And Cognition, 34*, 230-236.

Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin, 110*, 67-85.

Treynor, W., Gonzalez, R., & Nolen-Hoeksema, S. (2003). Rumination reconsidered: A psychometric analysis. *Cognitive Therapy and Research, 27*, 247-259.

Walker, W. R., Skowronski, J. J., & Thompson, C. P. (2003). Life is pleasant--and memory helps to keep it that way! *Review of General Psychology, 7*, 203-210.

Watkins, M. J. (1975). Inhibition in recall with extra-list cues. *Journal of Verbal Learning and Verbal Behavior, 14*, 294-303.

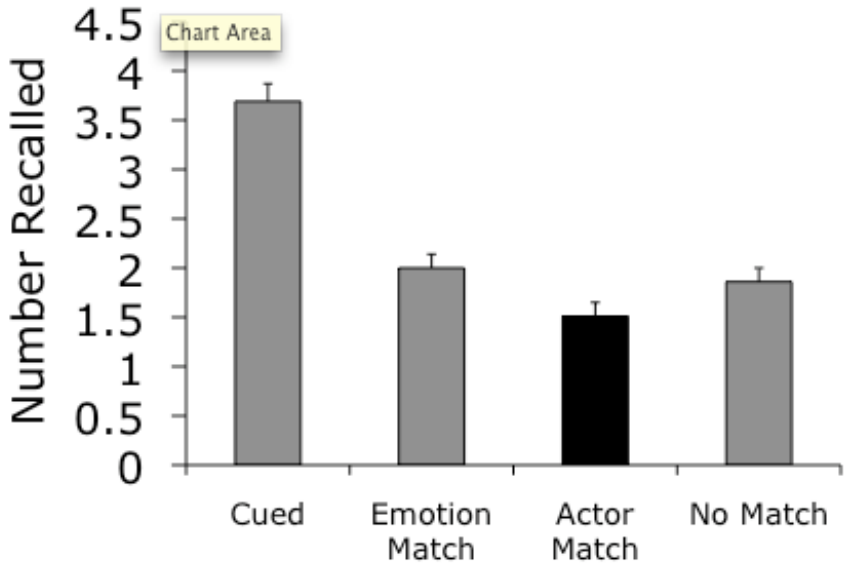
Wessel, I., & Merckelbach, H. (2006). Forgetting "murder" is not harder than forgetting "circle": Listwise-directed forgetting of emotional words. *Cognition & Emotion, 20*, 129-137.

Wickens, D. D., & Clark, S. E. (1968). Osgood dimensions as an encoding category in short term memory. *Journal of Experimental Psychology, 78*, 580-584.

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology, 55*, 235-269.

Figure 1
Sison and Mather (2007) found that: A) when instructions mentioned people versus animal categories, recall of non-cued actor-match pictures was impaired; whereas B) when instructions mentioned amusing versus fear categories, recall of non-cued emotion-match pictures was impaired. Thus, memory impairment for pictures from the same category as cued pictures only occurred if that particular category structure was made salient at the beginning of the experiment.

A)



B)

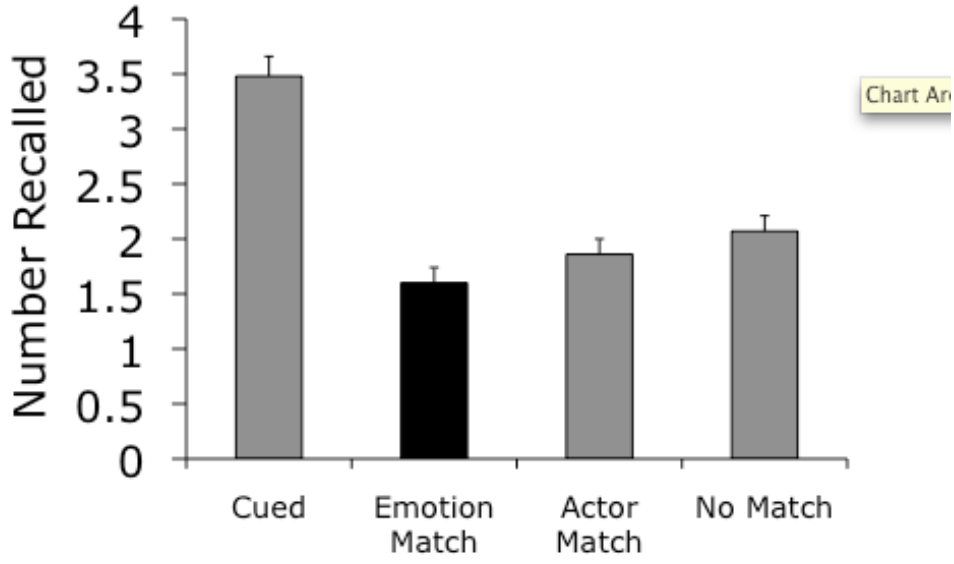


Figure 2
In Mather and Knight's (in press) Experiment 1, participants first learned which sounds preceded negative pictures (emotional harbinger sounds) and which sounds preceded neutral pictures (neutral harbinger sounds). Then, in the next phase, they were asked to learn associations between the sounds and digits (with an intervening color categorization task). In the final phase, they were asked to indicate which digit each sound had been paired with. Memory for the sound-digit pairings was worse for emotional harbinger sounds than for neutral harbinger sounds.

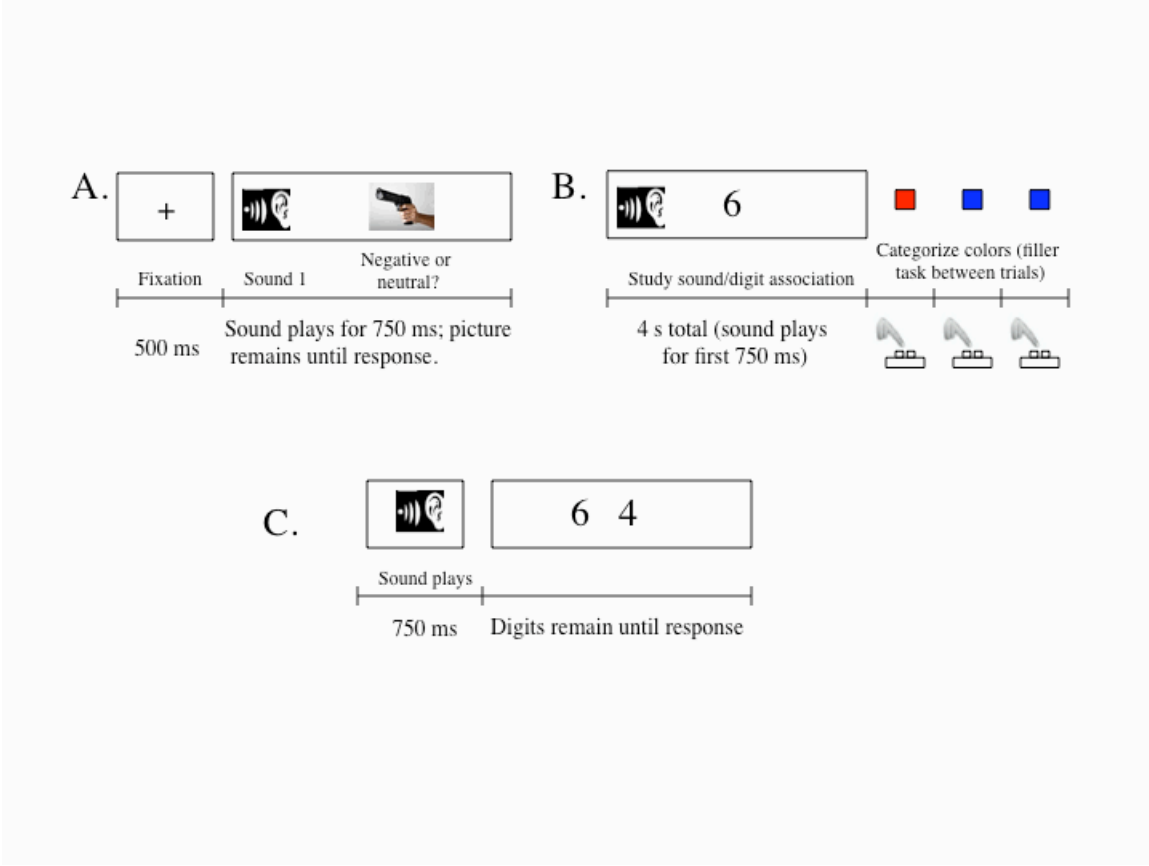


Figure 3
In Experiment 5 of their paper, Mather and Knight (in press) replicated the effect from their previous experiments that people were worse at learning new associations to emotional harbinger cues than to neutral harbinger cues (in this case, the cues were faces and the new associations were the face locations). In contrast, participants were better at learning the locations of new inherently arousing faces than new neutral faces. Thus, previous emotional associations to neutral faces interfered with learning new associations, whereas inherently emotional faces did not show the same interference. In addition, there was an overall impairment in learning the locations of the harbinger faces, suggesting that proactive interference from previous viewing of the faces made learning new associations to the faces more difficult.