Hot Cognition: Effects of Emotion on Interference Resolution in Working Memory

by

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Abstract

This study examined the effect of emotion on proactive interference resolution and attention in working memory. Proactive interference occurs when previously learned information interferes with new learning. Research has shown that taboo stimuli capture attention and delay response times (Siegrist, 1995). Other studies suggest that arousing stimuli help resolve interference (Levens & Phelps, 2008). This study uses a Taboo Stroop paradigm and an item-recognition task to determine the effect of both emotional (negative valence, high arousal) and taboo (offensive, high arousal) words on interference control. Results from the item-recognition task suggest increased interference for taboo words relative to neutral words, however emotional words did not produce this effect. Taboo Stroop results demonstrated increased response times to identify ink colors of both taboo and emotional stimuli relative to neutral stimuli. These findings support the argument that arousing stimuli capture attention and impede interference resolution in working memory.

Hot Cognition: Effects of Emotion on Interference Resolution in Working Memory

Individuals have a tendency to allow their emotions to influence and cloud their immediate cognitive processing much more than has been previously believed. While traditional theories about cognition have excluded emotion as an influential factor, recent examinations of neural systems of behavior have indicated a significant amount of overlap between emotional and cognitive systems (Phelps, 2006), suggesting that emotions play an exceptionally strong role in influencing thinking and decision-making. Countless studies have described the impact of emotion on cognitive processing; previous research has demonstrated that participants take longer to identify the ink colors of taboo stimuli relative to the ink colors of neutral stimuli (Siegrist, 1995), in an emotional version of the classic Stroop effect (Stroop, 1935).

In general, emotion has been thought to capture and divert attention away from non-arousing information, which in turn delays processing or completion of a task. To describe the relationship between emotion and cognitive processing, the term *hot cognition* was introduced (Abelson, 1963). *Hot* versus *cold cognition* refers to the distinction between thought processes associated with emotional and non-emotional information. Hot cognition is generally described as reasoning motivated by one's emotion or *gut*, whereas cold cognition describes rational, systematic reasoning, based on facts and critical thinking (Brand, 1987).

Just as emotion influences cognitive processing in general, it certainly must have a marked effect on memory. Although much theorizing and empirical research has explored the role of emotions on long-term memory (i.e., Brown & Kulik, 1977; Easterbrook, 1959), little research has been conducted on the role emotion in working memory until recently. Working memory is generally defined as the ability to maintain information in the mind that is necessary to execute reasoning or memory tasks (Baddeley & Hitch, 1974); it has a limited capacity

(typically of less than seven items), with a limited duration of information retention (generally ten seconds or less). Moreover, it features storage components that are material-specific (i.e., visual or phonological information), as well as other processing components to manipulate, update, and otherwise manage these small amounts of information over brief time intervals. Considering these complexities, one would expect the presence of emotional information to have considerable consequences for the normal functioning of working memory.

Processing and Retrieval of Emotional Memories

A phenomenon within long-term memory, known as flashbulb memories (Brown & Kulik, 1977), describes vivid snapshots of highly emotionally arousing moments that are highly resistant to forgetting, and that evoke very specific accounts of minute—often non-emotional—details from the event. September 11th is often cited as a modern-day example of a traumatic event that could induce the flashbulb memory phenomenon (Pezdek, 2002; Weaver & Krug, 2002). Recent studies have suggested that flashbulb memories may provide less accurate accounts than the original theory would suggest, however these memories remain experienced as extremely vivid images uncharacteristic of ordinary memory (MacKay & Ahmetzanov, 2005; Talarico & Rubin, 2003). This vivid account of emotional memory suggests that an increase in *arousal*—which can be defined as one's degree of reactiveness to certain stimuli—may cause increased memory consolidation for these arousing items. Because of this, forgetting of irrelevant, neutral information increases relative to the more arousing information. The presence of arousing stimuli results in a phenomenon known as Post-Stimuli Elaboration, in which this arousal may cause increased effort "to be invested in the elaboration of the experience," which would cause a deeper level of processing than would a neutral experience (Christianson, 1992).

Although this describes the role of emotion in affecting consolidation and retrieval of long-term memory, the concept of autobiographical elaboration and contextual cues has implications for emotional processing in working memory. A more recent study by MacKay and Ahmetzanov (2005), investigating emotion using a taboo Stroop paradigm and subsequent recall test, suggested that memory is increased for arousing stimuli relative to neutral stimuli, as participants could more easily recall the taboo probes than the neutral probes. Moreover, the same study tested the effects of arousal on contextual information, and demonstrated that people have superior location memory of taboo words than of neutral words, suggesting that these word locations are analogous to event locations of flashbulb memories (MacKay & Ahmetzanov, 2005). These findings provide insights on long-term emotional memory storage and retrieval, and additionally provide evidence for heightened encoding for emotional information during working memory.

Within the realm of information processing and encoding, Easterbrook's classic Cue-Utilization theory (1959) suggests that high arousal levels tend to cause attention narrowing; in an emotionally arousing situation, attention will be primarily focused on the arousing details (cues) of the stimuli. Under this theory, emotional information and details central to the arousing material will be encoded, while more marginal details will not be encoded, due to the lack of associated arousal. Under a situation of limited attention, the distinctiveness of the emotional information is said to result in prioritized processing of emotional information relative to non-emotional information (Kensinger, 2004; Ochsner, 2000).

Hot Cognition and Interference Resolution

During working memory processing, executive functions are said to control and manipulate information to ensure proper coordination of information as a task progresses

(Baddeley, 1986; Jonides, Smith, Marshuetz, Koeppe, & Reuter-Lorenz, 1998; Persson, Welsh, Jonides, & Reuter-Lorenz, 2007). Interference is common during a working memory task, and can impede accurate and rapid execution of a task. Proactive interference—a concept studied extensively in our laboratory—describes the forgetting of, or difficulty in properly learning new information due to interference from previously learned events. Previously learned material conflicts with current material, which slows decision-making in a task, resulting in competition between the information; interference is finally resolved when the correct decision is made.

Proactive interference has been studied using a version of the item-recognition test known as a Recent Probes paradigm (Monsell, 1978). The Recent Probes paradigm is designed to induce interference between trials, by inducing a conflict between familiarity and source recognition (Levens & Phelps, 2008). On interference-inducing Recent Probes trials, participants must overcome proactive interference in order to respond correctly; this time to resolve this conflict and respond is known as *interference*. Moreover, differences in response times reflect the extent of this interference. Previous research has shown that response times are longer for interference trials, and shorter for trials that do not provoke any interference (D'Esposito et al., 1999; Jonides, Smith, Marshuetz, & Koeppe, 1998).

Interference resolution is commonly studied in our laboratory using various manipulations, however never under the influence of emotion. A recent study by Levens and Phelps (2008) suggests that emotional stimuli—actually much more similar to offensive *taboo* stimuli used in various studies than simply negative valence, high arousal stimuli—serve to enhance interference control, and enable the resolution of interference more quickly than non-emotional stimuli. To explore the relationship between proactive interference and emotion, their study used a Recent Probes task with three-word memory sets (Monsell, 1978). In each trial,

participants were given a three-word set followed by a probe word, and then had to determine whether or not the probe word was included in the memory set. In the neutral condition of the task, memory sets consisted entirely of neutral words, and participants were probed with neutral stimuli; in contrast, the emotion condition contained both neutral and emotional stimuli in the memory sets, and contained both Emotional Probe and Emotional Distractor conditions. The Emotional Probe trials featured probes of words that were included in the three-word set, while the Emotional Distractor trials contained emotional probes that were not included in the three-word trial set. As described in their study, they found that emotional stimuli improved interference resolution relative to neutral stimuli, suggesting that emotional information serves to reduce interference.

Relevant to analysis of the Levens and Phelps findings, a recent study addressing distinctiveness and emotionally-enhanced memory concluded that in a working memory task, emotion enhances immediate memory only when "distinctiveness is allowed to play a role" (Talmi, Luk, McGarry & Moscovitch, 2007). The study defines distinctiveness as the degree to which an event or stimulus stands out relative to other stimuli in a list; considering that organization and distinctiveness work to enhance memory (Hunt & McDaniel, 1993), Talmi et al. (2007) assert that emotion's role in enhancing memory may be because it "links separate events together, and also allows them to stand out relative to background neutral events." Analogously, their study results suggest that, when comparing recall performance between neutral and emotional pure-stimuli lists, participants had no memory enhancement for the emotional stimuli relative to neutral stimuli. For mixed-stimuli lists, participants' memory for emotional items was enhanced only when distinctiveness was not controlled; in mixed lists in

which presentation of emotional stimuli was much more distinctive, participants had better recall for these stimuli than even semantically related neutral stimuli.

These results could offer some insight regarding the Levens and Phelps results, as their three-word-set Recent Probes trials did not seem to be controlled for distinctiveness; trials often contained two neutral words and one emotional stimuli, in which case the enhanced memory for the emotional word—and therefore reduced proactive interference—could be attributed to general arousal due to the word's distinctiveness. Assuming that arousal is responsible for driving memory enhancement, memory for emotional stimuli should be better for the mixed lists than for the pure lists.

Defining "Emotional" Stimuli

Previous studies have reported significant findings only for negative *emotional* stimuli of a high arousal (i.e., Levens & Phelps, 2008; Sharma & McKenna, 2001). In order to optimize the likelihood that our study would yield informative results, we used two sets of highly arousing stimuli: an *emotional* stimuli set (negative valence and high arousal), and a *taboo* stimuli set (containing offensive words that would likely be censored on television). Previous research has suggested that *emotional* stimuli (i.e., massacre; maggot) are often not arousing enough to produce a desired study effect, and that *taboo* stimuli (i.e., fuck; bitch) should be used instead to provoke arousal and attention (i.e., MacKay et al., 2004). This is especially true for university student participants: especially in a formal university laboratory setting, sexual words have been found to most strongly capture attention and distract participants from a given tasks, more so than emotionally positive, or even emotionally negative (i.e., threatening or anxious) stimuli (Arnell, Killman & Fijavz, 2007). With both emotional and taboo working memory tasks, we

seek to revisit this claim, and investigate the effect of *taboo* stimuli relative to simply *emotional* stimuli.

Our study seeks to revisit the role of emotion in proactive and attentional interference using a working memory and an attention task. To investigate proactive interference, we used a four-word Recent Probes design that differs from that of Levens and Phelps (2008) in that it eliminates some potential confounds in their design, and is consistent with previous studies (i.e., Jonides & Nee, 2006; Persson & Reuter-Lorenz, 2008). Considering the distinctiveness of arousal argument, we chose to use a Recent Probes design that differs from that of Levens and Phelps so that it controlled for distinctiveness: each four-word memory set contained two *hot* stimuli, and two unrelated neutral stimuli. By equating the number of words from hot and cold categories on each trial, any differences we observe between trials types can be attributed to the stimulus types rather than distinctiveness.

In addition, we used a Stroop paradigm for a different perspective on emotion and interference, with a focus on attention. Our within-subjects comparison of these two paradigms, seeks to examine the potential differences in interference resolution for emotional versus neutral stimuli; furthermore, we seek to explore a potential relationship between Recent Probes task performance and performance on the Stroop task.

Based on previous studies, we predict that our taboo and emotional Stroop tasks will demonstrate increased interference for emotional and taboo trials relative to neutral trials. We predict that the Recent Probes task results could present one of two possible outcomes. The first possibility is that the presence of emotional or taboo stimuli could distract participants and cause increased proactive interference in the Recent Probes task relative to neutral stimuli, suggesting that the arousing words are better learned than the neutral words and therefore harder to forget,

creating more interference. The second possibility, consistent with the prior work of Levens and Phelps (2008), is that the presence of emotional or taboo stimuli allow for better interference control and help to resolve proactive interference better than neutral stimuli, suggesting that the arousing words are better learned and therefore more easily identified than the neutral words. Moreover, using our within-subjects manipulation, we are able to consider a potential relationship between performance on the emotional or taboo Recent Probes and Stroop tasks.

Method

Participants

Fifty-six undergraduate students from the University of Michigan participated in the study for Introductory Psychology course credit. Seven participants were excluded due to technical difficulties, failure to complete the study, disruptive behavior during the taboo portions of the study (i.e. laughing), or because experimental results fell beyond 2.5 standard deviations from the mean. In total, forty-nine undergraduate students (twenty-two males, $M = 18.41$ years, $SD = 0.61$) were included in the analyses. Participants were native English speakers and primarily right handed (one participant was left handed). All participants gave informed consent and were explicitly informed prior to consenting that they would be seeing offensive stimuli, often censored on television, and that they could terminate their participation at any time. All included subjects completed the entire experiment.

Materials

Two sets of words were compiled, one containing taboo words and correspondingly balanced neutral words (referred to as taboo-neutral words), and the other containing emotional (negative valence, high arousal) words and correspondingly balanced neutral words (dubbed emotional-neutral words). Each set contained forty words, with twenty neutral words and twenty

emotional or taboo words. For the taboo stimuli set, twenty taboo-neutral and twenty taboo words were selected from a study by MacKay, Hadley, & Schwartz (2005). Taboo and taboo-neutral stimuli were balanced for familiarity (6.4 for taboo words vs. 6.64 for taboo-neutral words), $t(38) = 1.72$, $p = .093$, word length (4.4 letter for taboo words vs. 4.6 letters for taboo-neutral words), $t(38) = .93$, $p = .359$, and number of syllables (1.35 for taboo words vs. 1.125 for taboo-neutral words), $t(38) = .93$, $p = .35$ (see Table 1 for taboo and taboo-neutral word lists). For the emotional stimuli set, twenty different neutral and twenty emotional words were selected from the Affective Norms for English Words list (ANEW, Bradley, M.M., & Lang, P.J., 1999). Emotional stimuli were chosen as negative valence, high arousal words. Emotional and emotional-neutral stimuli were balanced for frequency (6.25 for emotional vs. 6.5 for emotional-neutral words), $t(38) = .17$, $p = .87$, word length (6.45 letters for emotional vs. 6 letters for emotional-neutral words) , $t(38) = -.94$, $p = .353$, and number of syllables (2 for emotional vs. 1.95 for emotional-neutral words), $t(38) = -.21$, $p = .833$ (see Table 2 for emotional and emotional-neutral lists). Note that while the word frequency/familiarity values for the taboo and emotional conditions are numerically similar, the words were taken from different lists and therefore may have slightly different measures for determining frequency and familiarity.

Additionally, while the stimuli were balanced within tasks, they were not balanced between tasks, and therefore have differing word lengths and number of syllables across the Taboo and Emotional tasks. A t-test comparing the word lengths of taboo-neutral and emotional-neutral words revealed a significant difference in word length between the two word types, $t(38) = -3.76$, $p = .001$; likewise, a comparison of the taboo and emotion word lengths also revealed that two were significantly different, $t(38) = -5.56$, $p < .001$. The number of syllables of taboo-neutral and emotional-neutral words also differed significantly, $t(38) = -5.05$, $p < .001$; similarly,

there was as significant difference between number of syllables of taboo and emotional words, $t(38) = -3.12$, $p = .003$. E-Prime software was used for stimulus presentation (Psychology Software Tools, Inc.). Words were presented against a black background, in courier new font, size 20.

Procedure

Prior to the computer tasks, each participant filled out an information sheet collecting demographic information, as well as the Edinburgh Handedness Inventory (Oldfield, 1971). After completing the computer tasks, participants were given a Digit Span test (Wechsler, 1997), and finally, asked to complete an exit survey on the study's tasks. Participants were tested individually, and given oral instructions along with on-screen instructions, as well as computerized examples and practice trials, prior to the actual tasks. For both tasks, participants were asked to respond as quickly and as accurately as possible. The study was a within-subjects design, containing a Recent Probes task (modified from Monsell, 1978) and modified Stroop task (Siegrist, 1995). For both the Recent Probes and Stroop tasks, participants performed both Taboo and Emotional versions of the tasks, completing four tasks in total. There were eight possible counter-balanced orders for which subjects completed the tasks; participants were given either the Stroop or Recent Probes tasks first, and within each task, either Taboo or Emotional version first.

Recent Probes. Both the taboo and emotional Recent Probes tasks consisted of two blocks of forty-eight trials each (a total ninety-six trials for each version of the Recent Probes tasks). Each trial was composed of set of four words displayed for 1500 ms, followed by a 3000 ms retention interval. Participants were then given a probe word, and told to respond by pressing a mouse button, indicating whether or not they had seen the word in the four-word set. The

words within the memory set were presented in lowercase font (size 20), while the probe words were presented in all uppercase letters, to eliminate the possibility of word shape recognition influencing task decision. Participants indicated "Yes" or "No" by choosing the left or right mouse button, respectively. A diagram of the Recent Probes task is included in Figure 7.

For both the taboo and emotion conditions of both tasks, there were an equal number of neutral probe and arousing (taboo/emotional) probe trials. Additionally, each block of trials was counterbalanced to include the following trial types: *NoFam0*, *NoFam1*, *NoFam2*, *YesFam1*, *YesFam2*. Within each block of trials, there were 8 *NoFam2* trials (4 emotional/taboo and 4 neutral), 8 *NoFam1* trials (4 emotional/taboo and 4 neutral), 8 *NoFam0* trials (4 emotional/taboo and 4 neutral), 4 *YesFam2* trials (two emotional/taboo and two neutral), and 20 *YesFam1* trials, with an equal number of emotional/taboo and neutral trials. *NoFam* trials were negative probe trials, meaning that participants should respond "No" because the probe word did not appear in the current four-word memory set. Both the *NoFam1* and *NoFam2* trials were designed to generate interference: the *NoFam1* trial type indicates a negative probe that did not appear in the present four-word set, but did appear in the previous trial's four-word set; correspondingly the *NoFam2* trial indicates a negative probe which did not appear in the present set, however did appear in both of the previous two trials' memory sets.

YesFam trial types were positive probe trials, meaning that participants should respond "Yes" because the probe word was included in the current four-word memory set. A *YesFam1* trial featured a probe that was included only in the present four-word set, and not in the previous trial. *YesFam2* trials were also positive probe trials, with the probe appearing in the present and previous trial's four-word set. Trial types are further described in Figure 8. Comparing this experimental design to that of prior Recent Probes studies (D'Esposito et al. 1999; Jonides &

Nee, 2006; Jonides et al., 1998), *NoFam0* trials could be likened to *Non-recent-No* trials, while the average of *NoFam1* and *NoFam2* trials correspond to *Recent-No* trials. Likewise, *YesFam1* trials correspond to *Non-recent-Yes* trials, while YesFam2 trials correspond to *Recent-Yes* trials.

Stroop Test. In the Stroop task, participants were told to ignore the meaning of the words presented, and only pay attention to the ink color of each word. The emotional and taboo Stroop tasks each contained two blocks of eighty trials, for a total of 160 trials in the Taboo Stroop, and 160 trials in the emotional Stroop task. During each trial, a 500 ms fixation point was presented in the center of the screen (in white), followed by a probe word, which remained on the screen until the participants responded (with a presentation limit of 2000 ms). Additionally, there was a 500 ms inter-trial interval.

Two versions of the Stroop task were examined in the study, differing in the modality of response. In the manual-response Stroop task, participants indicated their ink color responses manually, by pressing colored keyboard keys. Seventeen undergraduates (six men) participated in this version of the task (M = 18.35 years; SE = 0.60). Colored stickers were placed over the keys (the keys *c, v, b,* and *n* were colored as red, yellow, green, and blue, respectively). Subjects were told to press the key with the corresponding color as quickly as they could, without making mistakes. Ink colors were red, green, blue and yellow, colors commonly used for Stroop experiments (i.e. Siegrist, 1995). Each of the forty words w presented in each of the four ink colors, for a total of 160 trials across both blocks. Word and color presentation was completely randomized within each block.

Thirty-two participants (sixteen men) were given the voice-key Stroop task (M = 18.40 years, SE = 0.60). There were an equal number of participants for each of the orders, with half of participants given the Stroop task first, and half given the Recent Probes task first. In this version

of the Stroop task, participants indicated the ink colors of the words vocally, by speaking their ink color responses into a microphone, while the experimenter recorded the participants' response accuracy. Again, subjects were told to speak the ink colors as quickly as they could think of them, without making mistakes. A voice key recorded the onset of the vocal response and allowed analysis of response times to name the ink color. Note that the Recent Probes task remained identical, regardless of Stroop task modality.

Results

Stroop Tasks

The Stroop tasks were analyzed using a three-way analysis of variance (ANOVA) of response times (RT). Gender (male or female) and Task Order (Recent Probes task first, or Stroop task first) were between-subjects factors. Word Type was a within-subjects factor with four possible conditions (emotional-neutral, emotional, taboo-neutral, and taboo). Manual and the voice-key response modes were analyzed separately.

Manual response. An ANOVA of manual Stroop RTs revealed a significant main effect of gender, $F(1,13) = 6.72$, $p = .02$, such that male participants took significantly longer to identify ink colors ($M = 676.81$ ms, $SE = 24.95$) than did female participants ($M = 597.00$ ms, $SE = 18.01$). Results are presented in Figure 1. There was no significant main effect of Word Type, $F(3, 39) = .16$, $p = .93$, or of Task Order, $F(1, 13) = .14$, $p = .71$ (see Figure 2). There was also no significant interaction between word type and gender, $F(3, 39) = .12$, $p = .948$.

There was a significant interaction between Word Type and Task Order for manual Stroop RT, $F(3,39) = 3.76$, $p = .02$. Most notably, for the taboo condition, RT was slower when the Stroop task was presented first ($M = 638.32$ ms, $SE = 23.34$) than when presented second ($M = 617.38$, $SE = 21.00$). Beyond this finding, mean RTs were generally faster for participants

who received the Stroop task first than for participants who received the Stroop task second: This was true for the emotional-neutral condition (Stroop first: $M = 606.30$, $SE = 19.76$; Stroop second: $M = 644.40$, $SE = 28.84$), and the emotional condition (Stroop first: $M = 603.98$, $SE = 26.44$; Stroop second: $M = 636.37$, $SE = 29.21$), whereas the taboo-neutral condition displayed no difference in response times for task order (Stroop first: $M = 624.33$, $SE = 20.53$; Stroop second $M = 626.26$, $SE = 20.48$).

To examine trial accuracy, a three-way ANOVA was also performed using the same variables used for the RT data. Results revealed no significant main effects or interactions for accuracy, $p > .05$. Manual-response Stroop accuracy data is described in Table 3.

Vocal response. The mixed three-way factorial ANOVA on Stroop task vocal RT data displayed a significant main effect for word type, $F(3,84) = 14.14$, $p < .001$. This main effect is presented in Figure 3. Pairwise comparisons using the Bonferroni correction revealed significant RT differences between the taboo-neutral and taboo conditions ($p = .002$), with significantly slower RTs for taboo trials ($M = 628.29$ ms, $SE = 15.01$) compared to taboo-neutral trials ($M = 602.39$, $SE = 12.54$), suggesting that the taboo words made it more difficult for participants to name the ink colors. Additionally, RTs were longer for emotional words ($M = 594.96$, $SE = 14.52$) relative to emotional-neutral words ($M = 585.82$, $SE = 13.52$), a difference that approached significance ($p = .076$). Pairwise comparisons also demonstrated a significant difference between the emotional-neutral and taboo conditions ($p = .001$). Follow-up paired t-test comparing the each neutral condition to its corresponding arousal conditions combined confirmed significantly longer RTs for taboo words compared to taboo-neutral words, $t(31) = -4.52$, $p < .001$, as well as significantly longer RTs for emotional words relative to emotional-neutral words, $t(31) = -2.65$, $p = .01$. A comparison of the two neutral word types revealed that

taboo-neutral RTs were significantly slower than those of the emotional-neutral word type, $t(31) = 2.34$, $p = .026$.

Unlike the manual Stroop task, voice-key results indicated no main effect for gender, $F(1, 28) = .286$, $p = .597$, or for 7. The main effect for task order was also not significant, $F(1,28) = 2.14$, $p = 1.5$, which was consistent with the manual Stroop results. Additionally, ANOVA results revealed no significant interaction between emotion type and task order, $F(3, 39) = 2.18$, $p = .096$, which differs from the manual task, where task presentation did have an effect on response times for the different emotion types. All other interactions were not significant, $p > .05$. An ANOVA examining accuracy data was also conducted, and revealed no significant main effects or interactions for percent accuracy on the verbal Stroop task, $p > .05$ (see Table 3).

Recent Probes

Results from the Recent Probes task were analyzed using a mixed five-way ANOVA, conducted on RT. Between-subject experimental factors included Stroop modality (manual button response, or voice-key verbal response), task order (Recent Probes presented first, or Recent Probes presented second), and gender (male or female). Additionally, the ANOVA included two within-subject variables, word type (emotional-neutral, emotional, taboo-neutral, taboo) and probe type (recent and non-recent).

There was a significant main effect for probe type (recent versus non-recent), $F(1, 41) = 6.88$, $p < .001$, such that participants respond faster to non-recent trials ($M = 713.12$, $SE = 15.25$), than the recent trials ($M = 802.09$, $SE = 16.24$). These results successfully demonstrate an interference effect across all word types, indicating that RTs were longer for trials designed to induce interference, than for non-interference trials. No other main effects were significant, $p > .05$.

Moreover, there was a significant interaction between word type and probe type, $F(3,123) = 6.88$, $p < .001$. Results are depicted in Figure 4. Inspection of the means shows that for all four word types responses were slower for recent probe trials than for non-recent probe trials. Follow-up paired t-tests confirmed that these differences were significant. There was a significant difference between emotional-neutral non-recent probe RT ($M = 699.89$, $SE = 17.03$) and emotional-neutral recent probe RTs ($M = 802.75$, $SE = 18.15$), $t(48) = -9.43$, $p < .001$, and a comparable difference between emotional non-recent probe RTs ($M = 709.41$, $SE = 16.86$), and emotional recent probe RTs ($M = 810.69$, $SE = 18.20$), $t(48) = -9.26$, $p < .001$. The effects for taboo words were different from the emotional words, however. For the taboo-neutral condition the difference between the non-recent probe trials ($M = 743.12$, $SE = 18.60$) and the recent probe trials ($M = 789.98$, $SE = 17.68$), $t(48) = -5.50$, $p < .001$, was considerably less than the difference between taboo non-recent probe trials ($M = 700.01$, $SE = 17.43$) and taboo recent probe trials ($M = 804.93$, $SE = 19.99$), $t(48) = -10.42$, $p < .001$. Therefore, the interaction occurred because the difference in RT for non-recent and recent probe types was smaller (yet still significant) for the taboo-neutral condition.

Finally, there was a significant interaction between Stroop modality (manual or verbal) and task order for Recent Probes RT, $F(1, 41) = 5.56$, $p = .023$.[1] No other interactions were significant.

Further examination of interference effects. The Recent Probes task was designed to create proactive interference and to test participants' ability to control and resolve this interference with different word types as memoranda. To quantify the amount of interference participants experienced, for each word type we calculated a measure we refer to as *average*

interference, which is derived by determining the RT difference between the recent-no probe trials (the average of *NoFam1* & *NoFam2 scores*), and the non-recent-no probe trials (*NoFam0*).

To explore the significant interaction between probe type and word type, follow-up paired t-tests were conducted to compare the in interference effects for taboo and emotional words. The average interference effects were greater for taboo and taboo-neutral words $t(48) = -3.68$, $p = .001$. This was not true for emotional words, which showed virtually no difference in interference from emotional-neutral words, $t(48) = .24$, $p = .811$ (see Figure 5). An additional t-test directly comparing the interference for emotional and the taboo words revealed no difference between these conditions $t(48) = -.26$, $p = .799$. There was however a significant difference in interference between the taboo-neutral and emotion-neutral conditions, $t(48) = 3.78$, $p < .001$ (Figure 6).

Accuracy Data

A mixed five-way factorial analysis of variance on accuracy percentages for the Recent Probes task was also conducted using the same variables described for the Recent Probes response time data. Results display a significant main effect for probe type (recent versus non-recent), $F(1, 41) = 12.91$, $p = .001$, such that participants had better accuracy for non-recent probe trials ($M = 95.7\%$, $SE = .004\%$) than for recent probe trials ($M = 92.3\%$, $SE = .01\%$). There was also a significant main effect for emotion type (emotional-neutral, emotional, taboo-neutral, and taboo), $F(3, 123) = 19.28$, $p < .001$. Participants were slightly more accurate for the emotional-neutral trials ($M = 95.6\%$, $SE = .01\%$) than they were for the emotional trials ($M = 94.3\%$, $SE = .01\%$), however a pairwise comparison confirmed that this difference was not significant ($p = 1.00$). Participants were less accurate for the taboo-neutral trials ($M = 89.4\%$, *SE*

= .01%) than they were for the taboo trials (M = 96.7%, SE = .01%); this difference was found to be significant, ($p < .001$).

Moreover, a significant interaction between probe type and word type emerged, such that participants had greater accuracy for non-recent probes than for recent probes (interference trials) for all word types except the taboo-neutral type, in which case accuracy was increased for recent probes relative to non-recent probes, $F(3, 123) = 32.49$, $p < .001$; these accuracy data values are described in Table 4. All other main effects and interactions were not found to be significant.

Potential Correlation between Recent Probes and Vocal Stroop Performance

A Pearson correlation coefficient was computed to assess the relationship between average interference differences for neutral and arousing (taboo and emotional) conditions in Recent Probes, and RT difference between neutral and arousing stimuli in the Stroop task. Response time difference for the Stroop task was calculated by subtracting RTs for neutral trials from RTs for arousing trials for each subject. For the comparison of the taboo tasks, the correlation between the two variables was nonsignificant, r = -.03, p = .883. Additionally, the Pearson correlation coefficient for the emotional Recent Probes and Stroop task comparison was also not significant, r = -.11, p = .551. Further consideration of potential correlations—by examining the effect of task presentation order on task performance—also revealed nonsignificant correlations between Stroop and Recent Probes interference effects.

Discussion

Stroop Task

Manual response. This experiment was designed to explore the relationship between emotionality and attention in working memory. For the manual-response Stroop task, the analysis did not yield the classic interference effect described in the original Stroop test (Stroop,

1935), as there was no main effect for word type (emotional-neutral, emotional, taboo-neutral and taboo) on response times. Instead, the current results suggest that participants had no more difficulty identifying the colors of taboo words relative to taboo-neutral words, nor did they have more difficulty with emotional words relative to emotional-neutral words. Participants also showed no difference in accuracy between the four word types. Additionally, there was an interaction between word type and task order, however this result provides little insight on our experimental hypotheses. There was also a main effect for gender, suggesting that males were slower to respond overall thank females during the task. We speculate that this could be attributed to the fact that the researcher administering the studies—present during all stages of the experiment—was female, which could have caused intensified affect for males, and given them more of a shock response to the taboo words than for the female participants. Another possibility could be that males may be slower than females during certain motor tasks, although this is largely speculation. Regardless, this effect was not found in any of the other experimental tasks, and therefore remains inexplicable.

Revisiting the experiment's failure in demonstrating the expected Stroop interference, considering that our study design was modified from previous paradigms successfully demonstrating a significant effect, we found this null result to be quite curious. Indeed, further consideration of the prior literature indicated that a manual mode of response may be less sensitive to Taboo Stroop effects than a vocal response.

Stroop task and modality of response. Evidence challenging the efficacy of a key-press response was found in studies investigating mode of response on Stroop interference. A neuroimaging study investigating input type (manual vs. vocal response) revealed that while both response types displayed robust Stroop interference, the response types featured differing neural

distributions, suggesting a difference in processing (Liotti, Woldorff, Perez III & Mayberg, 2000). Similarly, a behavioral study using words and non-words in a Stroop task demonstrated a much more pronounced interference effect in the verbal version of the task, relative to the manual response mode (Repovs, 2004). These results suggest that a manual response introduces an additional "key mapping" process, which changes the nature of the Stroop task and could result in increased response times overall.

In our manual-response task, participants appeared to have difficulty with response mapping. Although a neutral practice version of the Stroop task was administered, participants still seemed to be having trouble remembering which key corresponded to which color. Although they were instructed not to look down, as this would divert attention away from the task, participants occasionally did have to glance at the keyboard. Hence, participants likely had difficulty remembering the stimuli response mappings, potentially making a manual response version less capable of detecting interference. Moreover, previous studies using a modified Stroop task had a verbal mode of input, where participants identified word colors by speaking into a microphone (i.e., MacKay et al. 2004; Siegrist, 1995). After considering these various factors, we concluded that a verbal mode of response might be superior for investigating Stroop effects.

Response competition in the voice-key Stroop task. After conducting a voice-key version of the taboo and emotional Stroop tasks, we were able to support our hypothesis that arousing words capture attention and increase interference. Results from the vocal-response Stroop experiment successfully replicated the Stroop interference effect found in previous research (Harrison & Boese, 1976; McKenna, 1986; Siegrist, 1955; Stroop, 1935), verifying the verbal response type as the superior mode of response. Statistical analyses confirmed that

participants had more difficulty when identifying the colors of taboo words relative to taboo-neutral words, as well as for emotional words relative to emotional-neutral words, although to a lesser extent.

Response times were larger overall for the taboo task relative to the emotional task. Moreover, a comparison of the neutral word types from taboo and emotional tasks revealed significantly longer response times for taboo-neutral words relative to emotional-neutral words. We speculate that this was likely due to increased caution of the participants during the taboo task; the prospect of accidentally blurting out a taboo word could have led to slower response times for the neutral words as well, as the presentation of a taboo word was unpredictable. Another possibility is that the presence of the taboo words within the taboo task captured attention throughout the task, causing increased response times overall.

Previous research has suggested that individuals take more time when reading erotic sentences relative to romantic or neutral sentences (Geer, Judice & Jackson, 1994); therefore, it would make sense that the presence of arousing material may cause increased response times, and potentially engage processes not present for neutral stimuli. Moreover, in a study manipulating the presentation rate of taboo and neutral words, people have been found to underestimate the duration of sexual taboo words relative to neutral, or even high-arousal negative words likened to our emotional stimuli (Tipples, 2010). The study results revealed that the "time flies" phenomenon—in which sexual taboo stimuli receive more attention than neutral stimuli and thus cause time to be perceived as passing more slowly than reality—exists for both sexual taboo words and non-sexual high arousal words, but to less of a degree. Still, there is evidence that non-taboo stimuli also produce interference effects: relevant to our non-sexual *emotional* stimuli, in a non-verbal working memory task by Kensinger & Corkin (2003),

participants had slower response times to fearful, emotional faces than to neutral faces during an n-back task. These studies provide insight on our voice-key Stroop task, and support the claim that the presence of arousing stimuli may affect overall cognitive processing.

Recent Probes Task

The Recent Probes portion of the study explored the effect of emotionality on interference resolution in an item-recognition task. Results from both taboo and emotional tasks, for all word types, successfully demonstrated increased response times for recent-no trials relative to non-recent-no trials, replicating previous proactive interference findings (i.e. Jonides et al., 1998; Jonides & Nee, 2006). With our Recent Probes task successfully exhibiting an interference effect, we then examined differing interference effects between probe types for both the taboo and emotional tasks.

The emotional task showed no difference in interference effect for the emotional word type relative to the emotional-neutral word type trials. Participants essentially had the same degree of interference when rejecting emotional-neutral and emotional words, suggesting that these negative valence, high arousal words were not arousing enough to alter cognitive processing. The taboo stimuli, on the other hand, did seem to be arousing enough to demonstrate differential processing. For the taboo task, participants exhibited a significantly greater interference effect for the taboo-probe trials than for the taboo-neutral-probe trials, suggesting that participants had much more proactive interference for the taboo trials, and that the taboo words were better learned than the taboo-neutral words. This finding is inconsistent with Levens and Phelps (2008), which demonstrated the opposite finding. Their study suggested that emotional words (recall that the study's *emotional* words were actually closer to offensive taboo words than non-offensive, high arousal, negative valence words) served to help resolve

interference when acting as a probe, and created more interference when acting as a distractor (and a neutral word was the probe).

Interference differences between neutral word types. A Comparison of the neutral probe trials from the taboo and emotional stoop task revealed a significant difference in interference between the two (Figure 6). Participants had better interference control for the taboo-neutral trials relative to the emotional-neutral trials. Additionally, a comparison of the taboo and emotional-probe trials revealed no difference in interference between the two. Given this result, we can assume that both taboo and emotional stimuli generate the same degree of interference in the Recent Probes task (although the increased interference for the emotional stimuli may be due to increased word length, as described earlier), and that interference differences lie in the corresponding neutral stimuli for the two tasks.

Although may be other factors involved that may have affected the experimental results, this finding seems to suggest that the presence of the taboo words helped reduce interference for the taboo-neutral words in the task. It may have been much easier to distinguish between the taboo-neutral words because they were presented amidst taboo stimuli; perhaps the salience of the taboo words aided in reducing proactive interference for the taboo-neutral trials, suggesting that the taboo-neutral words were not nearly learned as well as the taboo words during the task.

Still, this argument remains speculation, and further investigation must determine if this development is a replicable result, or simply due to differences in the stimuli for the taboo and emotional tasks. While we speculate that differences in word length between the taboo task stimuli and the emotional task stimuli may have affected the experimental outcome (see Tables 1 & 2)—because a common working memory strategy is to subvocally rehearse the word-set until the probe appears, response times should be longer in a task with longer words (Baddeley,

Thomson & Buchanan, 1975)—this should be accounted for, considering that the *average interference* score is a difference between recent and non-recent probe response times. Therefore, there are a handful of other factors that may be involved. Considering that the stimuli from the two tasks were taken from different databases, with different measures for frequency and familiarity, there are a variety of psycholinguistic factors that may have caused an interference difference between the neutral word types; follow-up studies should potentially aim to select taboo and emotional stimuli from the same database, and balance frequency and word length measures across all word types.

Performance Correlation Between Tasks?

Although we had hypothesized that there would be a within-subjects correlation between performance on the Stroop and Recent Probes tasks, statistical analyses were performed to examine a potential within-subjects relationship between performance on the taboo Stroop task and taboo Recent Probes task, no significant correlations were found. Participants who had more difficulty resolving interference for the taboo probe trials of the Recent Probes task did not necessarily have more difficulty expressly identifying the ink colors of the taboo words in the taboo Stroop task; this result was found even when separating experimental data by task order. While this result may be due in part to a habituation effect—participants may have become desensitized to the salient words as they progressed through the various experimental tasks—the lack of correlation may also be due to intrinsic differences between the experimental objectives of the two tasks. The Recent Probe task is primarily a memory task, designed to induce proactive interference and create false memories; the Stroop task has no memory component, and instead examines response competition and interference on an attentional level. Therefore, while adding arousing stimuli to both tasks was an attempt to bridge the two, and examine the power of

emotion on overall cognitive processing, the differences between the tasks may have been too pronounced to result in a performance correlation.

Degree of Arousal: Taboo vs. Emotional Stimuli

It is important to note the lack of effect found in the emotional Recent Probes task. While theoretically the complete lack of effect is peculiar, it is not unheard of considering previous research. Previous studies on "emotional" stimuli have addressed the difficulty in demonstrating interference effects for emotional stimuli (i.e. MacKay et al., 2004). Recall that we chose to only examine negative valence, high arousal stimuli (*emotional* words, and the more salient *taboo* words), as previous studies failed to demonstrate any real affect with low arousal (with a mean arousal score of 4.53), negative valence stimuli (Levens & Phelps, 2008). As stated, our study results suggest that even high arousal (our *emotional* stimuli had a mean arousal score of 5.85) emotional stimuli were not salient enough to produce an interference effect. Still, the Levens and Phelps negative, high arousal stimuli had a mean arousal score of 6.34; while these stimuli were sexual in connotation (very similar to our *taboo* stimuli), these results do suggest that perhaps an arousal level higher than that of the *emotional* words from our experiment may have been able to produce an interference effect.

Although participants did have increased response times for emotional words relative to the emotional-neutral word type in the voice-key Stroop task, difference was certainly less pronounced than that of the taboo Stroop task. Previous research on the emotional Stroop task has suggested that increased time pressure, or shorter time intervals between prior trial response and presentation of the subsequent trial word, is necessary to demonstrate an effect (Sharma & McKenna, 2001). Additionally, people generally have a much stronger reaction to sexual or offensive taboo words (i.e. *cock, pussy, rape*) than to simply emotional words (i.e. *maggot,*

slaughter, massacre). The lack of shock factor associated with emotional words is likely why an emotional interference effect is so difficult to replicate (see Dewhurst & Parry, 2000; Hadley & McKay, 2006; Maratos et al., 2000; Talmi & Moscovitz, 2004). Moreover, people may have different reactions to the same emotional stimuli, due to personal experience or reactivity levels. Words such as *massacre* may not be central to the personal concerns of daily life (Reiman & McNally, 1995).

Failure to Replicate Previous Research

Returning to the implications of the taboo Recent Probes results, it is crucial to address the disparity between our findings and that of Levens and Phelps (2008), as we failed to replicate their experimental result. While their study demonstrated that "emotion facilitates response selection amid interference in working memory" (p. 278), we believe that this was due to a design flaw within their Recent Probes paradigm, which resulted in an inaccurate explanation of arousal and interference resolution. Because the Levens and Phelps (2008) Recent Probes design featured a three-word set (rather than our four-word design), each trial in their experiment did not contain an equal number of neutral and arousing words. We postulate, therefore, that their experiment was not an examination of emotion effects; rather, it measured the effect of word distinctiveness (as described by Talmi et al., 2007). More than facing proactive interference due to arousing stimuli, participants appeared to be resolving interference more easily due to the distinctiveness of seeing an arousing word among neutral words.

As described previously, we believe that our experimental design provided a better measure of proactive interference effects, conflicting with the Levens and Phelps results, and even suggesting the opposite finding. Rather than displaying no significant difference in interference between taboo and neutral probe trials, our study suggests that people tend to learn

taboo words better than neutral stimuli, and that this increased memory leads to increased familiarity, and increased interference for these taboo stimuli. While this may be due in part to a false memory effect—because of the semantic similarity of the sexual taboo words—seen in previous studies on working memory and semantic interference (Atkins & Reuter-Lorenz, 2008), this possibility still does not explain why interference for the taboo-neutral words was driven down to such a degree.

Future Directions

This study provides strong evidence in favor of the idea that emotion works to increase proactive interference within working memory tasks, making it more difficult to resolve proactive interference. Despite these findings, there are a handful of Recent Probes paradigm manipulations that could be performed to support or weaken the findings of the present study. First, to investigate the discrepancy between the neutral probe types, future studies could intermix both sets of neutral words, and investigate interference differences between emotional-neutral and taboo-neutral probe trials. A similar investigation could include pure taboo-neutral and emotion-neutral tasks, to achieve baseline response and interference times for the two neutral types.

Another way to examine the legitimacy of the present findings would be to aim to replicate the same interference results, using the same database when selecting the taboo and emotional stimuli sets. As the two databases did not have the same psycholinguistic measures (potentially incompatible familiarity versus frequency scores), this may have had an effect on study results, and replicating the study with a new stimulus set would help legitimize these interference differences. Additionally, because mean word lengths and number of syllables were

not balanced across the two task conditions, doing so would also help strengthen or dismiss our present findings.

Another potential direction for future research would be to try and replicate the Recent Probes design of the Levens and Phelps (2008) study; doing so, using their three-word experimental design, would help further strengthen the notion that their results, suggesting better interference control for arousing words, were the result of word distinctiveness, rather than arousal. This would strengthen the legitimacy of our experimental design, and corresponding results. Additionally, the addition of recall tests (immediately after the item-recognition Recent Probes task) could provide some helpful information. Most studies on emotion and cognitive processing thus far have focused on recall; potentially adding a recall portion and replicating prior results could also help strengthen our experimental design. Should a recall test assessing memory for arousing and neutral words produce evidence that arousing words are better recalled than neutral words, this would help provide insight regarding the transition of emotional information from working memory to long-term memory, and strengthen the argument that arousing information may be better learned than neutral stimuli

Conclusion

The goal of the present study was to examine and clarify the role of emotion in attention and proactive interference within working memory. To do this, we used a modified Stroop paradigm to examine attention and interference due to response competition, as well as an item-recognition Recent Probes task to examine control of proactive interference. Within-subject task performance was also examined, as our study also sought to identify any potential relationship between interference effects on the two tasks.

Results from the voice-key response version of our Stroop task suggested that individuals take longer to identify the ink colors of arousing words than of neutral words, consistent with the belief that emotion captures attention and causes increased response competition, or attentional interference. Additionally, taboo Recent Probes task results support the hypothesis that *hot* stimuli—only those of an extremely salient and arousing nature (i.e., *taboo* stimuli)—are likely better learned during a working memory task, and therefore slow proactive interference resolution relative to non-arousing stimuli. Our present results conflict with a recent study—which used the same item-recognition task with a critical difference in the design of their paradigm—which demonstrated that arousing stimuli actually help resolve interference more quickly. Future experimentation should aim to replicate our result, and strengthen the conclusion that arousing stimuli capture attention and cause increased proactive interference in working memory.

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Footnotes

[1] For the Stroop first (Recent Probes second) order, participants who performed the manual Stroop task had shorter RTs for Recent Probes (M = 727.23, SE = 38.75) than those who performed verbal Stroop response task (M = 776. 60, SE = 24.17). Although Stroop modality should have no effect on Recent Probes when the Stroop task was presented second, participants who performed the manual response Stroop task had longer RTs for Recent Probes (M = 811.63, SE = 34.18) than participants who were given the verbal response Stroop task (M = 714.96, SE = 24.17), despite these participants receiving Recent Probes first.

Author Note

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Tables

Table 1

Average Scores for Taboo and Taboo-neutral Words

Neutral					*Taboo*				
Word	Letters	Familiarity	Obscenity	Syllables	Word	Letters	Familiarity	Obscenity	Syllables
Art	3	6.72	1	1	anal	4	6.19	3.44	2
bill	4	6.53	1	1	bitch	5	6.72	4.47	1
blast	5	6.53	1.03	1	clit	4	6.16	4.03	1
bloom	5	6.53	1	1	cock	4	6.34	4.34	1
chalk	5	6.81	1	1	cum	3	5.88	4.03	1
clay	4	6.53	1	1	cunt	4	5.75	4.72	1
crown	5	6.31	1	1	dick	4	6.59	4.25	1
crumb	5	6.41	1	1	dyke	4	6.41	5.06	1
doll	4	6.53	1.03	1	faggot	6	6.56	5.59	2
dream	5	6.75	1.06	1	fuck	4	6.81	4.88	1
drive	5	6.78	1	1	jizz	4	4.38	3	1
king	4	6.53	1	1	orgy	4	6.75	3.91	2
nation	6	6.84	1	2	penis	5	6.88	3.25	2
orbit	5	6.53	1.03	2	pubic	5	6.53	2.28	2
pearl	4	6.88	1.03	1	pussy	5	6.53	4.98	2
quail	5	6.13	1.13	1	queer	5	6.59	4.5	1
rain	4	6.97	1.31	1	rape	4	6.75	3.69	1
rent	4	6.91	1	1	semen	5	6.66	2.63	2
shake	5	6.84	1	1	slut	4	6.88	4.06	1
snack	5	6.84	1	1	whore	5	6.81	4.22	1
Mean	*4.6*	*6.65*	*1.02*	*1.13*	*Mean*	*4.4*	*6.41*	*4.07*	*1.35*

Note. Words were chosen from Mackay, Hadley, and Schwartz (2005) study. Taboo and taboo-neutral words were balanced for familiarity, word length and number of syllables.

Table 2

Average Scores for Emotional and Emotional-neutral Words.

Word	Letters	Valence	Arousal	Frequency	Syllables
Neutral					
activate	8	5.46 (0.98)	4.86 (2.56)	2	3
aloof	5	4.9 (1.92)	4.28 (2.1)	5	2
ankle	5	5.27 (1.54)	4.16 (2.03)	8	2
appliance	9	5.1 (1.21)	4.05 (2.06)	5	3
context	7	5.2 (1.38)	4.22 (2.24)	2	2
curtains	8	4.83 (0.83)	3.67 (1.83)	8	2
elbow	5	5.12 (0.92)	3.81 (2.14)	10	2
fabric	6	5.3 (1.2)	4.14 (1.98)	15	2
frog	4	5.71 (1.74)	4.54 (2.03)	1	1
kettle	6	5.22 (0.91)	3.22 (2.23)	3	2
lawn	4	5.24 (0.86)	4 (1.79)	15	1
locker	6	5.19 (1.31)	3.38 (2.13)	9	2
noisy	5	5.02 (2.02)	4.93 (1.76)	6	2
pamphlet	8	4.79 (1.05)	4.63 (1.48)	3	2
poster	6	5.34 (1.75)	4.91 (1.87)	4	2
quart	5	5.39 (2.01)	5.2 (1.86)	3	1
trunk	5	5.09 (1.57)	5.14 (1.91)	8	1
umbrella	8	5.16 (1.57)	5.42 (1.91)	8	3
vest	4	5.25 (1.33)	5.09 (1.24)	4	1
violin	6	5.43 (1.98)	5.18 (2.01)	11	3
Mean	*6*	*5.2*	*4.06*	*6.5*	*1.95*
Emotional					
addict	6	2.48 (2.08)	5.66 (2.26)	1	2
bloody	6	2.9 (1.98)	6.41 (2)	8	2
burn	4	2.73 (1.72)	6.22 (1.91)	15	1
carcass	7	3.34 (1.92)	4.83 (2.07)	7	2
corpse	6	2.18 (1.48)	4.74 (2.94)	7	1
crushed	7	2.21 (1.74)	5.52 (2.87)	10	1
drown	5	1.92 (1.48)	6.57 (2.33)	3	1
grief	5	1.69 (1.04)	4.78 (2.84)	10	1
intruder	8	2.77 (2.32)	6.86 (2.41)	1	3
lice	4	2.31 (1.78)	5 (2.26)	2	1
maggot	6	2.06 (1.47)	5.28 (2.96)	2	2
massacre	8	2.28 (1.74)	5.33 (2.63)	1	3
mutilate	8	1.82 (1.45)	6.41 (2.94)	3	3
pervert	7	2.79 (2.12)	6.26 (2.61)	1	2
slaughter	9	1.64 (1.18)	6.77 (2.42)	10	2
suffocate	9	1.56 (0.96)	6.03 (3.19)	1	3
suicide	7	1.25 (0.69)	5.73 (3.14)	17	3
surgery	7	2.86 (2.19)	6.35 (2.32)	6	3
tumor	5	2.36 (2.04)	6.51 (2.85)	17	2
vomit	5	2.06 (1.57)	5.75 (2.84)	3	2
Mean	*6.5*	*2.26*	*5.85*	*6.42*	*2*

Note. Words were selected from the "Affective Norms for English Words (ANEW)" list (Bradley & Lang, 1999). Emotional and emotional-neutral words were balanced for word length, frequency, and number of syllables. Means are presented, with standard deviations in parentheses.

Table 3

Stroop Task Performance Accuracy.

	Manual response		Voice-Key response	
	Mean Accuracy	SE	Mean Accuracy	SE
Emotional-Neutral	96.3%	1.3%	99.2%	2%
Emotional	95.4%	1.3%	99.0%	2%
Taboo-Neutral	95.4%	1.3%	99.0%	2%
Taboo	96.3%	1.4%	98.9%	2%

Table 4

Recent Probes Task Performance Accuracy.

	Non-Recent Probe		Recent Probe	
	Mean Accuracy	SE	Mean Accuracy	SE
Emotional-Neutral	98.0%	0.8%	93.2%	1.2%
Emotional	99.1%	0.6%	89.6%	1.6%
Taboo-Neutral	86.4%	1.1%	92.4%	1.3%
Taboo	99.4%	.06%	94.0%	1.2%

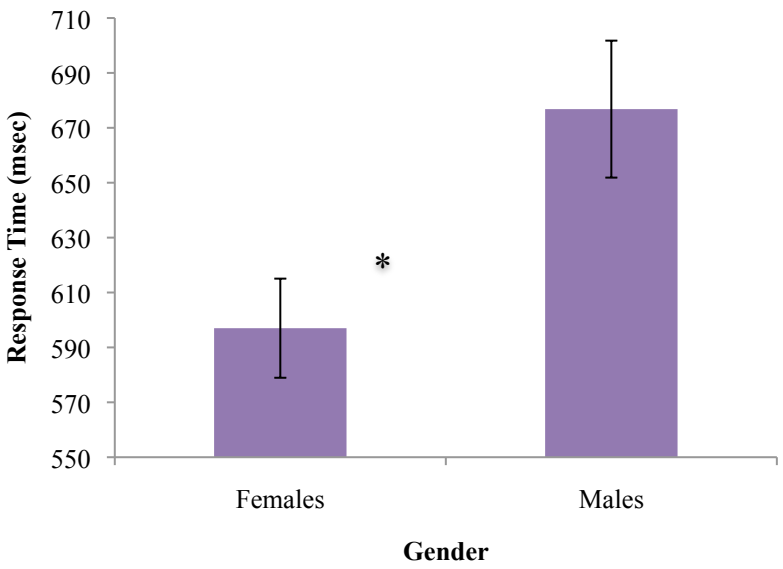

Figure 1. Main effect of gender on manual Stroop task - response times to identify ink colors, $p = .02$.

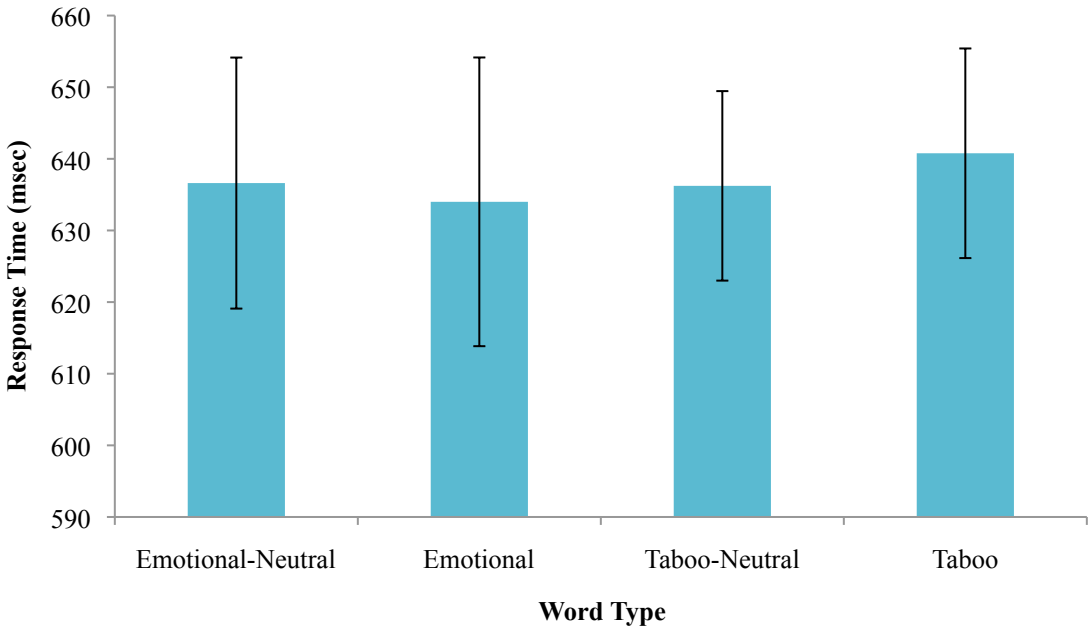

Figure 2. Response times on the manual Stroop task by word type.

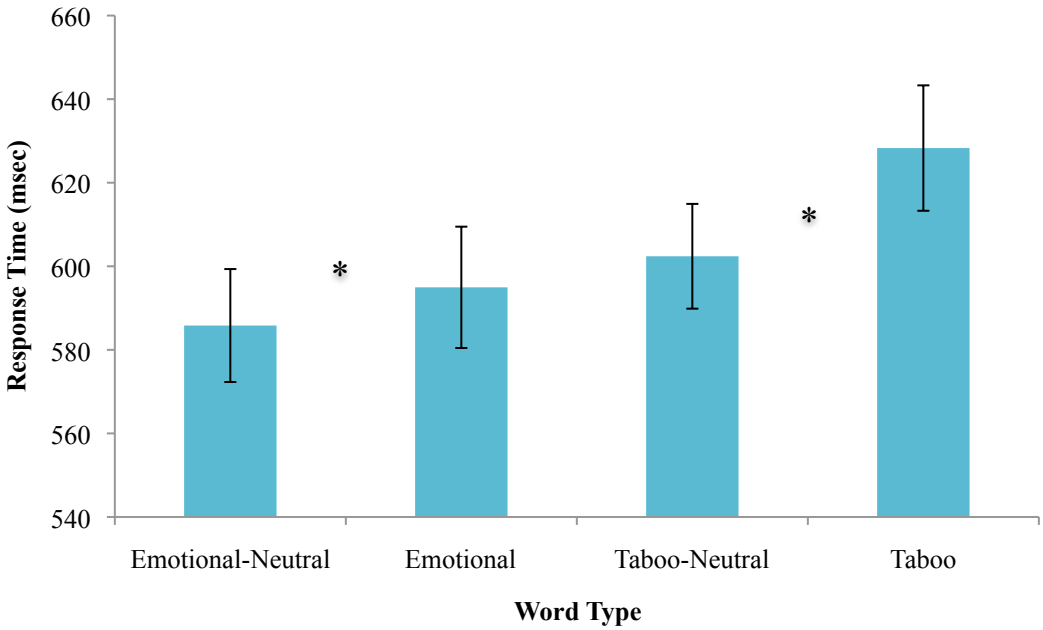

Figure 3. Main effect of word type on response times for Voice-key Stroop task. Follow-up t-tests revealed a significant difference between taboo-neutral and taboo conditions, $p < .001$, and between emotional-neutral and emotional word types, $p = .01$.

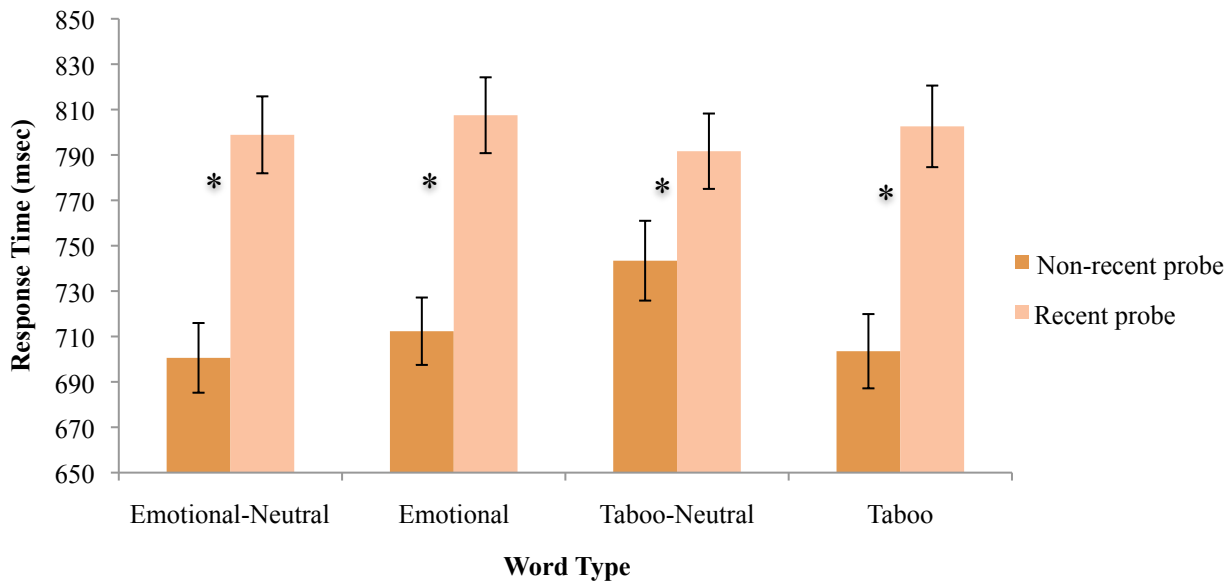

Figure 4. Interaction between probe type and word type for Recent Probes task. All word types had significant differences between non-recent probe and recent probe response times, $p < .001$.

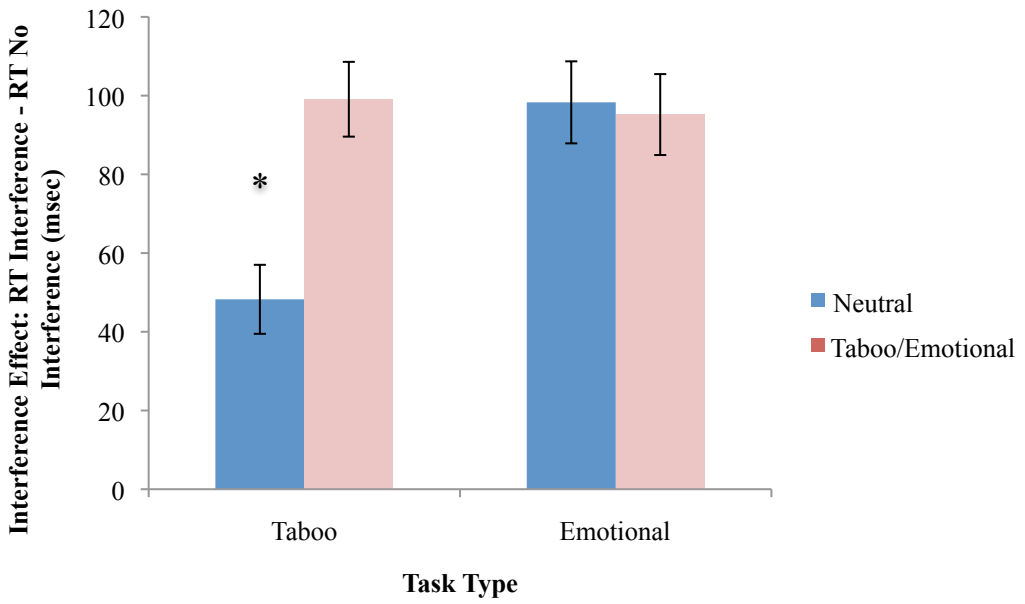

Figure 5. Average interference in Recent Probes task. Paired t-tests revealed a significant difference between interference effects for taboo-neutral and taboo word types, $p = .001$.

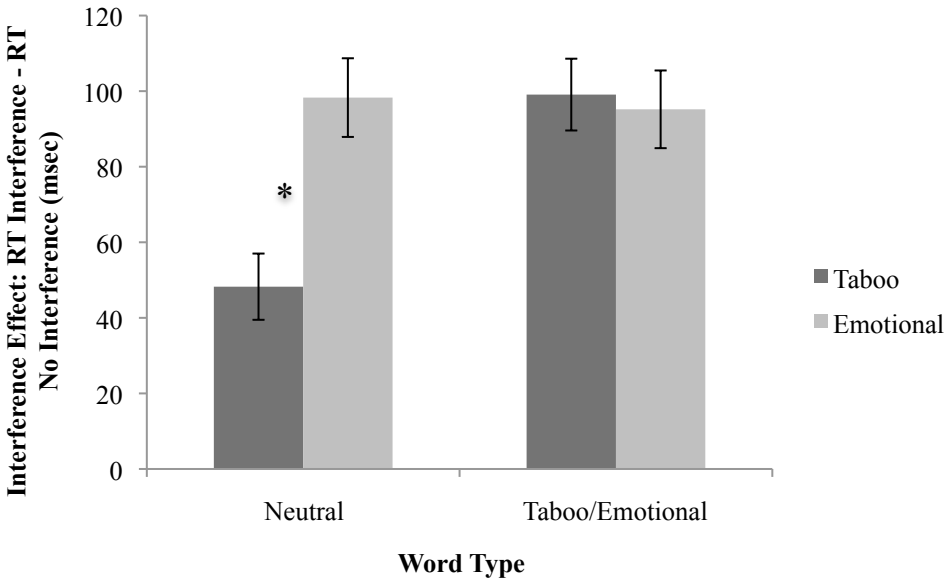

Figure 6. Average interference in Recent Probes – compare neutrals and *hot* probe trials. Note that the "Neutral" category compares taboo-neutral and emotional-neutral probe types, and the "Taboo/Emotional" category compares taboo and emotional probe types. There was a significant difference in interference effects between taboo-neutral and emotional-neutral word types, $p < .001$.

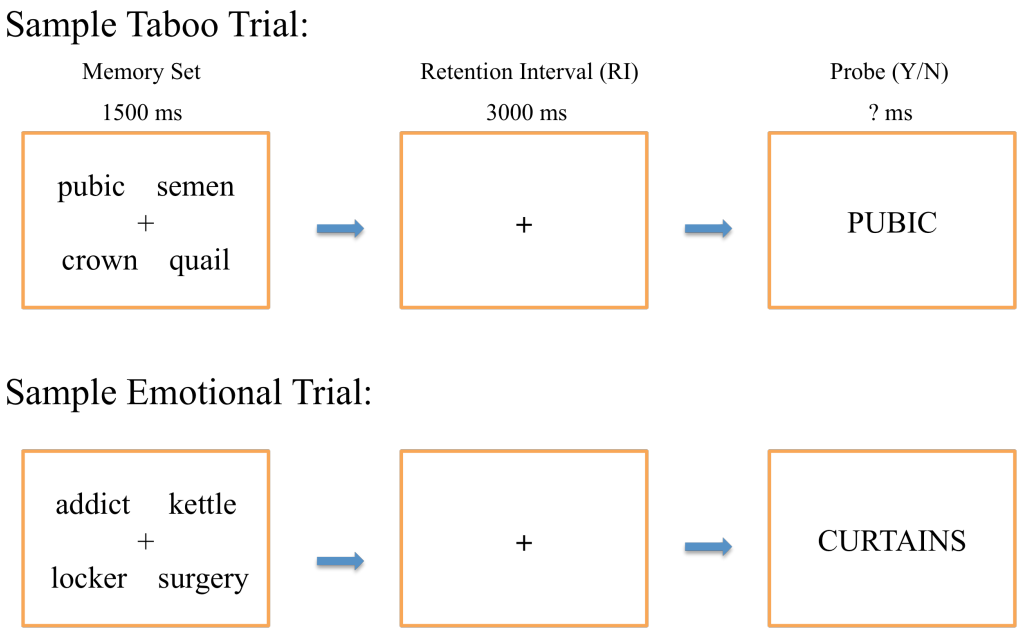

Figure 7. This figure describes presents sample trials from the Recent Probes task. Note that the four-word memory set contains two neutral and two taboo/emotional words.

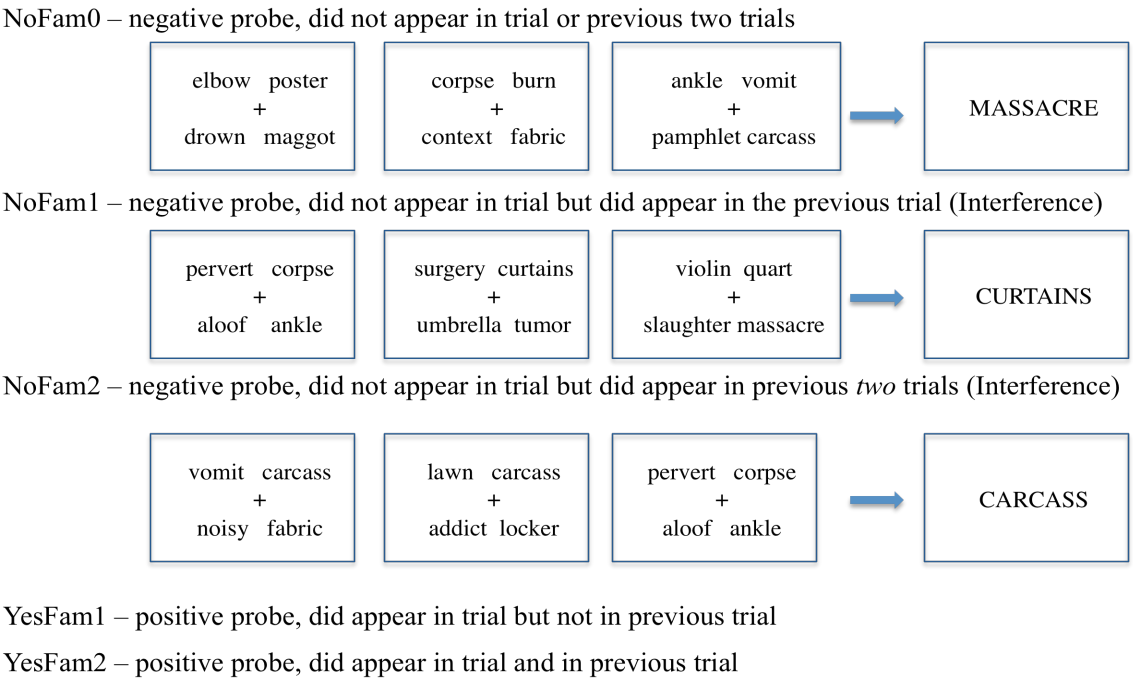

Figure 8. This figure describes the five probe types for the Recent Probes task. Shown here are sets of trials from the emotional Recent Probes task. The *NoFam0* probe type is equivalent to the *non-recent-no* probe. For the *recent-no* probe type, *NoFam1* and *NoFam2* response times were averaged.