EMOTIONALLY AROUSING STIMULI SURVIVE TAXATION OF PROCESSING RESOURCES

by

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(Under the Direction of Richard L. Marsh)

ABSTRACT

In two experiments, I investigated the connection between emotional valence and memory. A clear memory advantage has been demonstrated for emotional words and pictures in recent literature (Kensinger & Corkin, 2003). In this paper, I investigated the additional role of emotional arousal in the well-established memory enhancement. Both experiments show a clear advantage of arousing words above that of valenced-nonarousing words. It has been proposed that while valenced material is supported by the prefrontal cortex, arousing stimuli is mediated by amygdalar activation (Cahill & McGaugh, 1990; Kensinger & Corkin, 2004). By reducing participants attentional resources with a concurrent task, I was able to demonstrate the automaticity of this proposed arousal benefit. This lends credence to the claim that arousing items confer their advantage in memory via an amygdalar pathway.

INDEX WORDS: VALENCE, AROUSAL, MEMORY, ATTENTION

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B.A., North Carolina State University, 2003

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2006

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ACKNOWLEDGEMENTS

I wish to thank Sterling Thomas and Stephanie Choate for their dedicated help in collecting the experimental data.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

INTRODUCTION

Emotionally Arousing Stimuli Survive Taxation of Processing Resources

Understanding the complex relationship between emotion and memory has been an ongoing research endeavor for quite some time (for a review, see Christianson, 1992a). A number of interesting connections between emotion and memory have been uncovered. Brown and Kulik (1977) examined just such a connection when they first identified the concept of flashbulb memory. According to their research, sometimes an emotional event can be so powerful that it is encoded with above average clarity and detail. Flashbulb memories do not always have to be from a negative crime scene. Pillemer (1984) demonstrated robust flashbulb memories for the assassination attempt on President Reagan. On the other hand Neisser (1982) showed similar flashbulb memories for a more positive event, the resignation of President Nixon. However, it is important to note that some researchers do not require a special flashbulb mechanism to explain the memory enhancement for emotional material. Instead, some (e.g., Cohen, McCloskey, & Wible, 1988; for an opposing view see Schmidt, & Bohannon, 1988) appeal to more typical memory mechanisms, such as rehearsal, to explain the observed memory enhancement. Although flashbulb memories are often described as negative events, there does not seem to be anything in the basic definition of such a memory that would prevent a strong positive emotional event from resulting in a similar memory enhancement.

If the memory enhancement for flashbulb memories can be explained via ordinary mechanisms of rehearsal and elaboration, is there anything special about other emotional memories? Kensinger and Corkin (2003b) conducted a study using emotional and neutral pictures selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). The IAPS comprises a large variety of high-resolution pictures ranging in emotional valence, arousal, and dominance. These ratings have been shown to be reliably accurate in studies comparing the normative ratings of the IAPS with ratings obtained during an orienting task (Kern, Libkuman, Otani, & Holmes, 2005). In their first experiment Kensinger and Corkin (2003b) showed an emotional enhancement in long term memory. Participants in their study viewed positive, negative, and neutral pictures and were given a free recall task after a one day retention interval. They showed a general memory enhancement for emotional pictures: greater recall for positive and negative pictures relative to neutral. In two subsequent experiments they were able to replicate this emotional memory enhancement for words as well. Although they were never able to obtain the difference in measures of working memory in this study, they postulated this may have been due to emotional items receiving differential processing. Finally, in a fifth experiment they obtained quicker reaction times to respond to neutral face stimuli relative to emotional face stimuli. This outcome was taken as evidence of an obligatory process that is enacted whenever an emotional item is encountered which automatically takes up available processing resources, thus slowing down response times. Interestingly, this same finding was not evident in the latency for emotional words. No differences were obtained in response times between emotional and neutral words in this study.

Some contravening evidence has been obtained using the Stroop (1935; for emotional Stroop see Ray, 1979) paradigm. In a more current study, White (1996) presented participants with positive, negative, and neutral words and asked them to name the color in which the word was printed. White's argument was that if emotional information is associated with an obligatory process, then the colors of negative and positive words should be named more slowly than colors of neutral words, due to the putative automatic processes that fire when one encounters an emotional item. However, an alternative explanation is possible as well. If a specific mechanism for identifying emotional stimuli evolved over the course of human history, then one could expect that this mechanism would bias one to identify emotional items more quickly. Of course, having slower reactions to any potential threats would be maladaptive. Despite this alternative explanation, White's hypothesis of longer latencies for naming colors of emotion words was partially evidenced in the data. The colors of negative words were named slower than the colors of positive and neutral words and there was no difference in the latencies between positive and neutral items. Just as Kensinger and Corkin (2003a) did, White interpreted this finding as evidence of an obligatory process for emotional stimuli which usurps available attentional resources. Although this process is isolated to emotional items and may explain differences in latency measures, further evidence is needed to address any differences in memory measures. For example, longer latencies could demonstrate a lack of resources that would result in lower memory. Alternatively, the longer latencies certainly indicate a longer amount of processing time for the item, thus higher memory might be expected.

One mechanism that is often used to explain the memorial advantage accruing to emotional items is the process of elaboration. As Kensinger and Corkin (2003a; 2004; 2005) have noted numerous times, this elaboration could be semantic or more idiosyncratic and autobiographical. Emotional words, such as *torture* and *fantasy*, may be more easily associated with other self-relevant items, thus boosting memory by means of the self-reference effect (Rogers, Kuiper, & Kirker, 1977). Alternatively, the elaboration could take the form of further semantic processing of an emotional item after its presentation. One interesting way to explore such a theory is with what is referred to as an *attentional blink effect* (Kanwisher & Potter, 1989). During a rapid serial visual presentation paradigm, items to be encoded are displayed at a very quick pace, often with a very short interstimulus interval. Whenever a participant encounters an item that takes additional processing, such as an emotional item, attention can become stuck on this previous trial when the next item is presented. Thus, they are unable to process the subsequent item as a result of this blink in attention. Anderson (2005) used this paradigm to study the attention capturing nature of emotional items. He argued that any emotional items would hold attention and thus impair the identification of a subsequent item. Although he did find that the particular valence of the word was not the determinant of the attentional blink, the arousal of the word was a strong predictor. Arousal refers to the physiological response associated with an emotional item. This can be measured by galvanic skin response and other physiological measures but is most often done through self-report. However, in Anderson's study the arousing items were taboo words from the English language. It is unclear whether such taboo items might contain an additional characteristic beyond mere arousal that could contribute to his obtained effect.

Despite this concern, many studies have used taboo words as a proxy for negative-arousing stimuli. Kensinger and Corkin (2003c), showed greater *recollection* (Tulving, 1985) for negative-arousing words as compared with neutral words. However, because this study confounded valence with arousal, it is unclear what is driving the memory enhancement. In order to examine any potential differences between negative-arousing and taboo items, one must examine the third experiment. Here the authors found a memory enhancement for taboo items above and beyond the significant benefit for negative-arousing items. That outcome suggests that there is something special about taboo items above and beyond their mere arousing nature. Perhaps most interesting about this study was the use of Tulving's (1985) *remember-know* procedure. When a participant makes a remember response, they are indicating they have retrievable episodic details from having studied the item. In contrast, when a participant makes a know response, they have some sense of familiarity that the item was experienced but lack specific episodic details. Participants in Kensinger and Corkin's (2003c) study gave a greater proportion of remember responses for negative-arousing words as compared with neutral items. This outcome suggests deeper and stronger memory supported by recollection is the dominant retrieval process for deeper memory traces and thus will be susceptible to divided attention. In yet another study, Kensinger and Corkin (2003a) manipulated attention at study as well as the valence of studied words. Despite the typical finding of reduced recollection under divided attention, their participants nevertheless still showed greater recollection responses for negative words as compared with neutral words. Unfortunately, these data do not speak to any effect of arousal as they did not manipulate this particular item characteristic. However, the level of arousal of emotional items seems to be an important factor in many previous studies (e.g. Anderson, 2005).

Some researchers have proposed that arousing items occupy a special position within the brain when it comes to encoding and retrieval. Cahill and McGaugh (1990) were the first to propose a link between arousal and amygdala activation. In a thorough review paper, Kensinger (2004) makes the point that while processing of any stimuli is likely to involve the prefrontal cortex, arousing stimuli have a special link to amygdala activation. Other studies have demonstrated a similar connection between the likelihood of remembering emotional information and the degree of amygdala activation (Cahill & McGaugh, 1995; Cahill, Haier, Fallon, Alkire, Tang, Keator, Wu, & McGaugh, 1996). However, only recently did Kensinger and Corkin (2004) demonstrate a specific link between arousing items and amygdala activation. In that study, the authors show a correlation between successful encoding of arousing information and amygdala activation. This finding motivates the current study. If successful encoding and retrieval of an item generally requires attention (Craik & Lockhart, 1972), and control of attention is mediated by the prefrontal cortex (Luria, 1966), then by the transitive property, successful encoding and retrieval require activation of the prefrontal cortex. These attentional processes of the prefrontal cortex are largely strategic and thus under the control of the participant. Strategic processes, such as attention, can be disrupted by the use of a concurrent task to divide attention. If negative items experience a benefit in memory over neutral items as a result of a strategic process of elaboration, then dividing attention should theoretically reduce or eliminate this difference. Furthermore, if arousing items are processed through additional amygdalar activation, then one could predict the deficit from divided attention to be attenuated for arousing items because amygdalar activation is an automatic process immune to disruption. If valence benefits arise from elaboration and arousal benefits come from both elaboration and amygdala activation, arousing items should still be encoded and retrieved at a higher level than simply valenced items under divided attention conditions that eliminate the ability to elaborate.

EXPERIMENT 1

In this experiment I examined the effect of divided attention on recognition of negative-arousing, negative-nonarousing, and neutral words. I used random number generation (RNG) as the divided attention task because Baddeley (1986, 1998) argued that this task requires significant central executive resources. Furthermore, because I manipulated attentional load at both study and test, I wanted to be sure to use a divided attention task sufficiently strong enough to affect recognition memory. Hicks and Marsh (2000) found RNG at test to have significant effects on recognition of neutral word stimuli.

Four conditions were tested in this experiment. Full versus divided attention at study was crossed with full versus divided attention at test. Dividing attention during learning always has a more detrimental impact than does dividing attention at test when recognition is being tested (Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D., 1996; Naveh-Benjamin, M., Craik, F. I. M., Guez, J., & Dori, H., 1998). In the three conditions that had at least one type of divided attention, I predicted that any consequent effect on memory would be worse for the nonarousing items and neutral items as compared with the arousing items.

Method

Participants. All 100 participants in this experiment were University of Georgia undergraduate students who volunteered in exchange for partial fulfillment of a research appreciation requirement. Each participant was tested individually in sessions that lasted approximately 30 minutes. Participants were randomly assigned to one of four between-subjects conditions (with 25 in each).

Materials. Stimuli were chosen from the Affective Norms for English Words (Bradley & Lang, 1999). Words were chosen that were affectively neutral or negative based on these ratings. Furthermore, the negative words were subdivided into those that were arousing and those that were not. None of the three word groups differed on word frequency ($F = .177$, $p > .8$), as indicated within the ANEW norms (Bradley & Lang, 1999) and based on the Kučera and Francis (1967) normative compendium. Neutral and negative non-arousing words did not differ on their arousal levels ($p > .05$) but did differ on subjective valence ($p < .001$). Similarly, negative non-arousing and negative arousing words did not differ on valence ($p > .05$) but did differ on arousal levels ($p < .001$). See Table 1 for word frequency, valence, and arousal ratings for all three classes of words. Forty-eight words were chosen for each class of item, with half randomly presented at study. All item classes were presented intermixed and randomized anew for each participant tested.

In conditions with a concurrent task, participants also listened to a tape recorded metronome, on which a tone was played every second. The participants' task was to speak a single random digit for each tone. With the exception of the timing of the beeps, the procedure for the RNG task was identical to Hicks and Marsh (2000).

Procedure. At the beginning of the experiment, participants read instructions describing the task of learning words for a later memory test. In both conditions with DA at study, participants next read instructions for the RNG task. These instructions were identical to those used by Hicks & Marsh (2000) and emphasized staying random, avoiding common sequences (i.e. 2, 4, 6, 8), and spreading responses over all ten possible digits from 0 to 9. The experimenter then reiterated all instructions to the participant and the experiment began when both were satisfied. Following this, participants either began practicing random digits or were engaged in a distractor task consisting of 3-digit multiplication problems. The purpose of practicing random digits was to obtain a useable baseline in the later measure of randomness, without which costs to the concurrent task could not be measured. This task consisted of gathering 100 usable digits, which took on average two minutes. However, the randomness data will not be discussed further in the current study.

All words were randomly presented in the center of the computer monitor for two seconds. A total of 72 words were presented during the study phase (24 each of the three classes of items), with the remaining 72 used as distractors during the recognition test. After completing the study phase, all participants read instructions on how their memory would be tested. For participants in the DA at test conditions, they also read instructions for the RNG task if they had not already experienced it during the study phase. Immediately following these instructions participants either began practicing random numbers or worked on a multiplication task distractor. Participants who already performed RNG during study neither re-read the RNG instructions nor did they practice generating random digits a second time. Instead, they too engaged in the 2-minute multiplication task. The test sequence was presented in a new random order for each participant.

Results and Discussion

Unless specified with a *p* value, all statistical analyses in this experiment and the one that follows do not exceed chance by the conventional level of 5% probability of a Type I error. Proportions of hits, false alarms, and corrected recognition are summarized in Table 2. Although the overall hit rate is provided for descriptive purposes, all statistical analyses for this experiment were conducted on corrected recognition measures. Corrected recognition could be argued to give a more accurate proxy of a participant's memory because it removes the effect of bias (i.e., false alarms) that is present in overall hit rates. I tested an omnibus 3 (Item Type) X 2 (Attention at Study: FA, DA) X 2 (Attention at Test: FA, DA) mixed model Analysis of Variance on the corrected recognition measure. There was a main effect of item type, *F*(2, 95) = 27.808, η_p^2 = .23, and a main effect of attention at study, *F*(2, 95) = 25.034, η_p^2 = .21, and no interaction. Simple effects analyses revealed that corrected recognition of arousing stimuli was higher than nonarousing stimuli in both conditions involving RNG at only study or test (RNG at Study: *t*(24) = 2.15; RNG at test: *t*(24) = 2.67). As would be expected, the main effect of study attention was due to participants having higher corrected recognition when they had full attention at study versus when they had a concurrent RNG task, *t*(1, 48) = 4.05. One might ask why a similar effect was not found for divided attention at test. Given that Hicks & Marsh (2000) found a significant deficit to items retrieved under RNG, one should expect a similar finding here as well. However, one must keep in mind that the majority of manipulations that involve divided attention at test show little to no effects on recognition. This is presumably because recognition can be made on the basis of either recollection or familiarity (Jacoby, 1991) and although divided attention is known to reduce recollection it is rarely shown to have a noticeable reduction in familiarity. Therefore when attention is divided participants probably relied more on familiarity and thus were not affected as much by the concurrent RNG task.

Interestingly, participants who engaged in RNG at both study and test obtained numerically higher corrected recognition scores than participants who engaged in RNG only during study (*M* = .17 and *M* = .01, respectively). This finding has been shown before (Hicks & Marsh, 2000; see also Jacoby, 1991; Dodson & Johnson, 1996) and has been viewed as an ironic effect of dividing attention at both study and test. Under impoverished encoding conditions, participants are more likely only to encode an item with low-level familiarity as opposed to a deeper recollective trace. As a result, when they are placed in a testing situation in which they have full attentional resources they might still set a conservative criterion for recognition, thus not capturing any items in memory that may have been encoded more weakly. Alternatively, when they are placed under an attentional load at test as well as study, they are forced – due to a lack of resources – to use a more liberal criterion, thus allowing them to declare a greater number of weak items old.

A note should be made about the low corre cted recognition scores in the divided attention at study condition. Although neutral items did have a corrected recognition score hovering around zero, this can be explained by the nature of the dependent measure and the difficulty of the divided attention task. The RNG used in this study used a one second interval in between the tones that indicated a new random number should be given. When Hicks & Marsh (2000) used the RNG procedure, they used a 1.5 second interval between tones and were still able to lower participants' uncorrected recognition to just over chance performance. Therefore, that I would also obtain near chance performance for neutral stimuli with an even more difficult RNG procedure makes sense. Finally the reason why performance in my study was near zero, instead of near the usual chance performance in recognition (50%) is because the corrected recognition measure is calculated by subtracting the false alarms from the hit rate. If one were to simply look at the hit rate, as is reported in Hicks & Marsh (2000), then performance for the neutral stimuli under divided attention appears more reasonable ($M = .50$).

One purpose of the full crossing of divided attention at study and test was to identify the locus of the memory benefit for arousing stimuli. The amygdala activation that occurs at encoding may have been the sole driving force behind the better memory for arousing stimuli. Alternatively, it has been proposed that amygdalar activation during retrieval could potentially aid in recognition of arousing stimuli (Kensinger & Corkin, 2003a). By comparing the pattern of effects for divided attention at test to those for divided attention at study, I had hoped to better understand the nature of this memory enhancement effect. Unfortunately, the pattern was nearly identical in both conditions, with divided attention at test having overall higher corrected recognition. By reducing resources again in a novel way, the generality of the effect may allow a glimpse into its relative automaticity. An alternative way to measure automaticity has been to demonstrate the presence of an effect in older adults. Older adults have a deficit in strategic processing but not in automatic processing (Hasher & Zacks, 1979; Craik & Jennings, 1992). However, the results with testing arousal in older adults have been somewhat confusing. Older adults may have an opposing process operating against the arousal benefit that is found in younger adults (Carstensen, Isaacowitz, & Charles, 1999; Mather & Knight, 2005; for a review of age differences in memory for valence, see Mather & Carstensen, 2005). Rather than testing older adults, I decided to manipulate encoding time in Experiment 2 as an alternative metric for reducing encoding resources. In addition, Experiment 2 had the larger purpose of investigating the subjective states of awareness concerning participants' memory for these emotional words. To this end, Tulving's (1985) *remember-know* procedure was used.

EXPERIMENT 2

In this experiment encoding time was reduced to gauge the relative automaticity of the arousal benefit in memory. If the amygdalar activation confers its advantage early in the time course of encoding – or entirely at retrieval – then reducing encoding time should have relatively little effect. However, if the locus of this arousal effect is later on in the encoding process, then reducing encoding time should eliminate the benefit for these arousing items. Furthermore, the nature of this memory benefit is not yet fully understood in terms of the subjective states of memory underlying the enhancement of arousing items. Amygdalar activation that occurs during the processing of arousing word stimuli may result in a greater sense of familiarity for those arousing items. Alternatively, the activation may result in a deeper level of encoding, which would be evidenced in a greater amount of recollection for arousing stimuli (for a similar effect with valence, see Kensinger & Corkin, 2003c).

Method

Participants. Thirty University of Georgia undergraduate students participated in exchange for partial credit toward a research appreciation requirement.

Materials. All materials in this experiment were the same as those used in Experiment 1, with one exception. There was no concurrent task used in this experiment so the RNG cassette tape was eliminated.

Procedure. All participants read instructions describing the study phase. They were made aware that some words would be presented for a short duration (250 msec) and others would be presented for longer (2000 msec). This long duration of two seconds was used to replicate the study conditions in Experiment 1. The instructions were then reiterated by the experimenter, after which the study phase began. Upon completing the study phase, all participants read instructions for the *remember-know* procedure (Tulving, 1985). When both experimenter and participant were satisfied that the procedure was adequately understood, the test phase began. During this test, participants first made their old-new response by pressing one of two labeled keys. If the chose the old option, they were prompted to respond with an R versus a K response. The former indicates that the recognition decision is associated with recollecting some specific detail from the encoding episode whereas the latter indicates that the participant believes the item was studied, but it is only associated with a vague feeling of familiarity. The entire experiment lasted approximately 20 minutes, after which participants were debriefed on the nature of the study.

Results and Discussion

Proportions of remember, know, and new responses to studied items are presented in Table 3. Although the omnibus ANOVA on corrected recognition measure was not significant, this was not the primary dependent measure for this experiment. Shades of the earlier effect appear in inferred recognition measures calculated by summing the proportion of remember and know responses but this was not significant. Therefore, taking the remember-know judgments has somehow changed the overall effect that was observed in the full attention condition of Experiment 1. However, the purpose of this study was to examine the subjective states of awareness underlying the arousal enhancement of memory. Perhaps the reduction in encoding time was not powerful enough to evidence an effect in these overall, coarse measures of memory. To this end, participants' remember responses were submitted to a 3 (Item Type) X 2 (Encoding Time: 250ms or 2000ms) repeated-measures ANOVA. There was a significant effect of encoding time, $F(2, 29) = 38.31$, $\eta_p^2 = .57$, and a significant effect of item type, $F(1, 58) = 7.08$, $\eta_p^2 = .20$, and no interaction. As would be expected, the main effect of encoding time resulted in greater recollection for words encoded for 2000ms compared to words encoded for 250ms. The main effect of item type revealed greater recollection for negative-arousing words than both types of nonarousing words, $t(29) = 3.74$ (pooling over valence), with no differences between the latter, $t < 1$. Although the interaction was not significant, planned comparison t-tests appeared to indicate a slight dissociation between arousal and recollection under variable encoding conditions. Negative-arousing words were recollected more than negative nonarousing words under short encoding time, $t(29) = 2.091$, however this effect was not significant at longer encoding times, $t(29) = 1.77$, $p = .085$. Although the conventional probability of a Type I Error is exceeded by this test, the effect is still present in a nonparametric sign test, $Z = 1.86$, $p = .06$. However, perhaps there is a reason to expect this difference to be null at longer encoding times. The 2000ms encoding time used in Experiment 2 was the same duration of encoding used in Experiment 1, thus one would expect long duration items to behave just like the full attention condition of Experiment 1. Just glancing at the means in Table 1 indicate that this difference would be far from conventional significance, thus may have been preordained that this effect would not be significant. The lack of an interaction between encoding time and item type indicates that the effect is not merely a matter of length of encoding time. Even at short study presentations as low as 250ms, the benefit to arousing items is evidenced in recollection responses.

Next, participants' know responses were submitted to an identical 3 (Item Type) X 2 (Encoding Time) repeated measures ANOVA in order to examine the relative benefit of arousal to know responses. Before proceeding to the analysis, it should be noted that remember and know responses often trade-off (e.g., Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004) such that when one has greater recollection for a class of items, there is often less familiarity per force. There was not a significant effect of encoding time in Experiment 2 but there still a was significant effect of item type, $F(2, 58) = 3.17$, $\eta_p^2 = .10$. The lack of an effect of encoding duration could be due to the trade-off in remember and know responses or it could be the result of the relative automaticity of the class of memory purportedly measured by know responses. In studies of divided attention know responses are rarely affected because they presumably capture the effects of an automatic process that was not interfered with by the concurrent task. It is possible that reducing encoding time in the current experiment was not a powerful enough reduction in resources to lower know responses at shorter encoding times. The main effect of item type revealed no differences in know responses for negative-arousing and negative-nonarousing words, $t(29) = 1.77$, $p = .09$, but a significant difference between negative-nonarousing and neutral words, $t(29) = 2.231$. This finding would seem to indicate a greater contribution of familiarity to valenced stimuli, without any differences arising from arousal. On the other hand, arousal seems to confer its advantage in the deeper recollection responses. This difference could explain the lack of differences in inferred and corrected recognition measures as they would average over these two opposing effects.

GENERAL DISCUSSION

In two experiments, a memory benefit to arousing words was found above and beyond the mere valence benefit to negative items found in earlier work. Furthermore, this benefit was found to survive two manipulations designed to impoverish resources. By dividing attention in Experiment 1 with a difficult RNG task, the benefit to negative-nonarousing information was eliminated whereas the enhancement of negative-arousing words persisted. This effect was evidenced again in remember responses at short and long encoding times in Experiment 2.

The effect of arousal on memory has been postulated to be the result of a special link between arousal and amygdalar activation (Cahill & McGaugh, 1990; Kensinger & Corkin, 2004). Whenever an item is encoded, it requires some degree of central executive resources in order to direct attention. If these resources are soaked up by a demanding concurrent task, then less are available for the additional poststimulus elaboration thought to benefit valenced material (Christianson, 1992a). Unfortunately, the majority of studies investigating the effects of valence have either ignored the contribution of arousal or have confounded valence with arousal such that any dissociable effects are lost. Christinanson (1992a) did not explicitly address the separate contributions of valence and arousal on memory. He did, however, identify two potential ways that valenced material could obtain their memorial benefit: preattentive processing and poststimulus elaboration. By dividing attention in Experiment 1, any benefit due to poststimulus elaboration should have been reduced, largely leaving only preattentive processing to confer any advantages to memory. The obtained difference between negative-arousing and negative-nonarousing words in Experiment 1 demonstrates the role of preattentive processing in arousing stimuli. Combining these behavioral observations with Kensinger and Corkin's (2004) neurological findings, one could posit this preattentive processing is mediated by amygdalar activation, however further empirical work is needed to confirm such a claim.

Of course, there is now converging evidence that amygdalar activation can be a driving force to redirect attention when exposed to arousing stimuli (LeDoux cite). Some have argued that there are actually two amygdalar influences to memory performance. A direct, older projection from the visual pathways projects directly to the amygdala by which a trickle of information is received. The less direct projections through higher cortical structures is how most information converges on the amygdala (Phelps, 2004). Under conditions of divided attention, Christianson's (1992) notion of preattentive processing may actually be an effect of directing attention from the older, less efficient pathway. Once attention has been captured, perhaps arousing items underwent more elaborative encoding even under divided attention. Unfortunately, the use of the RNG task to divide attention does not allow us to examine whether the RNG performance suffered at those times when an arousing word was presented. If Christianson's notion of a preattentive process is actually a redirection of attention, then RNG performance should suffer when studying arousing as compared with more neutral material.

Cahill and McGaugh (1990) make the claim that the amygdalar activation plays a role in reward mechanisms of learning. This finding suggests arousing stimuli evoke a similar effect as rewarding stimuli, which serves to enhance memory relative to nonarousing stimuli. The memory advantage for arousing stimuli may appear contrary to the typical claim that memory is impaired in highly arousing situations, e.g. the scene of a crime. Anecdotal reports of poor eyewitness memory have likely fueled this misconception about the connection between arousal and memory (Christianson, 1992b). From an evolutionary perspective, a deficit in encoding of arousing stimuli could prove maladaptive in future encounters with the same stimuli. In a study by Kassin, Ellsworth, and Smith (1989; as discussed in Christianson, 1992), 71% of experts on eyewitness testimony agreed the following statement was reliable enough to offer in court: “Very high levels of stress impair the accuracy of eyewitness testimony.” Although there may be other confounding factors in such situations that would lead to lower accuracy, the arousal level itself seems only to confer an advantage in later memory. The pervasive nature of this misconception highlights the importance of the current study’s findings. In addition to arousal and valence, stimuli can also be classified by their type of valence (e.g. disgust). Future neuroimaging work should investigate this additional factor for its potential to mediate the amygdalar pathway in arousing items. Findings from such studies could elucidate the somewhat hazy state of the literature on emotion and memory.

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Table 1

Valence, Arousal, & Word Frequency for Stimuli in All Experiments

Item Type	Valence	Arousal	Word Frequency
Negative-Arousing	2.47	4.43	17.56
	(.07)	(.06)	(4.25)
Negative-Nonarousing	2.37	6.84	11.19
	(.08)	(.07)	(1.37)
Neutral	5.78	4.31	10.44
	(.03)	(.07)	(1.31)

Note. Standard errors are in parentheses.

Table 2

Recognition Accuracy in Experiment 1

		Memory measure and item type								
		Hits			False Alarms			Corrected Recognition		
Study Manipulation		NegNA	NegA	NeuNA	NegNA	NegA	NeuNA	NegNA	NegA	NeuNA
Full Attention	*M*	.76	.79	.68	.23	.20	.31	.54	.59	.36
	SE	(.03)	(.03)	(.04)	(.04)	(.03)	(.04)	(.07)	(.06)	(.07)
DA @ Study	*M*	.61	.66	.50	.40	.34	.50	.21	.31	.01
	SE	(.03)	(.03)	(.03)	(.03)	(.03)	(.03)	(.06)	(.06)	(.07)
DA @ Test	*M*	.73	.78	.69	.27	.22	.31	.46	.55	.39
	SE	(.02)	(.02)	(.03)	(.02)	(.02)	(.03)	(.05)	(.04)	(.05)
DA @ Both	*M*	.64	.67	.59	.36	.33	.41	.28	.33	.17
	SE	(.03)	(.03)	(.04)	(.03)	(.03)	(.04)	(.07)	(.06)	(.07)

Note. Standard errors are in parentheses.
Corrected Recognition = Hits - False Alarms.

Table 3

Proportion of Remember, Know, & New Responses in Experiment 2

Response Type	Study Duration and item type: Short (250 msec) NegNA	NegA	NeuNA	Long (2000 msec) NegNA	NegA	NeuNA
Remember	.33	.39	.30	.45	.54	.45
	(.03)	(.04)	(.03)	(.04)	(.05)	(.04)
Know	.35	.32	.30	.34	.30	.28
	(.03)	(.04)	(.03)	(.03)	(.03)	(.03)
New	.32	.29	.40	.21	.16	.28
	(.03)	(.03)	(.03)	(.02)	(.03)	(.03)

Note. Standard errors are in parentheses.