Journal of Experimental Psychology: General
2005, Vol. 134, No. 2, 258–281

0096-3445/05/$12.00 DOI: 10.1037/0096-3445.134.2.258

Affective Influences on the Attentional Dynamics Supporting Awareness

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Identification of a 1st target stimulus in a rapid serial visual presentation sequence leads to transient impairment in report for a 2nd target; this is known as the *attentional blink* (AB). This AB impairment was substantially alleviated for emotionally significant target words. AB sparing was not attributable to a variety of nonaffective stimulus factors that could result in augmented distinctiveness. Arousal value, not the valence of stimulus events, was found to be responsible for AB sparing. These results suggest that arousal is associated with decreased attentional prerequisites for awareness, enabling emotional significance to shape perceptual experience.

Perceptions and memories are not all created equal, nor should they be. It has been long known that memories for the significant and mundane events in a person's life are not formed with equal durability and fidelity but are instead modulated by their emotional significance (for a review, see Christianson, 1992). A functionalist account suggests this difference in the fate of remembered and forgotten events is due to the fact that memories are to serve some predictive utility that aids one's ability to later navigate within significant situations, enhancing survival fitness. This separation of the wheat from the chaff of daily existence is also likely a result of the limited nature of cognitive capacity, which ensures that selective processes are always at work. The mechanism by which information is selected or not selected for further perceptual processing is commonly referred to as *attention*. Although it is well established that emotion influences subsequent recollective experience (e.g., Ochsner, 2000), its shaping of initial perceptual experience is less appreciated. In the studies described here, I examine whether and how different dimensions of emotional significance interact with central processing resources to influence visual awareness. The *attentional blink* (AB)—a deficit in perceptual report reflecting the limitations on the temporal dynamics of attention—was used to demonstrate that arousal value, the energizing aspect of both pleasant and unpleasant events, represents a fundamental mechanism by which selection and relevance are coupled to alter the attentional prerequisites of perceptual experience.

A portion of this research was completed in partial fulfillment of the requirements for the degree of doctor of philosophy at Yale University. I am grateful to Elizabeth Phelps for her generous support of the initial studies and Mahzarin Banaji, Marvin Chun, Eve De Rosa, Yuhong Jiang, Ingrid Olson, Kevin O'Connor, David Panitz, and Uli Schimmack for critical feedback during different phases of this research. Portions of the data in this article were presented at the November 1999 annual meeting of the Psychonomic Society, Los Angeles, CA.

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Attention, Emotion, and Awareness

One of the fundamental questions in psychological science remains how stimulus significance interacts with attentional resources to shape subjective awareness. Awareness of even the most basic perceptual primitives may depend to some degree on the allocation of attention (e.g., Joseph, Chun, & Nakayama, 1997; Mack & Rock, 1998; Ross & Jolicoeur, 1999; Simons, 2000). Thus, the primary means by which a stimulus reaches awareness is through the allocation of attention toward its more complete processing. It has long been proposed that affect modulates information processing in a manner consistent with altered attention (e.g., Easterbrook, 1959); however, the precise mechanisms, the stimulus dimensions coordinating this influence, and its relation to subjective awareness are still not well understood.

Attentional selection is considered a result of the brain's natural capacity limitations, requiring the selective processing of certain stimulus features at the expense of others (Allport, 1989; Johnston & Dark, 1986). If the focusing of attention represents a prioritizing of information processing, then the allocation of resources should be tightly coupled with information of biological or motivational import to the organism. Consistent with the claim that negatively valenced events orient attention, a large body of findings now suggests that emotional stimuli attract or capture attention in a manner unlike that of neutral stimuli. Attentional capture typically refers to the reflexive allocation of attention toward a salient stimulus for its further processing (e.g., abrupt onset of a new object; Remington, Johnston, & Yantis, 1992). Evidence supporting the notion of attentional capture for affective events has been generated from variants of the *emotional Stroop* paradigm (Algom, Chajut, & Lev, 2004; Mathews & MacLeod, 1985; Pratto & John, 1991; Watts, McKenna, Sharrock, & Trezise, 1986). When participants are asked to name the color of emotionally significant and neutral words, color-naming latencies are typically longer for negatively valenced words, despite word valence being a task-irrelevant stimulus dimension. Similarly, the *dot probe* paradigm demonstrates facilitation in latency to detection of a simple lateralized target stimulus (the dot probe) when it follows a negatively valenced event, suggesting an attentional bias toward the region in space coincident with the negative prime (e.g., Fox, 1993; Mogg, Bradley, & Hallowell, 1994). These findings may suggest that affectively significant events are subject to an attentional bias, whereby after initial encoding, they are the recipients of more attentional resources toward their beneficial processing.

The attention-grabbing power of emotional stimuli has also been interpreted as reflecting their relative *automaticity*, or attentional independence, during encoding (e.g., Pratto & John, 1991; Williams, Mathews, & MacLeod, 1996; see Harris & Pashler, 2004, for a related viewpoint). Compared with neutral words, emotionally significant events, particularly of negative valence (Pratto & John, 1991), may be processed relatively automatically (e.g., Neuman, 1984, as cited in Styles, 1997; Schneider & Shiffrin, 1977) and thus compete more effectively for resources at a subsequent processing stage, resulting in behavioral interference. In their study of the disruptive effects socially significant stimuli have on color naming, Pratto and John (1991) construed this interference as indicating an "automatic vigilance" to undesirable stimuli in one's environment. Consistent with a diminished dependence on capacity-limited encoding processes is evidence of diminished search time in visual search tasks for threat stimuli (Ohman, Flykt, & Esteves, 2001; Ohman, Lundqvist, & Esteves, 2001).

Emotional value can potentially influence information processing at various levels, from attentionally limited encoding processes to postencoding maintenance and response selection stages. Although many studies suggest that emotional events are bestowed with special attentional status during encoding, evidence for such a claim requires manipulation of the degree of attention during encoding, a condition that is rarely met. For instance, demonstrations of interference or facilitation associated with emotional event processing cannot alone implicate whether emotional value influences attentional dependence at encoding or later processing stages. Establishing that affectively significant events have special attentional status during encoding requires direct manipulation of the degree of available attentional resources.

Transient interference effects associated with emotionally charged events (Harris & Pashler, 2004) do not address how emotion and attention interact to enable conscious experience. Researchers conducting early work from the New Look movement in perception of the 1950s pursued the notion that the emotional values of negative stimuli are processed prior to conscious perception, allowing for these stimuli to be kept out of awareness, a response referred to as *perceptual defense* (e.g., McGinnies, 1949). Thus, interference can be mediated by unconscious processing of affective content (Greenwald, Klinger, & Liu, 1989; Kemp-Wheeler & Hill, 1992; Mogg et al., 1994); as such, interference effects do not necessarily implicate awareness. As demonstrated in dissociations between the factors that influence implicit and explicit memory (Roediger & McDermott, 1993), affective influences on unconscious processing do not necessarily generalize to conscious processing. Thus, there is little direct evidence that emotional value interacts with attentionally limited encoding stages to influence awareness.

It is also unclear which stimulus dimensions are related to the hypothesized special attentional status of emotionally significant events. Emotional space is not unidimensional—emotional versus nonemotional—but is at least differentiable into dimensions of positive and negative valence and the arousal or energetic intensity of experience orthogonal to but often strongly associated with these valence dimensions (Feldman-Barrett & Russell, 1999; Watson, Clark, & Tellegen, 1988). Evidence suggests a critical valence asymmetry in stimulus processing, with negative stimuli being differentially attended (e.g., Erdelyi & Appelbaum, 1973; Koster et al., 2004; Mogg & Bradley, 2002; Ohman, Flykt, & Esteves, 2001; Ohman, Lundqvist, & Esteves, 2001; Pratto & John, 1991; Williams et al., 1996) as well as processed temporally earlier (Smith, Cacioppo, Larsen, & Chartrand, 2003) and under degraded subliminal conditions (Dijksterhuis & Aarts, 2003). In addition to the attentional bias frequently attributed to negative events is the empirical bias toward investigating their presence. Hypothesized attention effects are largely sought and found for negatively valenced stimuli. Such a valence asymmetry presupposes that organisms maintain specialized processes and supporting neural structures to efficiently evaluate stimuli associated with defensive or avoidance versus appetitive or approach action tendencies (Ohman & Mineka, 2001). "Biologically prepared" stimuli (e.g., snakes, spiders, angry faces) are thought to be recipients of special attention shaped by evolutionary pressures, and this stimulus class is invariably associated with threat (Ohman & Mineka, 2001). However, negatively valenced stimuli tend to be associated with greater arousal responses than their positive counterparts are (Anderson, Christoff, Stappen, et al., 2003; Bradley, Codispoti, Cuthbert, & Lang, 2001; Hamann, Ely, Grafton, & Kilts, 1999). With arousal being so closely tied with negative valence, it is difficult to dissociate their influence (Anderson, Christoff, Stappen, et al., 2003). Recent studies suggest that arousal value may play a critical role in guiding attention (Bradley et al., 2003; Gronau, Cohen, & Ben-Shakhar, 2003; Keil & Ihssen, 2004; Schimmack, in press; Schupp, Junghofer, Weike, & Hamm, 2004). Additionally, novelty and distinctiveness have also been associated with autonomic arousal responses referred to as the *orienting response* (Sokolov, 1963), as well as the recipients of special attention (e.g., Dafner et al., 2000; Harris & Pashler, 2004; Johnston, Hawley, Plewe, Elliott, & DeWitt, 1990; Otten & Donchin, 2000). Special attentional status may not be related to affective value at all but with associated nonaffective stimulus dimensions that enhance distinctiveness.

Affective Modulation of Visual Awareness: Investigations With the AB

After the identification of a single target stimulus, there is a transient impairment in report for a subsequently presented second target, referred to as the AB (Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992). The typical AB paradigm requires two highlighted targets to be selected from a stream of masking distractor items in a rapid serial visual presentation (RSVP) stream. After the successful report of a first target (T1), detection of a second target (T2) is impaired for up to 500 ms, with the severity of impairment increasing with a decreasing interval between T1 and T2 (Raymond et al., 1992). Although the AB is of postsensory locus, not reflecting the degradation of the earliest stages of sensory processing (Luck, Vogel, & Shapiro, 1996), it demonstrates that perceptual encoding depends on a capacity-limited short-term consolidation process (Chun & Potter, 1995; Jolicoeur, 1999a, 1999b; Jolicoeur & Dell'Acqua, 1998) that restricts the placement of perceptual information into working memory (Vogel, Luck, & Shapiro, 1998).

In contrast with the distinct phenomenon of repetition blindness that has been argued to reflect a bias in memory output (Whittlesea & Podrouzek, 1995), the AB has been shown to reflect attentional limitations during encoding that restrict perceptual awareness (Chun, 1997; Jiang & Chun, 2001; Jolicoeur, 1999a, 1999b; Jolicoeur & Dell'Acqua, 1998; Raymond, Shapiro, & Arnell, 1995) and thus gates the experience of seeing. As evidence of this early gating of perceptual features reaching awareness, the AB is diminished by perceptual factors that increase target perceptual salience (Chun, 1997; Chun & Potter, 1995; Jiang & Chun, 2001; Raymond et al., 1995). Converging neuroimaging evidence shows that the AB results in diminished activation in extrastriate regions (Marois, Yi, & Chun, 2004) thought to gate conscious perception (Tong, Nakayama, Vaughan, & Kanwisher, 1998). Thus, the AB affords an objective characterization of stimulus salience in terms of the degree of attentional resources necessary for perceptual report.

Dual-target RSVP allows for a graded manipulation of resources available during encoding. Specifically, the time course of the AB is a visible analog of available attentional resources for awareness. If emotional value has privileged attentional status for awareness, then emotionally significant events should modulate the magnitude and time course of the AB, attenuating the impairing effects of the decreasing interval between T1 and T2. Enhanced report in the middle of the AB, at early or short temporal lags (<500 ms), would suggest that affective events require fewer attentional resources during encoding to gain entry into awareness. By contrast, if emotional events do not result in a diminished AB, emotional influences would be characterized as a bias in later postattentive processing stages that do not limit entry into awareness.

In the current studies, I used the AB to explore processing of emotional versus neutral linguistic stimuli. Linguistic events are unlikely to be confounded with low-level featural differences between neutral and emotionally significant events. Instead, affective linguistic content is dependent on an association between an arbitrary word form and its emotional value. My first aim was to examine the hypothesized special attentional status of emotional events under varying degrees of available attention by examining the susceptibility of emotionally significant words to the AB. My second aim was to specify the precise stimulus dimensions underlying the hypothesized interaction between attention, emotional significance, and awareness, addressing the importance of valence, arousal, and distinctiveness. Experiment 1 allowed me to assess how manipulating the arousal value of negatively valenced words influenced the AB. In Experiment 2, I addressed the importance of negative valence by manipulating the arousal value of positively valenced words. In Experiments 3A–3C, I examined the contributions of different sources of distinctiveness potentially confounded with arousal value. Experiment 4A allowed further examination of the special attentional status of arousing events under conditions of relatively low (single-task) and high (dual-task) attentional load conditions. In Experiment 4B, I more closely examined the attentional dynamics between T1 and T2 by using a T1 speeded choice response to assess the role of attentional orienting in enhanced awareness.

Experiment 1: Affective Stimulus Dimensions and Awareness, Negative Valence

In Experiment 1, I examined reports of neutral, negative, and negative, highly arousing taboo T2 events during dual-target RSVP. By manipulating both the negative valence and the arousal attributes of T2 events, it is possible to examine their influence on the AB. If negative valence is associated with reduced dependence on a resource-limited encoding stage that gates entry into awareness, then negative events should be spared from the AB relative to more neutral events. If the arousal value of negative events is critical, then the degree of AB sparing should be greatest for negative arousing events.

Method

Participants. Forty volunteers from the Yale University community participated in this experiment for pay. Half of the participants were randomly assigned to the negative condition and the other half to the negative-arousal condition. In all experiments, participants reported normal or corrected-to-normal vision and gave their informed consent prior to testing.

Materials and procedure. T1 stimuli were 56 neutral words averaging 4.38 letters in length. Distractor items were 79 neutral words of much longer length ($M = 11.66$ letters) to appropriately mask all target stimuli and also to maintain distinctiveness between the target and distractor stimuli. Pilot studies revealed that errors in T2 report were rarely (< 3% of trials) due to transpositions of target and distractor stimuli. The T2 stimuli consisted of four lists comprising one list of 28 negative words, one list of 28 taboo (negative-arousing) words, and two lists of 28 neutral words (see Appendix A). In the negative condition, negative and neutral T2 words were of equal word length (Ms = 5.25 vs. 5.25 letters, respectively) and written word frequency (Ms = 43.75 vs. 44.36 occurrences per million, respectively; Kučera & Francis, 1967, accessed from the MRC Psycholinguistic Database at http://www.psy.uwa.edu.au/MRCDataBase/uwa_mrc.htm). In the negative-arousal condition, negative-arousing and neutral T2 words were of approximately equal length (Ms = 5.14 vs. 5.07 letters, respectively), but because of their colloquial slang origin, the negative-arousing words were of lower written word frequency (Ms = 5.29 vs. 106.36 occurrences per million, respectively). Fifteen negative-arousing words had no written frequency entry and were assigned a frequency of 0. The potential effect of low-frequency words is controlled and further examined in subsequent experiments (see Experiment 3B). Neighborhood frequency was assessed by calculating the number of words created from single and two-letter replacements (on the basis of the Kučera & Francis corpus). Because of the diagnosticity of infrequent letter combinations, lower neighborhood frequency is associated with ease of recognition. Average neighborhood frequency was similar in the negative (negative = 4.2; neutral = 3.5) and negative-arousal conditions (negative arousing = 5.18; neutral = 4.89).

Seven independent judges rated each of the T2 items on valence (1 = *pleasant* to 7 = *unpleasant*) and arousal (1 = *low arousal* to 7 = *high arousal*). Negative T2 words ($M = 5.93$) were rated as more negative than negative-arousing T2 words ($M = 5.34$), $t(6) = 2.68$, $\eta^2 = .31$, and neutral T2 words ($M = 3.83$), $t(6) = 9.53$, $\eta^2 = .61$. Negative-arousing T2 words ($M = 4.02$) were rated as more arousing than negative ($M = 3.06$), $t(6) = 2.28$, $\eta^2 = .46$, and neutral T2 words ($M = 1.83$), $t(6) = 5.15$, $\eta^2 = .82$. Because of the significant number of missing frequency entries in the negative-arousal condition, ratings of familiarity were also obtained to supplement the written frequency ratings that likely underestimate the frequency (spoken and written) of taboo words. Negative T2 words ($M = 5.05$) were rated as approximately equally familiar (1 = *low* to 7 = *high*) to both neutral ($M = 5.39$) and negative-arousing T2 words ($M = 4.87$).

Participants in the negative and negative-arousal conditions were presented with stimuli selected randomly from their respective T1 and T2 lists, with the constraint that each word was used once in each block of trials. Each trial consisted of 15 items, 2 targets (T1 and T2) and 13 distractors. T1 and T2 appeared in bright green while the distractor words appeared in black. In all experiments, stimuli were presented in uppercase and on a gray background. Each item in the stream was presented for approximately 100 ms and was immediately followed by the subsequent item. There were seven lags between T1 and T2, ranging from Lag 1 (no intervening items, stimulus onset asynchrony [SOA] ~ 100 ms) to Lag 7 (6 intervening items, SOA ~ 700 ms). T1 appeared equally often in serial positions 2–5 of the 15-item stream. The serial position of T1 was crossed with T1–T2 lag and T2 type. In both the negative and the negative-arousal conditions, there were 16 trials for each factor combination of lag (7) and condition (2), for a total of 224 trials, divided into four experimental blocks of 56 trials each.

Each trial began with a central fixation point appearing for 1 s. The RSVP stream was presented 500 ms after the fixation offset. The task was to monitor the stream and report the two green-colored targets. After presentation, participants indicated the two targets by typing each word in separate dialog boxes, in any order. Participants were instructed to guess where appropriate and to press the return key when identification was not possible. No feedback was provided. The experiment was conducted on a Macintosh computer using MacProbe Version 1.6.8 or Psyscope 1.2.1 and in normal room illumination held constant for all participants. The word stimuli were presented in 24-point Geneva font. The stimuli were viewed from an average distance of 40 cm. Comparable experimental conditions existed for all experiments.

Analysis. In all experiments, the percentages of accuracy on T1 and T2 report contingent on the correct report of T1 (T2/T1) were considered separately in factorial analyses of variance (ANOVAs), with condition (e.g., negative vs. neutral) and T1–T2 lag (1–7) entered as separate within-subject factors. T2 responses were considered correct only on trials with correct T1 reports to ensure that proper attention was devoted to T1. An alpha level of .05 was used for all studies. The *p* values are reported only where effects are marginally significant. Effect sizes were estimated with eta squared, representing the proportion of accounted variance ($\eta^2 < .1$ = small effect size; η^2 between .1 and .25 = medium effect size; $\eta^2 > .25$ = large effect size).

To assess the presence of a response bias, I conducted further analyses to examine the types of errors made when T2 was incorrectly identified. In these analyses, I calculated the percentage of trials on which T2 was incorrectly reported as either a neutral or an emotionally significant (E_{neut} vs. E_{emot}) word. A liberal criterion was used, with responses classified as emotionally significant even if they were only mildly or ambiguously so (e.g., *slit*). The percentage of such emotional and neutral output errors was submitted to factorial ANOVAs, with error type (E_{emot} vs. E_{neut}), lag, and condition (e.g., negative vs. neutral) entered as separate within-subject variables. Across all studies, the results of these analyses demonstrated that where target identification was most impaired in the middle of AB, neutral guesses (E_{neut}) were much more frequent than emotional ones (E_{emot}). Thus, participants did not reveal a response bias to report emotional targets. The results for each experiment are presented in Appendix B.

Results

As illustrated in Figure 1, neutral T2 events were subject to a robust lag-dependent impairment in report (i.e., the AB), with some sparing at Lag 1. Consistent with the reduced attentional requirements for perceptual report, negative T2 events resulted in a smaller AB than did neutral T2 events, and negative-arousing events demonstrated a further AB sparing.

Analysis of T2 accuracy. In the negative condition, report of T2 depended on lag, with report decreasing from Lags 7 to 2, $F(6, 114) = 42.21$, $\eta^2 = .27$. Across lags, report of negative T2 was more accurate than that of neutral T2 (M = 82.2%, SD = 21.0, vs. M = 77.4%, SD = 23.5, respectively), $F(1, 19) = 21.04$, $\eta^2 = .53$. A focused contrast on the Lag × Condition interaction revealed that the effect of lag (early = average of Lags 1 and 2 vs. late = average of Lags 6 and 7) was less pronounced for negative relative to neutral T2 words, $F(1, 19) = 21.24$, $\eta^2 = .53$.

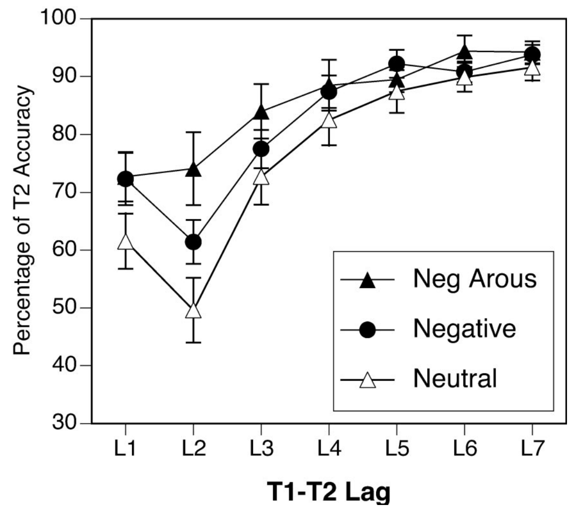

Figure 1. Mean percentage of accurate second target (T2) report given first target (T1) report (T1/T2) at each T1–T2 lag (L) in Experiment 1. Error bars represent standard errors of the means. Negative = negative and lower arousal T2 words; Neg arous = negative and highly arousing T2 words; Neutral = neutrally valenced and low-arousal T2 words.

In the negative-arousal condition, accuracy was again lag dependent, $F(6, 114) = 38.49$, $\eta^2 = .25$. Across lags, report of negative-arousing words was more accurate than that of neutral words (M = 85.3%, SD = 24.5, vs. M = 75.6%, SD = 29.6, respectively), $F(1, 19) = 20.07$, $\eta^2 = .51$. A focused contrast on the Lag × Condition interaction revealed that the effect of lag was less pronounced for negative-arousing words than for neutral words, $F(1, 19) = 28.83$, $\eta^2 = .60$.

To examine the influence of manipulations of negative arousal more directly, I submitted report accuracy of negative T2 words from the negative and negative-arousal conditions to an additional two-way ANOVA, with lag (2 vs. 7) and condition (negative arousal vs. negative) entered as separate within-subject and between-subjects variables. Accuracy remained dependent on lag, $F(1, 38) = 78.69$, $\eta^2 = .67$; however, the impairing effect of lag was less pronounced for negative-arousing words than were negative T2 words, $F(1, 38) = 4.31$, $\eta^2 = .10$.

Analysis of T1 accuracy. Enhanced report of negative T2 words was not associated with a trade-off between T2 and T1 accuracy. In the negative condition, there was an effect of lag, $F(6, 114) = 12.02$, $\eta^2 = .10$, with accuracy lower at Lag 1; however, T1 report was not significantly influenced by T2 content (negative, M = 94.1%, SD = 12.8, vs. neutral, M = 93.5%, SD = 14.3). In the negative-arousal condition, there was a similar effect of lag, $F(6, 114) = 5.26$, $\eta^2 = .04$, with overall accuracy for T1 report not influenced by T2 content (negative-arousing, M = 92.1%, SD = 15.7, vs. neutral, M = 92.1%, SD = 15.5). There was some evidence of a lag-dependent effect of T2 condition on T1 accuracy, $F(6, 114) = 3.69$, $\eta^2 = .03$. At Lag 1, T1 accuracy was lower when followed by negative-arousing versus neutral T2 words, $F(1, 114) = 6.20$, $\eta^2 = .05$. In contrast with a general trade-off between T2 and T1 processing, T1 report was more accurate preceding negative-arousing than neutral T2 words at Lag 2, $F(1, 114) = 4.10$, $\eta^2 = .04$, where the advantage for negative-arousing T2 words was greatest.

Discussion

Negative words were less susceptible to the AB than were neutral words of similar orthographic neighborhood, written frequency, and subjective familiarity. Negative-arousing taboo words with greater arousal value yielded an even more pronounced AB sparing. As the emotional intensity or arousal value associated with T2 was increased, there was a commensurate decrease in the magnitude of the AB. In fact, negative-arousing words were rated as more arousing but slightly less negative than negative words. Thus, the arousal value of negative events may be critical to their special attentional status. Although arousal was associated with a diminished AB, there remained a lag-dependent impairment in report. This is consistent with a relative but not an absolute attentional independence during encoding.

Although given similar ratings of familiarity in the present study, highly arousing taboo words are of lower written usage frequency than negative words. Low-frequency words are typically associated with longer visual duration thresholds (e.g., Johnson, Thompson, & Frincke, 1960; Solomon & Postman, 1952) and longer naming and lexical decision latencies (e.g., Besner & McCann, 1987). If word frequency played a significant role, then it should have had the effect opposite of that evidenced, resulting in a larger AB. Rather, events associated with the presence of negative arousal reduced attentional prerequisites for awareness. This is supported by evidence that taboo words result in greater emotional Stroop effects (MacKay et al., 2004) and enhanced memory even when presented outside one's attentional focus (Sharot & Phelps, 2004).

Harris and Pashler (2004) suggested that the attention-grabbing nature of salient events (e.g., one's own name) is transient, evident mostly on first presentation, reflecting a surprise response. Post hoc analyses revealed that a diminished AB for negative and negative-arousing words was evident on their first presentation. However, the AB remained diminished for these events throughout each of the four experimental blocks. Thus, the reduced AB for negatively arousing events appears neither attributable merely to a transient surprise response nor attributable to an accrual of familiarity across the testing session.

Experiment 2: Affective Stimulus Dimensions and Awareness, Positive Valence

The reduction of the AB may only be present for items that are not only arousing but also negative in valence. This would be consistent with findings of an attentional bias toward stimulus events only with negative or threatening content. However, negative events tend to be associated with greater arousal value, and thus valence asymmetries are often confounded with underlying differences in arousability (Anderson, Christoff, Stappen, et al., 2003; Hamann et al., 1999). If negative valence is critical, then there should be no evidence of AB sparing for positive T2 events. If arousal is the critical stimulus dimension, then AB sparing should also occur for positive T2 events and, further, should follow their arousal value rather than positive valence. In Experiment 2, I examined these valence and arousal hypotheses by comparing AB magnitude for neutral T2 items and those that were either relatively high in arousal value but considered mildly pleasant in valence or lower in arousal content but considered highly pleasant.

Method

Participants. Thirty-six volunteers from the Stanford University community participated in this experiment for course credit. Participants were randomly assigned to either the positive ($n = 18$) or the positive-arousal condition ($n = 18$).

Materials and procedure. There were 28 T2 items in each condition (see Appendix C). The T2 items in the positive-arousing condition were mildly positive words of a highly arousing sexual nature, whereas those in the positive condition were more strongly positive in valence but lower arousal value (e.g., *flower, holiday*). To control for the possible effect of T2 category membership, I made the neutral T2 words the names of tools. The positive and neutral T2 words were comparable in terms of word frequency ($M = 37.53$ and $M = 35.07$ occurrences per million, respectively); the positive-arousal condition was more infrequent in the corpus, with 11 missing entries ($M = 9.21$ occurrences per million). The valence and arousal values of stimuli were assessed and confirmed in each participant and are provided in the *Results* section.

T1 items were presented in white and T2 items in green. Target colors were altered to reduce the enhanced report at Lag 1 (i.e., Lag 1 sparing) found in Experiment 1. Distractor items were also presented in one of four colors (red, blue, yellow, or magenta) to increase the difficulty of target detection, which was at ceiling levels for longer lags in Experiment 1. I removed the potential influence of T1's neutral lexical content by making T1 stimuli letter strings of a single character, each eight characters in length (e.g., *NNNNNNNN*, *OOOOOOOO*). Observers indicated the first target by typing a single letter. Distractors were neutral words flanked on the right and left by nonalphanumeric characters (@#$%&) to ensure sufficient masking of the target items. The role of distracter content is assessed in Experiments 3B and 3C. Each of the positive-arousal and positive conditions consisted of four blocks of 56 trials each, for a total of 224 trials. Each of the 14 stimulus combinations (2 conditions × 7 lags) was represented equally in each block of trials.

Participants in the positive and positive-arousal conditions were presented with stimuli selected randomly from their respective emotional and neutral T2 lists. After the dual-target RSVP task, participants rated the valence (1 = *unpleasant* to 7 = *pleasant*) and arousal (1 *low* to 7 = *high*) of 112 items, including the 84 words making up the neutral, positive, and positive-arousal lists, and an additional 28 filler items of relatively negative value.

Results

As illustrated in Figure 2, there was a smaller AB for positive T2 items than for neutral T2 items. Consistent with the importance of arousal rather than valence, this AB sparing was more pronounced for highly arousing, mildly positive events.

Analysis of T2 accuracy. In the positive condition, report was less accurate at early (short) relative to later (long) temporal lags, $F(6, 102) = 58.09$, $\eta^2 = .36$, and for neutral T2 words belonging to the tools category relative to positive T2 words, $F(1, 17) = 11.45$, $\eta^2 = .40$. A focused contrast on the Lag × Condition interaction revealed that the effect of lag (early = average of Lags 1 and 2 vs. late = average of Lags 6 and 7) was less pronounced for positive than for neutral T2 items, $F(1, 17) = 6.28$, $\eta^2 = .27$.

In the positive-arousal condition, report was less accurate at early relative to later lags, $F(6, 102) = 24.47$, $\eta^2 = .19$, and for neutral compared with positive-arousing T2 items, $F(1, 17) = 19.15$, $\eta^2 = .53$. A focused contrast on the Lag × Condition interaction revealed a less pronounced effect of lag on positive-arousing than neutral T2 items, $F(1, 17) = 11.01$, $\eta^2 = .39$.

To examine more directly the relative influence of arousal and valence on the AB, I submitted the report accuracy for positive T2

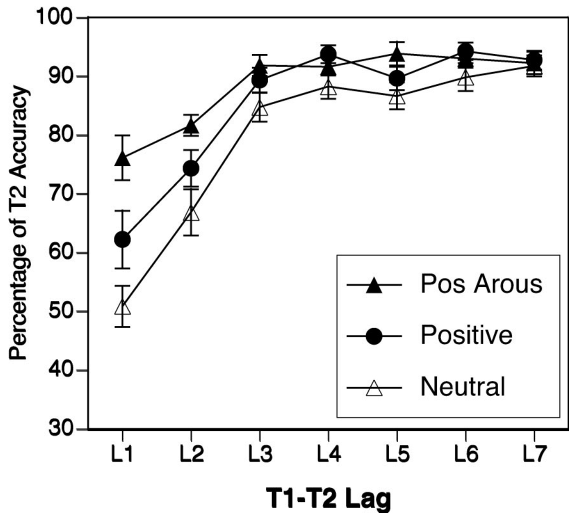

Figure 2. Mean percentage of accurate second target (T2) report given first target (T1) report (T1/T2) at each T1–T2 lag (L) in Experiment 2. Error bars represent standard errors of the means. Positive = highly pleasant, mildly arousing T2 words; Pos arous = mildly pleasant, highly arousing T2 words; Neutral = neutrally valenced low-arousal T2 words belonging to the category *tools*.

items from the positive and positive-arousal conditions to an additional two-way ANOVA, with lag (early [average of Lags 1 and 2] vs. late [average of Lags 6 and 7]) and condition (positive-arousal vs. positive) entered as separate within- and between-subjects variables. Early lags resulted in less accurate report, $F(1, 34) = 57.66$, $\eta^2 = .63$, with the impairing effect of lag less pronounced for positive-arousing than for positive T2 items, $F(1, 34) = 5.00$, $\eta^2 = .13$.

Analysis of T1 accuracy. Enhanced accuracy for positive T2 words was not associated with a trade-off between T2 and T1 accuracy. In the positive condition, there was a significant effect of lag, with T1 performance dipping at Lag 1, $F(1, 17) = 5.23$, $p < .0001$, $\eta^2 = .24$. However, T1 accuracy was independent of T2 condition (positive, $M = 94.6\%$, $SD = 7.5$, vs. neutral, $M = 94.2\%$, $SD = 8.4$). Similarly, in the positive-arousal condition, T1 accuracy decreased at Lag 1, $F(1, 17) = 3.80$, $\eta^2 = .18$, but was independent of T2 condition (positive-arousing, $M = 96.1\%$, $SD = 5.6$, vs. neutral, $M = 95.9\%$, $SD = 5.6$).

Analysis of valence and arousal ratings. Figure 3A depicts a scatter plot of the 28 items in each of the neutral, positive, and positive-arousing T2 lists. Each list occupied a largely distinct portion of the two-factor (arousal and valence) space. Valence and arousal ratings were submitted to separate one-way repeated measures ANOVAs. Consistent with the intended composition of the T2 lists, as illustrated in Figures 3B and 3C, ratings of positive valence increased monotonically from neutral to positive-arousing to positive T2 items, $F(2, 70) = 45.98$, $\eta^2 = .40$. By contrast, arousal ratings increased monotonically from neutral to positive to positive-arousing T2 items, $F(2, 70) = 61.05$, $\eta^2 = .47$. Within the valence and arousal ratings, all pairwise comparisons were statistically reliable ($\eta^2 > .23$).

Valence and arousal ratings: Correlation analyses. If the relative arousal value of T2 stimuli accounts for AB sparing, then individual differences in arousal valuation of T2 events may predict AB magnitude. For each individual in the positive-arousal condition, the magnitude of AB sparing (indexed by the difference score between positive-arousing and neutral T2 stimuli across

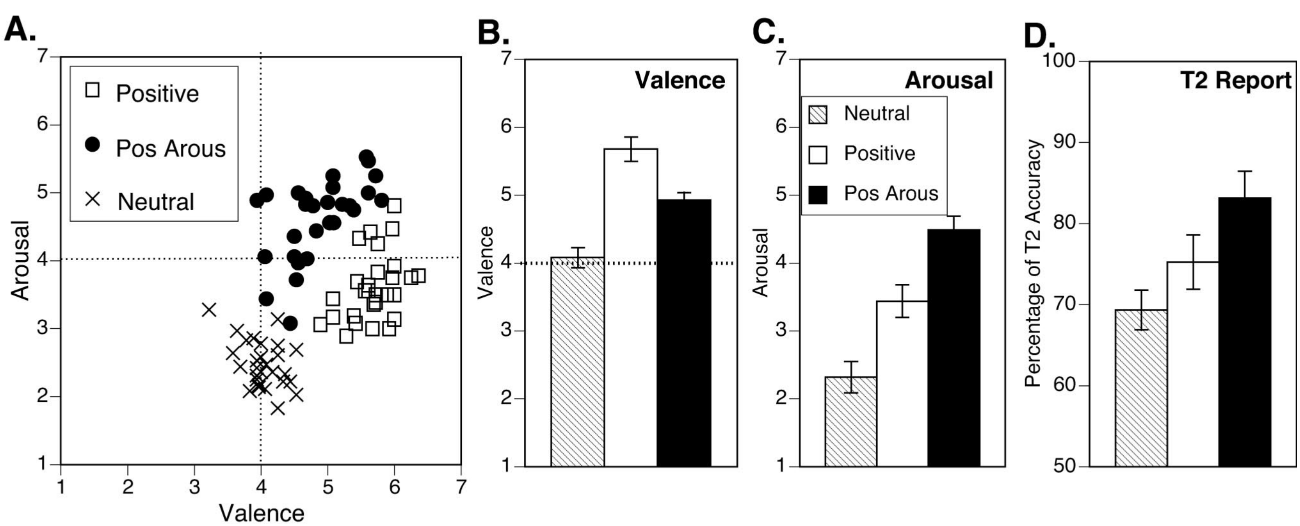

Figure 3. Mean arousal and valence ratings of second target (T2) items in Experiment 2. For each T2 condition, the figure shows (A) a two-factor plot of mean arousal and valence ratings for each item, (B) mean valence (rated on a scale of 1 = *unpleasant* to 7 = *pleasant*; the dotted line represents neutral), (C) mean arousal ratings (rated on a scale of 1 = *low* to 7 = *high*), and (D) mean T2/T1 report for early T1–T2 lags (100–300 ms). Error bars represent standard errors of the means. T1 = first target; Positive = highly pleasant, mildly arousing T2 words; Pos arous = mildly pleasant, highly arousing T2 words; Neutral = neutrally valenced, low-arousal T2 words belonging to the category *tools*.

Lags 1–3) was regressed against an individual's arousal and valence ratings (the difference score between positive-arousing and neutral T2 stimuli). Subjective arousal value significantly predicted the magnitude of AB sparing, $r = .47$, $F(1, 16) = 4.51$, $p < .05$. By contrast, there was no significant positive relationship between valence and AB sparing, $r = -.27$. The independence of perceived valence and arousal in predicting AB sparing was confirmed with stepwise multiple regression. After removing variance associated with valence, the predictive relation between arousal ratings and AB sparing was maintained, $\beta = .49$, $F(1, 15) = 5.18$, $p < .04$.

Discussion

Positively valenced T2 words were more resistant to the AB than were neutral words. Sexually arousing T2 words resulted in a further diminished AB. In both Experiments 1 and 2, highly arousing stimuli resulted in greatest AB sparing. Thus, events associated with appetitive (e.g., sexual) and defensive (e.g., threat) arousal are associated with AB sparing.

The diminished AB for both positive and negative events may suggest that either (a) extremity of valence, of either negative or positive value, or (b) arousal value, common to both positive and negative events, underlies AB sparing. If the former interpretation is correct, then AB magnitude should follow the relative extremity of positive valence rather than arousal of T2 events. To the contrary, as illustrated in Figures 3B–3D, AB magnitude followed observers' ratings of T2 arousal and not valence.

Individuals who found T2 events most arousing tended to demonstrate the greatest AB sparing. This suggests that subjective affective factors rather than nonaffective stimulus-related factors underlie AB sparing. In an effort to address other nonaffective stimulus dimensions potentially responsible for AB sparing, in Experiment 2, I examined the role of semantic relatedness in AB sparing. By using a neutral list of well-defined categorical structure, the present experiment demonstrated that AB sparing was not due to explicit strategic or implicit priming associated with greater semantic associations among similarly valenced T2 words.

Experiments 3A–3C: Role of Affective Value and Nonaffective Distinctiveness

Distinctiveness is associated with enhanced memory (for a recent example, see Otten & Donchin, 2000) and perceptual encoding (e.g., Johnston et al., 1990). Previous studies have similarly shown that AB magnitude is influenced by similarity between targets and distractors (Chun, 1997; Chun & Potter, 1995; Raymond et al., 1995). AB sparing for emotional events may be related to the degree of distinctiveness of these events and not their arousal value. The notion of distinctiveness, however, can refer to many distinguishing features. In addition to the role of semantic distinctiveness examined in Experiment 2, the roles of other sources of distinctiveness that may account for the hypothesized arousal-based AB sparing were addressed in Experiments 3A–3C. In Experiment 3A, I examined the contributions of low-level orthographic distinctiveness. In Experiment 3B, I examined the role of intrinsic item and contextual distinctiveness. In Experiment 3C, I examined the role of unexpectedness.

Experiment 3A: Orthographic Distinctiveness

In Experiment 3A, I examined AB magnitude for arousing and neutral T2 stimuli, as well as neutral T2 stimuli orthographically similar to arousing T2 words. This allowed an examination of the importance of low-level visual features idiosyncratic to arousing words for AB sparing.

Method

Participants. Forty-four volunteers from the Yale University community participated in this experiment for course credit. Half of the participants were randomly assigned to the arousal condition and the other half to the visually similar control condition.

Materials and procedure. T1 stimuli and distractors were those used in Experiment 1. The arousal condition comprised 28 arousing words (largely of negative valence) and 28 neutral words, which were matched for average word length ($M = 4.57$ letters) and written word frequency (52.32 vs. 52.21 occurrences per million, respectively). The control condition contained the same 28 neutral words as well as 28 words orthographically similar to the arousing words, constructed by a single letter displacement (e.g., *rape* → *rope*, *cancer* → *dancer*; see Appendix D). The visually similar list was of higher average word frequency ($M = 99.5$ occurrences per million). Targets appeared in green and distractors in black. In both conditions, there were 16 trials for each factor combination of lag (1–7) and condition (arousing vs. neutral words for the arousal condition and visually similar vs. neutral words for the control condition), for a total of 224 trials.

Results

In contrast with the importance of low-level visual features for AB sparing, as illustrated in Figure 4, AB sparing was present for arousing T2 words but not for orthographically similar neutral T2 words.

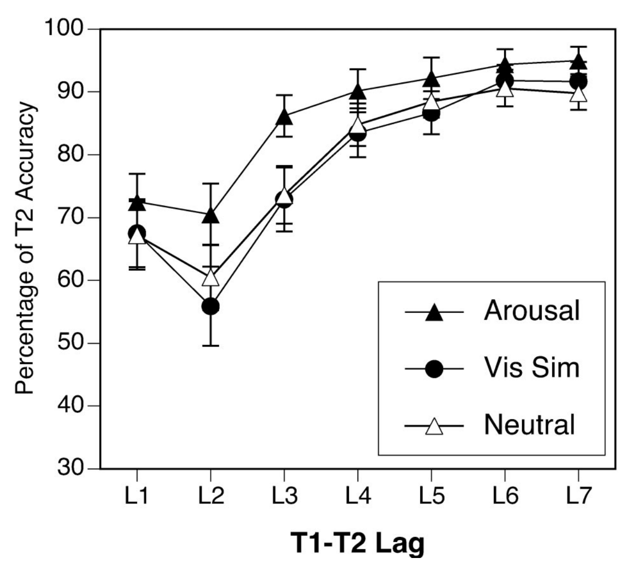

Figure 4. Mean percentage of accurate second target (T2) report given first target (T1) report (T1/T2) at each T1–T2 lag (L) in Experiment 3A. Error bars represent standard errors of the means. Arousal = arousing T2 words; Vis Sim = words neutral and visually similar to the arousing T2s; Neutral = neutral T2 words.

Analysis of T2 accuracy. The visually similar control condition was considered first. A response was considered correct if the observer reported either the actual target or its visually similar counterpart. For example, when presented with the word *rope*, report of *rape* was scored a correct response, providing a more liberal assessment of the influence of orthographic features on T2 report.

Report was less accurate at early relative to later lags, $F(6, 126) = 36.91$, $\eta^2 = .23$, but was not more accurate for neutral T2 words orthographically similar to arousing words as compared with other neutral T2 words ($M = 78.6\%$, $SD = 29.4$, vs. $M = 79.3\%$, $SD = 28.9$, respectively), $F(1, 21) < 1$. A focused contrast revealed no statistical evidence of a lag-specific interaction with condition, $F(1, 21) < 1$.

The arousal condition was considered next. Report was lag dependent, $F(6, 126) = 40.13$, $\eta^2 = .24$. Unlike their visually similar counterparts, report of arousing T2 words was more accurate than report of neutral words ($M = 85.8\%$, $SD = 23.8$, vs. $M = 81.1\%$, $SD = 26.4$, respectively), $F(1, 21) = 27.26$, $\eta^2 = .57$. A focused contrast on the Lag × Condition interaction revealed that the effect of lag was less pronounced for arousing than for neutral T2 words, $F(1, 21) = 8.52$, $\eta^2 = .29$.

Analysis of T1 accuracy. In the visually similar control condition, there was an effect of lag, $F(6, 126) = 7.16$, $\eta^2 = .05$, with less accurate report on Lag 1. In the arousal condition, there was a similar effect of lag, $F(6, 126) = 10.40$, $\eta^2 = .08$. Across lags, T1 performance was nearly identical for arousing and neutral T2 words ($M = 93.1\%$, $SD = 13.3$, vs. $M = 93.5\%$, $SD = 13.0$, respectively).

Experiment 3B: Item Distinctiveness

AB sparing may be related to the degree of word-level item distinctiveness or uniqueness and not arousal value. In the present experiment, arousing T2 words were compared with unusual or distinctive neutral T2 stimuli. Further, in the prior studies, it may have also been easier to distinguish arousing as compared with neutral T2 stimuli from neutral distractors. To control for the influence of such contextual distinctiveness, I made T1 stimuli numerical targets and distractor items nonwords, both having no neutral or affective lexical content.

Method

Participants. Seventeen volunteers from the Yale University community participated in this experiment for pay or course credit.

Materials and procedure. The T2 neutral word list comprised 28 unusual or distinctive words (see Appendix E). Commensurate with their unusualness, these words were, on average, of lower written word frequency than their arousing counterparts were ($M = 0.93$ vs. $M = 38.68$ occurrences per million, respectively). Distractor items were nonwords created from the distractor items from Experiment 1. T1 items appeared in white and T2 items in green. Each distractor appeared in a color randomly selected from a set of four colors. T1 items were strings of identical numbers (i.e., *00000000* to *9999999*) that observers reported by typing a single digit. Sixteen trials for each combination of T2 condition (arousing vs. neutral) and lag (1–7) yielded 224 experimental trials.

Results

In contrast with the item distinctiveness interpretation of AB sparing, as illustrated in Figure 5, the AB was smaller for arousing than for unusual neutral words.

Analysis of T2 accuracy. T2 report was less accurate at early relative to later T1–T2 lags, $F(6, 96) = 17.08$, $\eta^2 = .15$, and for neutral relative to arousing T2 stimuli, $F(1, 16) = 63.50$, $\eta^2 = .80$. A focused contrast on the Lag × Condition interaction revealed that the effect of lag was less pronounced for arousing than for unusual neutral T2 stimuli, $F(1, 16) = 8.15$, $\eta^2 = .28$.

Analysis of T1 accuracy. T1 accuracy was independent of T2 condition (arousing, $M = 91.8\%$, $SD = 9.4$, vs. neutral, $M = 91.2\%$, $SD = 10.3$).

Experiment 3C: Unexpectedness

In Experiment 3B, nonword distractors had no lexical content but were nonetheless affectively neutral. Within a trial and across the experimental session, occurrence of arousing events was relatively rare. Because of this inequity, arousing events may have been differentially salient. If such an inequity is responsible for the observed AB sparing, then it should be possible to generate AB sparing when neutral targets are surrounded by arousing distractors. This was examined in Experiment 3C. If infrequency relative to surrounding elements (within a trial and across trials) accounts for AB sparing, then sparing should be present for neutral items when they are surrounded by arousing relative to neutral distractors.

Method

Participants. Twenty volunteers from the Stanford University community participated in this experiment for course credit.

Materials and procedure. T2 stimuli were 112 neutral words (average word frequency = 26.77 occurrences per million). The arousing and

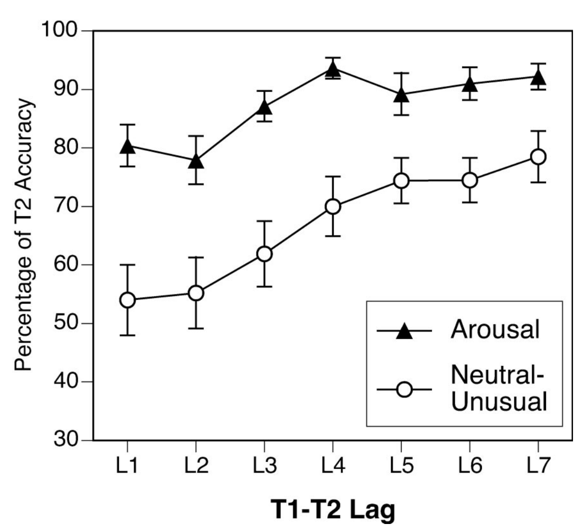

Figure 5. Mean percentage of accurate second target (T2) report given first target (T1) report (T1/T2) at each T1–T2 lag (L) in Experiment 3B. Error bars represent standard errors of the means. Arousal = arousing T2 words; Neutral-Unusual = distinctive or unusual neutral T2 words.

neutral distractor lists comprised 80 items of comparable average word length (*M*s = 5.45 vs. 5.46, respectively) and approximate word frequency (*M*s = 26.08 vs. 23.86 occurrences per million, respectively; see Appendix F). Distractor words were flanked on the right and left by random sequences of nonalphanumeric characters (*@#$%&*). T1 was a string of identical numbers (i.e., *00000000* to *9999999*) appearing in white. T2 was green and distractors appeared randomly in one of four colors. Each experimental run consisted of four blocks of 56 trials, with 16 trials per combination of lag (1–7) and distractor condition (arousing vs. neutral). Trial blocks alternated between distractors of arousing and neutral content (e.g., arousal, neutral, arousal, neutral). Participants were randomly assigned to one of the two counterbalancing conditions, starting with either the arousal or the neutral distractor block.

Results

In contrast with the role of target unexpectedness in AB sparing, as illustrated in Figure 6, neutral targets were less accurately reported when presented in the context of arousing distractors than when they were presented with neutral distractors.

Analysis of T2. Report was less accurate on early relative to later lags, $F(6, 108) = 79.10$, $\eta^2 = .43$, and when surrounded by arousing relative to neutral distractors ($M = 57.5\%$, $SD = 26.0$, vs. $M = 67.4\%$, $SD = 24.2$, respectively), $F(1, 18) = 50.57$, $\eta^2 = .74$. Distractor type did not interact with lag, $F(1, 18) < 1$.

Analysis of T1. T1 accuracy was lower on Lag 1 relative to the remaining lags, $F(6, 108) = 6.25$, $\eta^2 = .06$, and when in the context of arousing compared with neutral distractors ($M = 90.4\%$, $SD = 10.8$, vs. $M = 93.5\%$, $SD = 8.2$, respectively), $F(1, 18) = 13.88$, $\eta^2 = .44$. This difference was greatest at Lag 1, $F(6, 108) = 4.24$, $\eta^2 = .04$.

Discussion

If the AB represents competition between T1, T2, and distractor events for limited resources (Shapiro, Raymond, & Arnell, 1994), then emotionally arousing events might have a competitive advantage as a result of various sources of distinguishing features. Experiments 3A–3C examined different sources of distinctiveness that could potentially account for AB sparing found for arousing targets. In Experiment 3A, no AB sparing was observed for T2 stimuli orthographically similar to arousing words, even when misperceptions were considered a correct response (e.g., reporting *rape* rather than *rope*). Thus, neither distinctiveness of visual features of arousing words nor altered decision criteria under conditions of uncertainty likely account for AB sparing (see Appendix B for further treatment of response bias). Experiment 3B addressed whether intrinsic and contextual distinctiveness contributed to AB sparing. There remained a smaller AB for arousing versus unusual neutral T2 words when both T1 (numerical stimuli) and distractors (nonwords) had neither neutral nor affective lexical content.

The rarity of occurrence of affectively significant events during the experiment may have rendered them unexpected and thus bestowed with special status. In Experiment 3C, within a block of trials, only 7% of the presented word events were neutral, compared with 93% for arousing events. Under these conditions, there was no evidence of AB sparing for neutral T2 stimuli. If AB sparing reflects reduced attentional prerequisites for encoding, then one may expect impaired report because irrelevant arousing stimuli may serve as more potent distractors. Consistent with findings of greater Stroop interference for significant events associated with increased physiological arousal (Gronau et al., 2003; MacKay et al., 2004), report of neutral T2 items was less accurate when they were surrounded by arousing relative to neutral distractors.

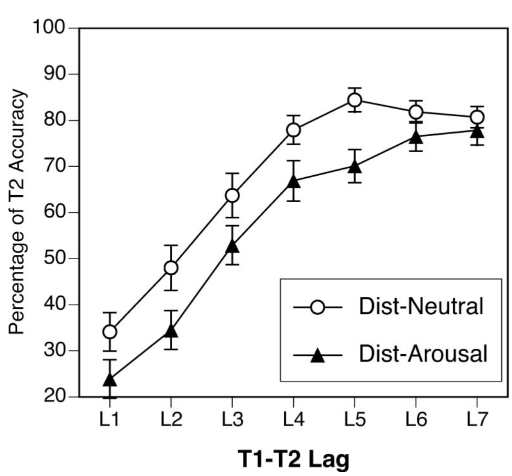

Figure 6. Mean percentage of accurate second target (T2) report given first target (T1) report (T1/T2) at each T1–T2 lag (L) for neutral T2 words embedded within neutral and arousing distractors in Experiment 3C. Error bars represent standard errors of the means. Dist-Arousal = arousing distractors; Dist-Neutral = neutral distractors.

Experiment 4: Does Arousal Influence Resource-Limited Encoding Processes?

Experiment 4A assessed more directly whether arousal value influences resource-limited encoding processes to influence awareness. In Experiment 4B, I examined whether arousal value influences perceptual report by orienting attention toward arousing events or by rendering encoding of these events relatively free of resource constraints.

Experiment 4A

The AB reveals that resources for stimulus encoding are limited in a temporally graded fashion. Suggesting an interaction with such resources, arousing T2 items were less affected by T1–T2 lag, with the largest report benefit at short T1–T2 lags. Potential ceiling effects for arousing T2 items at later lags, however, complicate this interaction. Further evidence was sought that different attentional requirements during encoding result in enhanced subjective awareness.

The AB occurs under dual-task conditions. When T1 is ignored, the AB is largely eliminated. Such single-task conditions demonstrate that the AB is a reflection of resource limitations (Raymond et al., 1992). If AB sparing reflects an interaction between arousal value and capacity-limited encoding processes that limit entry into awareness, then there should be a disproportionate advantage for arousing T2 words under dual- compared with single-task conditions. This was examined in Experiment 4A.

Method

Participants. Twenty volunteers from the Yale University community participated in this experiment for course credit. Ten participants were randomly assigned to each of the single-task and dual-task conditions.

Materials and procedure. The 28 items in each of the neutral and arousing T2 lists were of comparable written word frequency (*M*s = 6.82 vs. 5.46 occurrences per million, respectively; see Appendix G). T1s appeared in white, T2s in green, and distractors in black. For both the single- and the dual-target conditions, there were 20 trials for each combination of T2 condition (2) and lag (7), yielding 280 experimental trials. Observers assigned to the single-task condition were asked to identify the green target (T2), with no mention of T1. Observers in the dual-task condition were asked to identify both the white (T1) and the green (T2) targets.

Results

Consistent with their different attentional status during encoding, as illustrated in Figures 7A–7B, there was a disproportionate report advantage for arousing T2 words under dual- compared with single-task conditions.

Analysis of T2 accuracy. Under dual-task conditions, report was less accurate at early relative to later temporal lags, $F(1, 9) = 20.88$, $\eta^2 = .70$, and for neutral relative to arousing T2 words ($M = 71.8\%$, $SD = 18.6$, vs. $M = 81.1\%$, $SD = 17.5$, respectively), $F(1, 9) = 14.67$, $\eta^2 = .62$. A focused examination revealed that lag had a less pronounced effect on report of arousing T2 words than on neutral T2 words, $F(1, 9) = 10.59$, $\eta^2 = .55$.

In the single-task condition, there remained a significant drop-off in report at Lag 1 compared with later lags, $F(1, 9) = 17.98$, $\eta^2 = .67$. This dip in accuracy likely reflected transient attention to the salient white T1 stimulus presented among black distractors. Although accuracy remained higher for arousing than for neutral T2 words ($M = 93.3\%$, $SD = 7.9$, vs. $M = 88.8\%$, $SD = 10.3$, respectively), $F(1, 9) = 11.98$, $\eta^2 = .57$, unlike in the dual-task condition, a focused examination revealed that this advantage did not interact with T1–T2 lag, $F(1, 9) < 1$.

To further assess the effect of arousal on report under different attentional loads, I submitted the data from the single- versus dual-task conditions to a 2 × 2 × 2 factorial ANOVA, with condition (arousing vs. neutral) and T1–T2 lag (short [average of Lags 1 and 2] vs. long [average of Lags 6 and 7]) entered as separate within-subject variables and task (single vs. dual) as a between-subjects variable. Accuracy was greater for long relative to short lags, $F(1, 18) = 58.71$, $\eta^2 = .77$, under single- compared with dual-task conditions, $F(1, 18) = 14.58$, $\eta^2 = .45$, and for arousing relative to neutral items, $F(1, 18) = 41.45$, $\eta^2 = .70$. Consistent with the attentional origin of the AB, an interaction between lag and task revealed the effect of lag was much more prominent under dual- versus single-target conditions, $F(1, 18) = 12.12$, $\eta^2 = .40$.

Collapsing across single- and dual-task conditions, an interaction between lag and condition demonstrated that the advantage for arousing items was greater at short relative to long T1–T2 lags, $F(1, 18) = 9.54$, $\eta^2 = .35$. Collapsing across lags, an interaction between task and condition revealed that there was a disproportionate advantage in report for arousing T2 words under dual- compared with single-task conditions, $F(1, 18) = 5.48$, $\eta^2 = .23$. Consistent with the resource-limited nature of arousal AB sparing, a three-way interaction between task, condition, and lag revealed that the report advantage for arousing T2 words during short lags was most pronounced under dual-task conditions, $F(1, 18) = 8.25$, $\eta^2 = .31$.

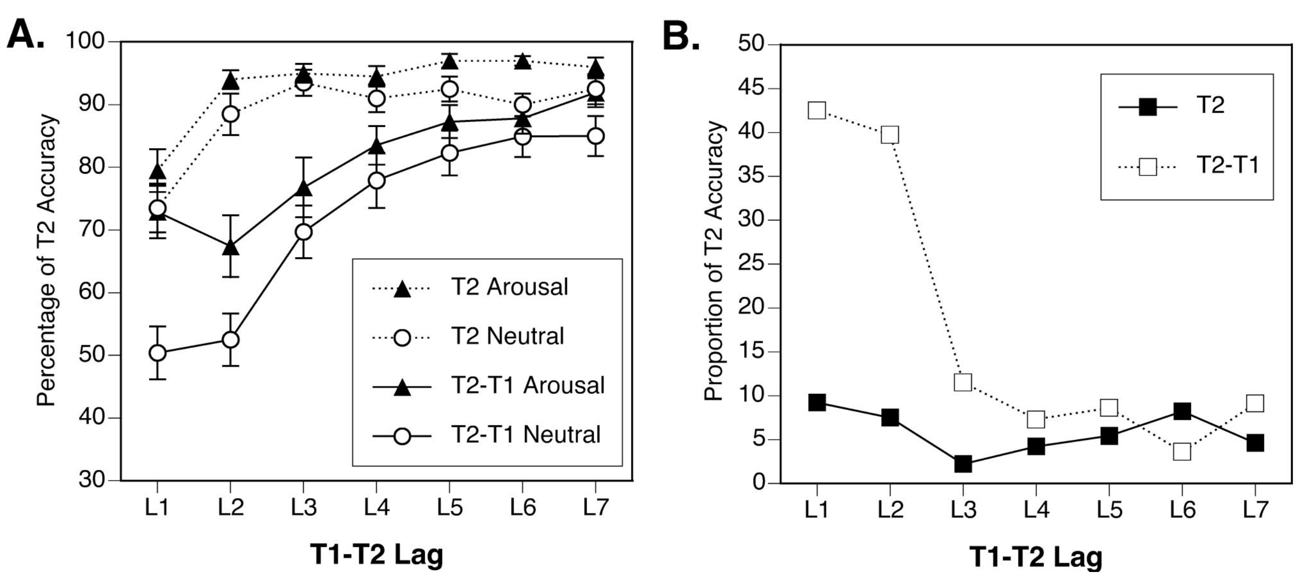

Figure 7. Mean percentage of accurate second target (T2) report given first target (T1) report (T1/T2) at each T1–T2 lag (L) in Experiment 4A. A: Percentage of report accuracy under single-task and dual-task conditions. B: Proportional advantage (in %) for arousing over neutral T2 report in the dual- and single-task conditions. Error bars represent standard errors of the means. T2 Arousal = arousing T2 words under single-target report; T2 Neutral = neutral T2 words under single-target report; T2-T1 Arousal = arousing T2 words under dual-target report; T2-T1 Neutral = neutral T2 words under dual-target report; T2 = single task; T1-T2 = dual task.

Analysis of T1 accuracy. In the dual-task condition, there was a significant effect of lag on T1 performance, with accuracy dropping at Lag 1, $F(6, 54) = 5.34$, $\eta^2 = .09$. Performance on T1 did not significantly depend on T2 content ($M = 87.4\%$, $SD = 10.0$, vs. $M = 86.3\%$, $SD = 9.7$, for arousing and neutral words, respectively).

Experiment 4B

With its results showing a disproportionate advantage for arousing T2 words under dual-task conditions, Experiment 4A demonstrated that arousal value interacts with resource-limited encoding processes to influence awareness. How it goes about doing so, however, remains unclear. In Experiment 4B, I examined more precisely how arousal influences resource dynamics during encoding. AB sparing suggests that the encoding of arousing events may be characterized as either (a) relatively automatic or preattentive, being less constrained by resource limitations during encoding to reach awareness, or (b) postattentive, reflecting that these events attract resources toward their beneficial processing. To distinguish between these two mechanisms, in Experiment 4B, I used a speeded choice response to T1.

AB magnitude can be viewed as direct competition between T1 and T2 for a central resource-limited processing stage (Arnell & Jolicoeur, 1999; Dell'Acqua & Jolicoeur, 2000; Jolicoeur, 1998, 1999a, 1999b; Raymond et al., 1992). When T1 is made readily accessible, for example, by the deletion of its subsequent distractor, the AB diminishes greatly. Conversely, prolonged processing of T1, for example, through increasing central processing load (Jolicoeur, 1999a; Jolicoeur & Dell'Acqua, 2000; McLaughlin, Shore, & Klein, 2001), results in a greater AB. Duration of T1 processing has thus been critically associated with susceptibility to the AB (Jolicoeur, 1998). AB sparing for arousing T2 words may then result from altered T1 processing. Experiment 4B directly examined such potential changes in T1–T2 processing dynamics. If AB sparing reflects the diversion of processing resources toward arousing T2 words, then this should be evidenced in altered T1 latency. By contrast, if arousing T2 words are less dependent on processing resources, then their report should occur with relative independence from T1 processing duration.

Method

Participants. Twenty volunteers from the Stanford University community participated in this experiment for course credit.

Materials and procedure. T2 stimulus items were identical to those of Experiment 4A, and distractor events were those used in Experiment 1. Unlike in previous experiments, observers were asked to enter a speeded binary response to T1 stimuli. T1 was a string of eight uppercase *X*s or *O*s. Observers were asked to discriminate white *X*s or *O*s as quickly and accurately as possible. At their own pace, observers typed the green word (T2) after the end of the RSVP stream. Prior to testing, 120 practice trials were administered to teach the appropriate T1 stimulus–key response mapping.

Initial pilot testing revealed a bimodal T1 latency distribution, indicating that on a significant portion of trials, observers waited until the end of the RSVP stream to enter their T1 response. In the present experiment, observers were further urged to respond as quickly and as accurately as possible to T1 and were instructed that the response to T1 was of primary importance. In addition, analyses were restricted to T1 trials that were less than or equal to 1,000 ms in length. When T1 latency was greater than 1,000 ms, the trial was excluded from T2 analysis and coded an incorrect T1 response. This criterion resulted in the exclusion of no more than 3% of the trials for any participant. Four participants were excluded from analysis for having more than 15% of their T1 trials excluded.

Results

As illustrated in Figures 8A–8C, enhanced report of arousing T2 words was not associated with a significant change in the latency of response to T1. By contrast, as illustrated in Figure 8D, arousing T2 words were less influenced by the duration of T1 processing for successful report.

Analysis of T2 accuracy. Report was less accurate at early than at later lags, $F(6, 114) = 31.62$, $\eta^2 = .22$, and for neutral than for arousing T2 words, $F(1, 19) = 41.65$, $\eta^2 = .69$. A focused examination revealed that lag had a smaller effect on arousing than on neutral T2 words, $F(1, 19) = 5.78$, $\eta^2 = .24$.

Analysis of T1 accuracy. Figure 8A illustrates that AB sparing for arousing T2 words was not accompanied by decreased accuracy in report of the preceding T1 during the AB period. There was, however, a nonsignificant trend for report to be less accurate after arousing T2 words than after neutral T2 words ($M = 83.3\%$, $SD = 12.2$, vs. $M = 84.9\%$, $SD = 11.2\%$, respectively), $F(1, 19) = 3.62$, $p < .08$, $\eta^2 = .16$, and this difference was not specific to early versus later temporal lags, $F(6, 114) < 1$.

Analysis of T1 response latency. Response times were only considered for correct T1 responses. As illustrated in Figure 8B, the mean T1 latency did not differ significantly on arousing and neutral T2 trials, even when T2 was presented within the first few hundred milliseconds of T1 (for Lags 1–3, $M = 486$ ms, $SD = 57$, vs. $M = 487$ ms, $SD = 55$, for arousing and neutral T2 trials, respectively), $F(1, 19) < 1$. Further, T2 content did not influence T1 latency in a lag-dependent manner, $F(6, 114) < 1$. In a further analysis of the influence of T2 content on T1 processing, the distribution of T1 response latencies on arousing and neutral T2 trials was examined. T1 response latency probability density functions were computed for each individual (ranging from 200 to 1,000 ms, in 50-ms bins). As depicted in Figure 8C, the average T1 latency distributions were highly similar for arousing and neutral T2 trials, with the ratio of variance approximating unity (.0067/.0066 = 1.015).

T1 response latency quartile analysis. The influence of T1 latency on T2 accuracy was next analyzed. Consistent with T2 report depending critically on resources devoted to T1 processing, it has been shown that increasing T1 latency is associated with decreasing T2 accuracy, that is, a more pronounced AB (e.g., Jolicoeur, 1998). Following Jolicoeur (1998), I sorted T2 responses according to the T1 response time quartile (Quartile 1 being the 25% of trials with the shortest T1 latency and Quartile 4 being the longest for each of the 14 cell types in the design). Analysis was performed on data from Lags 1–3 where T2 accuracy was far from ceiling levels and where the advantage for arousing over neutral T2 stimuli was most pronounced. Condition (arousing vs. neutral) and quartile (1–4) were then submitted as separate variables to a repeated measures ANOVA. Figure 8D illustrates that longer T1 latency had less of an effect on arousing T2 stimuli than on neutral T2 stimuli.

Arousing T2 words were reported more accurately than were neutral items ($M = 64.3\%$, $SD = 20.2$, vs. $M = 45.5\%$, $SD = 21.7$,

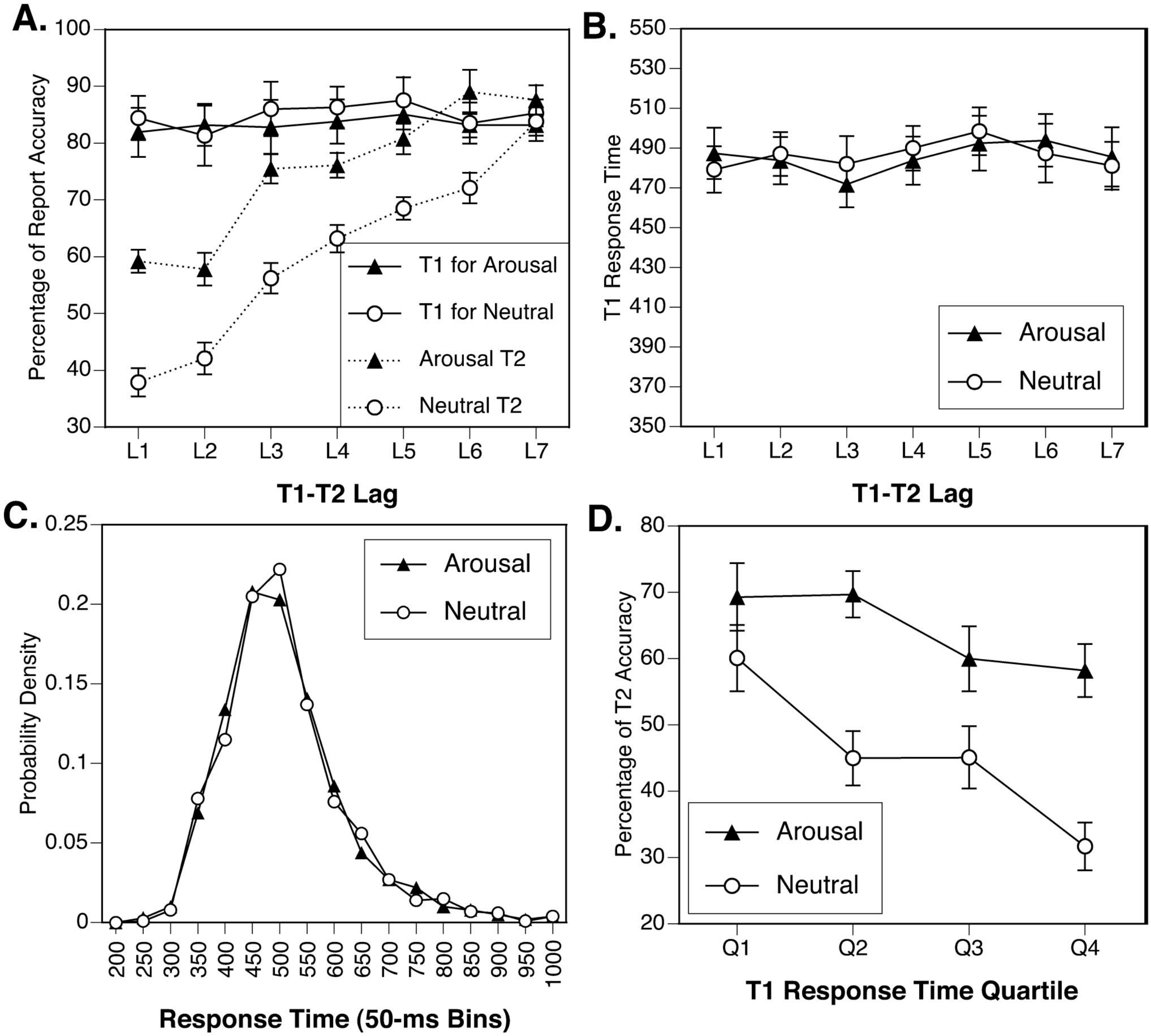

Figure 8. During speeded first target (T1) response in Experiment 4B, (A) mean percentage of accurate report of T2/T1 and the preceding T1 at each lag for the arousing and neutral second target (T2) conditions; (B) mean T1 response times at each lag (L); (C) mean probability density functions for T1 response times; and (D) mean percentage of accurate T2/T1 report (average of Lags 1–3) when sorted from the fastest (Q1) to slowest (Q4) T1 response time quartile (Q). Error bars represent standards error of the means. Arousal = arousing T2 words; Neutral = neutral T2 words.

respectively), $F(1, 19) = 37.32$, $\eta^2 = .66$. The effect of quartile reflected that longer latency T1 responses were, as shown previously, associated with less accurate T2 report, $F(3, 57) = 11.24$, $\eta^2 = .17$. An interaction between condition and quartile, $F(3, 57) = 5.03$, $\eta^2 = .08$, demonstrated that there was a differential effect of T1 latency on arousing and neutral T2 stimuli. As T1 response latency increased (from Quartiles 1 to 4), report of neutral T2 events was differentially impaired (a proportional decrement of 89.6%), $F(1, 57) = 60.19$, $\eta^2 = .51$, relative to arousing T2 events (a decrement of 19.1%), $F(1, 57) = 9.17$, $\eta^2 = .14$. Thus, AB sparing for arousing relative to neutral T2 stimuli was largest where T1 processing was most prolonged (Quartile 4, proportional benefit of 83.6%), $F(1, 57) = 52.25$, $\eta^2 = .48$.

Discussion

If AB sparing reflects an interaction with a resource-limited encoding stage, then the report advantage for arousing targets should be most pronounced under dual- compared with single-task conditions. When the attentional demands of T2 report were combined with report of T1, the advantage for arousing T2 words was superadditive, suggesting a resource-limited locus of arousal modulation. To further confirm this interpretation, I performed a summary analysis across Experiments 1–4 to examine AB sparing independent of potential confounding ceiling effects at later lags. When restricted to observers performing well below ceiling performance at later lags (i.e., the bottom quartile within each experiment), there was a robust interaction between T1–T2 lag (early vs. late) and T2 arousal content, $F(1, 37) = 35.45$, $\eta^2 = .49$. Thus, the arousal content of T2 results in a genuine change in the magnitude and time course of the AB.

It might be argued that enhanced report of arousing T2 words reflects postencoding maintenance. That is, episodic memory for T2 may fade more rapidly for neutral than for arousing T2 stimuli over the interval before report. However, T1–T2 lag would then not likely interact with amount of available attention for T2 encoding (i.e., single- vs. dual-task conditions). The delay interval between encoding and report of T2 was equal across single- and dual-task conditions, and thus the likelihood of forgetting should similarly be equal. Rather than enhanced memory, arousing T2 words appear to have special attentional status for reaching awareness.

Experiment 4B addressed this special attentional status by allowing more precise examination of how arousal may influence resource dynamics supporting perceptual report—determining whether arousing T2 words were associated with altered T1 processing duration. AB sparing for arousing T2 words was associated with neither altered mean nor distribution of T1 processing latency. In contrast with the null effect of T2 arousal value on T1 latency, there was evidence of the converse—increasing T1 processing duration differentially impaired report of neutral relative to arousing T2 stimuli. Rather than a reallocation of resources devoted to T1 processing, it is the freedom from resource constraints imposed by T1 processing that characterizes encoding of arousing events.

General Discussion

In the present set of studies, I had two primary aims: (a) to examine whether and by what means emotional events exhibit special attentional status for awareness and (b) to explore the stimulus dimensions underlying this special status. The first aim was addressed by examining whether emotional value interacts with an attentional bottleneck for stimulus encoding that limits entry into awareness. The use of dual-target RSVP allowed for a precise and graded titration of available resources for stimulus encoding as they vary over time, as indexed by the presence of the AB. Across multiple experiments, it was shown that the AB was significantly attenuated for emotional relative to more neutral words. Enhanced report was most pronounced at short intervals between T1 and T2, in the middle of the AB (Experiments 1, 2, and 3A–3B), and this report advantage was also greater during dual- relative to single-task conditions (Experiment 4A). Consistent with their special attentional status, both sources of evidence indicate that the locus of emotional modulation of awareness was specifically at a resource-limited encoding stage. Further, direct examination of T1–T2 resource dynamics (Experiment 4B) suggests enhanced encoding of emotional events is best characterized as a relative enhancement of preattentive bottom-up processing rather than a postattentive top-down modulation of resources toward these events. Enhanced awareness did not depend on paying greater attention to emotional events; rather, these events were less dependent on the availability of capacity-limited encoding processes to reach awareness. It is important to note that all experiments demonstrated an AB for emotionally significant words. This is consistent with a relative but not an absolute attentional independence during encoding.

The second aim was to establish which precise stimulus dimensions interact with attention to enhance entry into awareness (Experiments 1, 2, and 3A–3C). AB sparing for emotional words was shown to be independent of factors such as word frequency, semantic cohesiveness, altered decision criteria (for further treatment, see Appendix B), and various forms of distinctiveness. These results demonstrate that relative to other stimulus dimensions, emotional value has privileged attentional status. AB sparing was further shown to be bivalent, with both pleasant and unpleasant events resulting in a diminished AB (Experiments 1 and 2). Rather than valence, an arousal dimension common to both ends of the valence spectrum was most predictive of AB sparing. In sum, these results converge on the notion that arousal is associated with diminished attentional requirements for stimulus consolidation and, ultimately, enhanced entry into awareness. The present experiments thus provide important insights into the fundamental underlying mechanisms and affective dimensions that allow emotional significance to shape perceptual experience.

Affective Persistence

What information-processing qualities would render arousing events more resistant to the attentional limitations imposed by the AB? The AB reveals that, in addition to limitations across space, there are critical limitations on the distribution of attention over time. Thus any account of the AB and its diminution should relate to the temporal dynamics of stimulus processing. One account of the AB posits a two-stage model for stimulus identification (Chun & Potter, 1995). This model invokes a first-stage buffer where stimulus features are processed in parallel. This buffer is characterized by rapid decay time. A second capacity-limited stage results in the consolidation of stimulus features into a more durable format. This capacity-limited stage has been argued to reflect a short-term perceptual consolidation process (Dell'Acqua & Jolicoeur, 2000; Jolicoeur, 1999b; Jolicoeur & Dell'Acqua, 1998; Subramaniam, Biederman, & Madigan, 2000) whereby stimuli are consolidated into short-term memory, making sensory events accessible for conscious report—that is, promoting the subjective experience of seeing. According to such models, the AB results from the loss of fragile T2 representations while a capacity-limited perceptual consolidation stage is preoccupied with the processing of T1 stimuli.

Arousing stimuli may then be less susceptible to the AB because they are less prone to decay, bridging the gap in time where resources are unavailable for encoding into awareness. By what means would arousing events be less susceptible to decay? According to the biased competition model of attentional selection (Duncan & Desimone, 1995), attention primarily serves to resolve interference between competing events, biasing which events will win the competition for awareness by increasing or decreasing the volume and contrast controls of sensory inputs. Attention is thus most critical when having to sift through multiple sources of stimulation and less so when the need for selection is limited, as when a stimulus is presented in spatial and temporal isolation. Affective value may bias a competition with subsequent stimulus events (i.e., the following distractors) that vie for conscious report when resources are limited in the middle of the AB.

Aligning with the competitive bias theory of attention, the interference model of the AB (Shapiro et al., 1994) indicates that T1, T2, and immediately following distractors (Duncan, Ward, & Shapiro, 1994) compete for access to a limited supply of processing resources that are engaged for approximately 500 ms after T1 selection. The AB thus occurs from a conjunction of critical conditions: attention to T1 as well as the presence of T1 and T2 trailing distractors, without which the AB is substantially diminished. However, the T1 and T2 trailing distractor events do not play the same role in generating the AB (Kawahara, Di Lollo, & Enns, 2001). The resource component of the AB is related to T1 processing, with its following distractor causing prolonged T1 processing (Seiffert & Di Lollo, 1997). By contrast, the T2 trailing distractor competes with T2 for access to these limited resources. When T1 is fully attended, resources are unavailable in the middle of the AB to resolve the competition between T2 and its following distractor. Thus, arousing T2 words may be less susceptible to the AB, because of diminished attention to T1 or diminished interference from the T2 trailing distractors.

When directly examining the presence of altered T1–T2 processing dynamics (Experiment 4B), it was found that AB sparing for arousing T2 words was not associated with altered T1 processing time. Rather than redirecting resources toward the encoding of emotional T2 stimuli, these events were less susceptible to interference when attention was unavailable. This reduction in interference was not a simple reflection of a mismatch in affective content of T2 events and distractors—a product of comparing apples and oranges. In Experiment 3C, it was shown that when their roles were switched (e.g., looking for oranges among apples), neutral T2 stimuli were not more accurately reported when among arousing distractors. This asymmetric relationship suggests that affective AB sparing does not reflect a simple mismatch between stimuli with differing emotion tags. Rather, arousing events are bestowed with enhanced resistance to interference from competing information. This is consistent with a recent physiologically plausible model of the temporal dynamics of visual awareness. A critical aspect of attention's role in awareness is the synchronization between feedforward and reentrant feedback processing loops (Di Lollo, Enns, & Rensink, 2000). A mismatch between reentrant (top-down) signals and ongoing (bottom-up) visual stimulation results in an overwriting of prior events when attention is limited (Di Lollo et al., 2000; Giesbrecht & Di Lollo, 1998). Without sufficient attention available, stimulus persistence is rendered fleeting, with prior events erased from consciousness by new incoming information. Greater arousal value may then increase stimulus persistence, reducing the likelihood of overwriting and thereby rendering these events more accessible to consciousness.

A critical question is, at what representation level(s) do emotional events demonstrate enhanced resistance to interference, enabling them to win the competition for awareness? Although the AB is not associated with modulation of early sensory components (Vogel et al., 1998), examination of different sources of similarity between targets and distractors has shown that featural more than categorical similarity modulates the AB (Raymond et al., 1995). For instance, similarity in perceptual features such as color between T2 stimuli and distractors increases AB magnitude (Jiang & Chun, 2001). When T2 stimuli and following distractors are significantly discrepant in visual form, color, or location, the AB is substantially reduced (Chun, 1997; Chun & Potter, 1995; Jiang & Chun, 2001; Raymond et al., 1995). Thus, it may not be the categorical content of arousing words alone that accounts for their resistance to the AB but rather the nature of their underlying perceptual representations. Consistent with emotional influences on perceptual rather than conceptual processing, event-related potential studies of the time course of visual stimulus processing suggest emotional content influences visual cortical representations (Schupp, Junghofer, Weike, & Hamm, 2003) within the first 100 ms of stimulus processing (Eger, Jedynak, Iwaki, & Skrandies, 2003; Pourtois, Grandjean, Sander, & Vuilleumier, 2004). Perceptual representations of arousing events may burn brighter and longer relative to competing neutral distractor events. This notion is consistent with the findings from Experiment 3C, which show emotional events may serve as more potent distractors, even when outside the focus of attention. This account also predicts that AB sparing would diminish when emotional targets are surrounded by similarly significant events. Emotional targets would afford no additional persistence, endowing them with a competitive edge over trailing events. Further investigation is required to specify the precise levels of this proposed representational persistence.

Arousal, Feature Binding, and Object File Instantiation

A functionalist account of visual encoding suggests that the visual system decomposes visual events into distinct representations of *what* occurred *where* and *when*. *What* representations are thought to be subserved by activation of visual types stored in long-term semantic memory. *When* and *where* representations are thought to be subserved by spatiotemporal tokens capturing the episodic context of stimulation. It is proposed that these distinct visual type and token codes require attention for binding into temporary representations, referred to as *object files* (Kahneman, Treisman, & Gibbs, 1992), which give rise to unified percepts of objects rather than random assemblages of features. Attention thus provides the glue by which semantic information (types) and spatiotemporal episodic information (tokens) are assembled into stable internal representations supporting awareness.

Within this type–token architecture, the AB may be considered a failure in establishing object files (Chun, 1997). During the AB, T2 events that do not reach awareness nevertheless activate their semantic representations (Luck et al., 1996; Shapiro, Driver, Ward, & Sorensen, 1997). Without additional resource support, these semantic type activations decay rapidly. Awareness depends on the transference of type activation into a second stage of capacity-limited processing, where type and spatiotemporal token representations are bound (Chun, 1997). Without sufficient resource support, the activation of T2 visual types is insufficient to discriminate them from surrounding distractors. Only the attentional binding between a visual type and its particular episodic tokenization (e.g., visual form, color, and time) allows for the construction of an object file. AB sparing suggests that the probability of binding between visual types and their episodic tokenization is increased. Such emotionally augmented binding likely reflects the enhanced durability of type and token activations during limited resource support, being resilient in the face of interfering stimulation. The result of this persistence of semantic type and episodic token activations is that emotionally significant events are more prone to unification into object files that gate entry into awareness.

Arousal, Automaticity, and Awareness

Although there are many definitions of automaticity, some of the critical features of automatic processes are that they (a) operate without capacity limitations, (b) are largely stimulus driven and mandatory, and (c) can occur outside of awareness, without conscious access to the results of their processing (Neuman, 1984). Several lines of evidence suggest that the processing of emotional valence is automatic. For example, psychophysiological measures demonstrate that intrinsically aversive stimuli and stimuli with acquired aversion (e.g., associated with shock) can be processed without awareness (Corteen & Wood, 1972; Lazarus & McCleary, 1956; Ohman & Soares, 1993; Wexler et al., 1992). Significantly faster affective (good vs. bad) and lexical decision (word vs. nonword) judgments of negative and positive words have been shown when they followed masked valence-congruent versus -incongruent primes (Greenwald et al., 1989; Kemp-Wheeler & Hill, 1992), suggesting the valence of the affective primes is processed without conscious access. Explicit positive or negative evaluations have also been shown to occur independently of the awareness of the source of the elicited affect (e.g., Bargh, Litt, Pratto, & Spielman, 1989; Johnson, Kim, & Risse, 1985; Kunst-Wilson & Zajonc, 1980; Murphy & Zajonc, 1993).

As defined by independence from conscious access, the above results suggest that stimulus valence can be processed automatically. Such unconscious processing, however, does not necessitate that valenced items will be endowed with enhanced access to awareness. In the present study, it is shown that arousal and not the valence of positive and negative events is associated with AB sparing. This dissociation between the unconscious processing of valence and the arousal modulation of conscious processing suggests that the mechanisms by which valence and arousal influence information processing may differ critically (Maljkovic & Martini, 2005). Valence may be associated with one component of automaticity, independence from conscious access, whereas arousal may be associated with the reduction of capacity limitations for conscious processing.

Relative attentional independence has been argued for special classes of biologically prepared stimuli (Ohman & Mineka, 2001) that may have evolutionarily shaped specializations for their enhanced encoding (e.g., angry facial expressions, spiders, snakes) (Hansen & Hansen, 1988; Ohman, Flykt, & Esteves, 2001; Ohman, Lundqvist, & Esteves, 2001). Encoding of evolutionarily relevant threatening stimuli may draw on internalized templates that exploit common distinctive visual features in these stimuli, for example, the curviness of a snake or the downward-turned eyebrows and lips of an angry face. However, the present findings are not based on such privileged classes of stimuli. Visual word forms of one's acquired native language, by definition, cannot draw on evolutionarily shaped templates. Selective pressures may have nonetheless provided a means by which information-processing systems can flexibly acquire enhanced processing even when events of importance are not defined by common, simple features. In the absence of greater external physical signal (e.g., luminance, temporal duration) or distinctive visual configurations, stimuli associated with arousal reactions may be selected for preferential processing. The present studies suggest that arousal modulation may afford the flexible tuning of perceptual systems to enhance perceptual experience.

Arousal-Enhanced Perceptual Encoding

Stimuli associated with extensive practice (Maki & Padmanabhan, 1994) or highly overlearned stimuli such as one's own name (Moray, 1959; Shapiro, Caldwell, & Sorenson, 1997; Wood & Cowan, 1995) demonstrate reduced capacity limitations for awareness. This suggests that affective (i.e., emotion-based) and cognitive (practice or exposure-based) forms of automaticity may exhibit similar behavioral signatures. Nonetheless, these different expressions of automaticity are likely supported by fundamentally different psychological and neural mechanisms. Unlike the effects of extensive exposure, the present studies suggest that the relative automatic encoding of affectively significant events into awareness depends on arousal enhancement of perceptual encoding. It has been long thought that arousal influences information processing (Easterbrook, 1959; Eysenck, 1976; Yerkes & Dodson, 1908). In particular, substantial evidence indicates that arousal influences memory maintenance (see Cahill & McGaugh, 1998; Christianson, 1992), with increased arousal associated with greater long-term memory retention (Kleinsmith & Kaplan, 1963; LaBar & Phelps, 1998; Nielson, Radtke, & Jensen, 1996). Arousal influences on memory have been shown through a variety of means, including increased stimulation, caffeine intake, natural diurnal variations, and basal arousal levels associated with personality traits (Revelle & Loftus, 1992).

In addition to showing that arousal enhances the durability and accessibility of representations of one's past experiences in episodic memory (e.g., Hamann et al., 1999), the present studies are consistent with the notion that arousal is also critically associated with enhancing the accessibility of representations of one's present experience (see also Keil & Ihssen, 2004). The arousal-based mechanism by which people tend to more frequently remember events infused with emotion may also provide a means to more efficiently apprehend stimulus events during perceptual encoding itself. Evidence from neuroscience also suggests that similar neural mechanisms may underlie the emotional modulation of both memory and perception (Anderson & Phelps, 2001). The human amygdala has been intimately tied with emotion. Consistent with its role in processing both pleasant and unpleasant stimuli (Anderson, Christoff, Stappen, et al., 2003; Cahill & McGaugh, 1990), the amygdala is instrumental to enhanced memory (Hamann et al., 1999) and perception (Anderson & Phelps, 2001) for emotionally arousing events. The amygdala may orchestrate these arousal-modulatory influences by altering processing dynamics in target cortical regions specialized for different types of processing. Just as enhanced episodic memory for emotionally arousing events is supported by amygdala modulation of the hippocampus (e.g., Hamann et al., 1999), the amygdala may support enhanced perceptual encoding through modulation of perceptual processing in primary and secondary cortical regions (Anderson & Phelps, 2001; Morris, Friston, & Dolan, 1998). Functional neuroimaging studies have shown that affectively significant words result in coactivation of the amygdala and extrastriate word processing regions (Isenberg et al., 1999). Similar to the behavioral indices of automatic processing shown here, amygdala responses (Anderson, Christoff, Panitz, et al., 2003) as well as extrastriate lexical representations associated with arousing words (Anderson, Evans, Yamaguchi, & Gabrieli, 2003) demonstrate reduced attentional requirements for their activation. The amygdala may act to diminish the burden on central processing resources for activation of extrastriate representations of visual word forms and their meaning, enhancing their accessibility to consciousness (Anderson & Phelps, 2001).

Because of humans' limited cognitive resources, information selection is a necessity in an overwhelmingly information-rich world. As a result, not all events are equally prone to perception and recollection. In addition to the known benefits of arousal on episodic memory consolidation, the present studies demonstrate that arousal reduces the attentional prerequisites for perceptual consolidation, promoting enhanced entry into awareness. Arousal enhancement of information processing appears to be a fundamental mechanism by which selection and relevance are coupled, granting privileged access to consciousness.

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(*Appendix follows*)

Appendix A

T2 and Distractor Words From Experiment 1

Negative condition		Negative-arousing condition				
Neutral	Negative	Neutral	Negative	Distractors		
AGREED	AFRAID	AUNT	ANUS	ALBUQUERQUE	ENTREPRENEUR	JOURNEYMAN
APPLE	ANGRY	AVOCADO	ASSHOLE	AMPHITHEATER	ERADICATE	JUSTIFICATION
AUTUMN	BEATEN	BASS	BARF	ANTHROPOLOGY	ESTABLISHMENT	KALEIDOSCOPE
BRANCH	BLOOD	BEARD	BASTARD	BEATIFICATION	EXCEEDINGLY	LOGROLLING
BREAD	CRASH	BELIEVE	BITCH	BIOGRAPHY	EXIGENCIES	MERETRICIOUS
CALL	CRISIS	CABINETS	CLITORIS	BOOTSTRAPPING	EXTRAPOLATION	MOTORCYCLE
CANVAS	DOOM	CAFE	COCK	BUSINESSMAN	FERTILIZER	OBSERVATORY
CARROT	FAIL	CALM	CUNT	CHRYSANTHEMUM	FORESHADOW	ORGANIZATION
CLOCK	FIRE	DATES	DILDO	CIRCUMFERENCE	FURTHERMORE	OSCILLATION
DERIVE	FRIGHT	ETHICAL	EJACULATE	CLASSIFICATION	GENERALIZATION	PERTURBATIONS
DIVIDE	GUILT	FACE	FART	COMEDIAN	GLOBALIZATION	PONTIFICATION
EAGLE	HELL	FADE	FUCK	CONDENSATION	GOVERNMENT	PURIFICATION
EXCEED	HURT	HANGAR	HERPES	CONFEDERATION	HALLUCINATION	SIMULTANEOUS
FABRIC	MISERY	ICICLE	INCEST	CONGREGATION	HANDKERCHIEF	SINUSOIDAL
FIELD	MURDER	LENGTHY	LESBIAN	CONTORTIONIST	HIEROGLYPHIC	SOUNDLEVEL
LAYER	PAIN	NOTICE	NIPPLE	DELETERIOUS	HOUSEKEEPER	TABLEWARES
LEAGUE	PANIC	OMELET	ORGASM	DELICATESSEN	HOUSESITTER	THOROUGHBRED
LEVER	PLAGUE	ONCE	ORGY	DEMOGRAPHICS	HUMMINGBIRD	THOROUGHLY
NAVEL	SCREAM	POINT	PENIS	DEMYSTIFY	HYPOTHETICAL	THREADBARE
NOTE	SHOCK	POND	PISS	DICTIONARY	ILLUMINATION	TIDDLYWINKS
PATROL	SORROW	RULE	RAPE	DIFFERENTIATION	INCOMPREHENSIBLE	TOPOGRAPHY
PLATE	SPITE	SIT	SEMEN	DISAMBIGUATE	INTELLECTUALISM	TOURNAMENT
ROSE	SUFFER	SOFT	SEX	DISAPPEARANCE	INTERNALIZATION	TRANSPORTATION
SEND	TENSE	SOLD	SHIT	DESCRIPTION	INVESTIGATION	UPHOLSTERY
SOLAR	TERROR	SOUND	SLUT	DISINTEGRATE	IRREPROACHABLE	WINDSHIELD
THUMB	THREAT	TEST	TITS	EMULATION	IRRESPECTIVE	WINTERLAND
TRUCK	TRAGIC	VACATE	VAGINA	ENCYCLOPEDIA		
WAGON	WOUND	WHILE	WHORE			

Note. T2 = Second target.

Appendix B

Analysis of Error Types

Experiment 1

If the presence of affectively significant words altered participants' guessing strategies toward the benefit of emotional T2 report, then more negative than neutral words should have been reported when correct identification was not possible, particularly at early lags. As illustrated in Figures B1A and B1B, the distribution of error types did not support such a pattern of response bias. In the negative condition, an incorrect guess was much more likely to be a neutral (E_{neut}) than an emotional word (E_{emot}), as indicated by the effect of error type, $F(1, 19) = 71.89$, $\eta^2 = .79$ (E_{neut}, $M = 6.9\%$, $SD = 14.1$, vs. E_{emot}, $M = 1.8\%$, $SD = 7.1$). The propensity to report neutral words was most prominent where performance was least accurate—at early temporal lags, $F(6, 114) = 3.86$, $\eta^2 = .03$, and on neutral trials, $F(1, 19) = 7.35$, $\eta^2 = .28$.

Similarly, in the negative-arousal condition, output errors were more likely to be neutral than emotional words (E_{neut}, $M = 6.9\%$, $SD = 13.5$, vs. E_{emot}, $M = 1.7\%$, $SD = 6.7$), $F(1, 19) = 34.65$, $\eta^2 = .64$, and neutral word report was most pronounced where performance was worst—at early temporal lags, $F(6, 114) = 7.07$, $\eta^2 = .06$, and on neutral trials, $F(1, 19) = 12.00$, $p < .003$, $\eta^2 = .39$.

Experiment 2

As illustrated in Figures B2A and B2B, in contrast with a response bias toward reporting positive words, incorrect guesses tended to be neutral rather than emotional words. In the positive condition, output errors were much more likely to be of neutral than emotional content (E_{neut}, $M = 7.6\%$, $SD = 8.7$, vs. E_{emot}, $M = 1.9\%$, $SD = 3.9$), $F(1, 17) = 49.39$, $p < .0001$, $\eta^2 = .74$. Differential E_{neut} was greatest where report was most impaired—at early temporal lags, $F(6, 102) = 8.90$, $\eta^2 = .08$, and on neutral trials, $F(1, 17) = 15.82$, $\eta^2 = .48$.

In the positive-arousal condition, output errors were again more likely to be neutral than emotional (E_{neut}, $M = 6.2\%$, $SD = 8.5$, vs. E_{emot}, $M = 1.4\%$, $SD = 3.1$), $F(1, 17) = 40.20$, $\eta^2 = .70$, being most pronounced at early temporal lags, $F(6, 102) = 5.37$, $p < .0001$, $\eta^2 = .05$, and on neutral trials, $F(1, 17) = 6.32$, $p < .03$, $\eta^2 = .27$.

Experiment 3A

In the visually similar control condition, emotional output errors were restricted to the words on which they were orthographically based. This analysis allowed for an examination of the tendency for observers to report

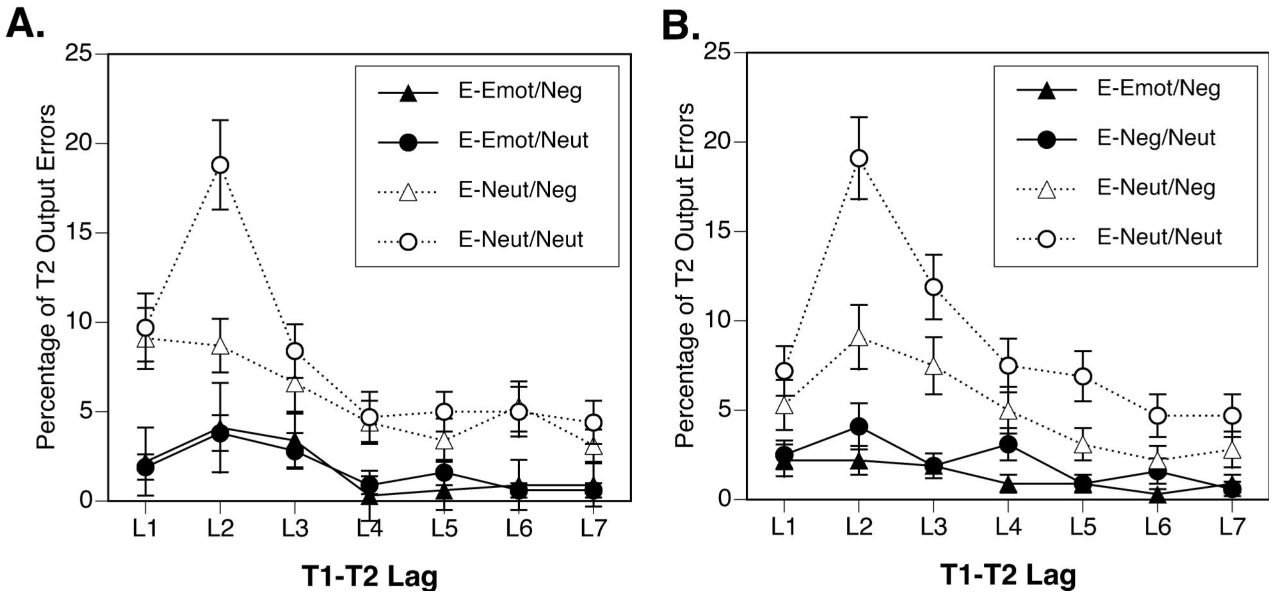

Figure B1. Mean percentage of error type (emotional vs. neutral) at each T1–T2 lag (L) in the (A) negative and (B) negative-arousal conditions for Experiment 1. Error bars represent standard errors of the means. E-emot/Neg = emotional output errors on negative T2 trials; E-emot/Neut = emotional output errors on neutral T2 trials; E-neut/Neg = neutral output errors on negative T2 trials; E-neut/Neut = neutral output errors on neutral T2 trials.

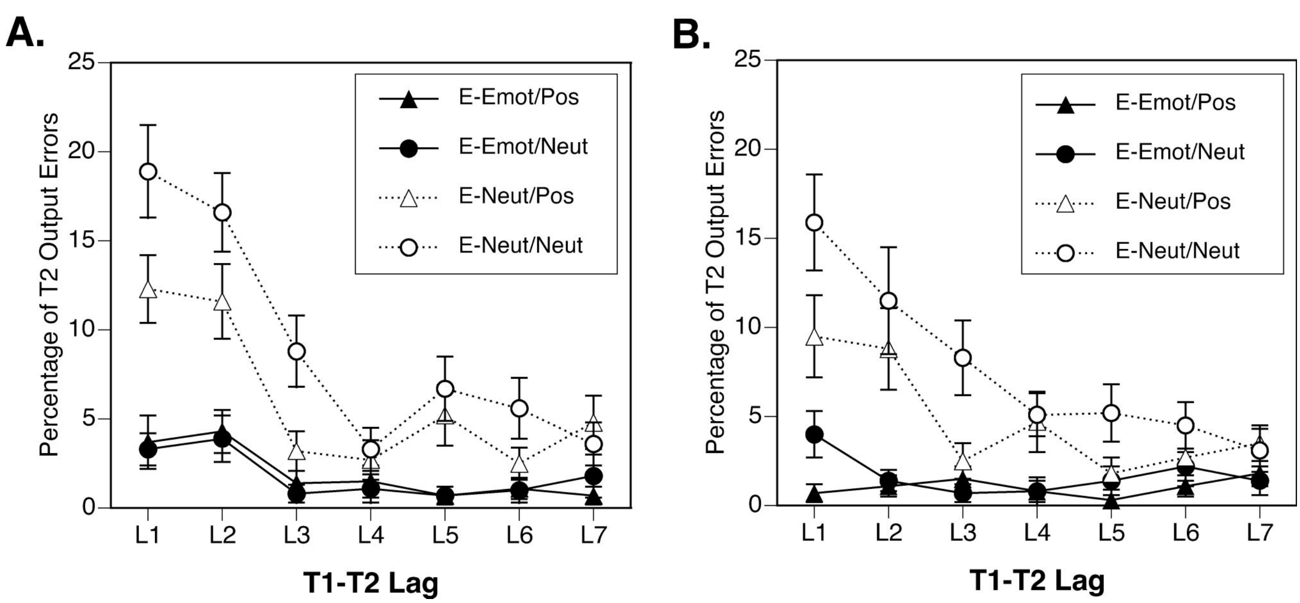

Figure B2. Mean percentage of error type (emotional vs. neutral) at each T1–T2 lag (L) in the (A) positive and (B) positive-arousal conditions in Experiment 2. Error bars represent standard errors of the means. E-emot/Pos = emotional output errors on positive T2 trials; E-emot/Neut = emotional output errors on neutral T2 trials; E-neut/Pos = neutral output errors on positive T2 trials; E-neut/Neut= neutral output errors on neutral T2 trials.

(*Appendixes continue*)

emotional words independent of their actual presentation. Theses analyses suggest that neutral words visually similar to arousing T2 words did not result in a significant increase in emotional output errors. E_{neut} occurred more often than did E_{emot} (M = 7.5%, SD = 14.3, vs. M = 1.4%, SD = 6.9, respectively), $F(1, 21) = 6.45$, η^2 =.24, particularly at early lags, $F(6, 126) = 5.63$, $\eta^2 = .04$. The likelihood of E_{emot} was not greater on trials with neutral words visually similar to arousing T2 words, $F(1, 21) < 1$.

In the arousal condition, E_{neut} occurred more often than did E_{emot} (M = 6.0%, SD = 13.0, vs. M = 0.9%, SD = 4.6, respectively), $F(1, 21) = 43.85$, $\eta^2 = .68$. E_{neut} was most prominent at early lags, $F(6, 126) = 8.52$, $\eta^2 = .06$, and on neutral trials, $F(1, 21) = 4.28$, $\eta^2 = .17$.

Experiment 3B

Observers were more likely to mistakenly report seeing neutral words than emotional words (E_{neut}, M = 6.4%, SD = 8.5, vs. E_{emot}, M = 3.0%, SD = 5.6), $F(1, 16) = 12.20$, $\eta^2 = .43$, and this trend was most evident on neutral T2 trials, $F(1, 16) = 37.52$, $\eta^2 = .70$.

Experiment 3C

To examine the influence of distractor condition on T2 performance, I restricted errors analysis to items belonging specifically to either the emotional or the neutral distractor lists. Collapsing across distractor conditions, the likelihood of making emotional and neutral output errors did not significantly differ (E_{neut}, M = 7.2%, SD = 12.5%, vs. E_{emot}, M = 7.9%, SD = 13.1%), $F(1, 17) < 1$. The likelihood of making a particular type of output error, however, was strongly associated with distractor condition, $F(1, 17) = 31.42$, $\eta^2 = .65$. E_{emot} occurred almost exclusively during the emotional distractor trial blocks and E_{neut} during the neutral distractor trial blocks.

Experiment 4A

Error analysis of the single-task condition was not undertaken because of the high level of T2 report accuracy. In the dual-task condition, incorrect guesses were more likely to be neutral than emotional words (E_{neut}, M = 5.7%, SD = 6.7, vs. E_{emot}, M = 1.9%, SD = 4.9), $F(1, 9) = 10.65$, $\eta^2 = .54$, and this difference was greater on neutral trials, $F(1, 9) = 8.30$, $\eta^2 = .48$.

Experiment 4B

Observers were more likely to mistakenly report seeing neutral than emotional words (E_{neut}, M = 10.7%, SD = 11.6%, vs. E_{emot}, M = 3.3%, SD = 5.8%), $F(1, 19) = 41.74$, $p < .0001$, $\eta^2 = .69$. This was most pronounced at early lags, $F(6, 114) = 3.05$, $p < .009$, $\eta^2 = .27$, and on neutral trials, $F(1,19) = 42.99$, $p < .0001$, $\eta^2 = .69$.

Appendix C

T2 Words From Experiment 2

Neutral	Positive-arousing	Positive
AXE	AROUSED	BEAUTY
CHISEL	BREAST	BIRTHDAY
CLAMP	CARESS	BOUQUET
CROWBAR	CLIMAX	CHAMP
DRILL	CLITORIS	CHEER
FILE	CONDOM	EXCITED
HACKSAW	COPULATE	FLOWER
HAMMER	EJACULATE	FRIENDLY
HATCHET	ERECTION	FUN
JIGSAW	EROTIC	GOLD
LATHE	FOREPLAY	HOLIDAY
LEVEL	SPERM	JOYFUL
MALLET	GAY	LEISURE
NAILS	LESBIAN	LOTTERY
PLANE	LUST	PLEASURE
PLIERS	NAKED	PRIZE
PLUMB	NIPPLE	SKY
PUNCH	NUDE	SMART
RASP	ORGASM	SMILE
RULER	ORGY	SOFT
SANDER	PENETRATE	SOUL
SANDPAPER	PENIS	SUCCESS
SAW	PUBIC	SUN
SCREWS	RUBBER	SWEET
SQUARE	SENSUAL	TENDER
VISE	SEX	TREASURE
WEDGE	TESTICLE	VACATION
WRENCH	VAGINA	WARM

Note. T2 = Second target.

Appendix D

T2 Words From Experiment 3A

Neutral	Arousing	Visually similar
AISLE	BITCH	BATCH
AXLE	BLOOD	FLOOD
BAR	BURNED	TURNED
BINDER	CANCER	DANCER
CLAM	DANGER	RANGER
COLUMN	DEATH	HEATH
FENCE	DOOM	ZOOM
FIELD	FEAR	HEAR
FLAG	FIRE	FARE
FORK	GRAVE	GROVE
GRADE	GUILT	BUILT
GROW	HATE	LATE
INCH	HELL	TELL
JACKET	HURT	HUNT
JUNE	KILL	MILL
LUNCH	LUST	LAST
NOTE	PISS	PASS
OBTAIN	RAGE	PAGE
OWNER	RAPE	ROPE
PEAL	SEX	SIX
RADIO	SIN	SON
SADDLE	SLAVE	SLATE
SCAN	SLUT	SLOT
SEWN	SUFFER	BUFFER
SHADE	THREAT	THREAD
VIEW	WASTE	TASTE
WET	WEEP	DEEP
WIRE	WOUND	FOUND

Note. T2 = Second target.

Appendix E

T2 Words and Distractor Nonwords From Experiment 3B

Neutral	Arousing	Distractors		
ANCHOVY	BASTARD	ADTHREBARE	GRAPHDEMOICS	POLAEXTRATION
BLIMP	BITCH	ALIZGLOBATION	HOLSTUPERY	POLOGANTHROY
BLUBBER	BLOOD	AMPHIERTHEAT	HOUSEERKEEP	PORTTRANSATIO
CRUMP	CANCER	ANTHECHRYSMU	ICATERADE	PRENEURENTRE
DAZZLE	DANGER	BIDHUMRMING	IFICABEATTION	QUEALBURQUE
DRIZZLY	DEATH	BLISHESTAMENT	IFICPONTATION	RAPHYTOPOG
GIGGLE	DESTROY	BREDROTHOUGH	IGATINVESTION	RESPIRECTIVE
GURGLE	FAILURE	CECIRECUMFERN	IGENCEXIES	SCRIPDETION
GUZZLE	EVIL	CEEDEXINGLY	ILMINALUTION	SERVOBATORY
HAGGLE	GRAVE	CILLOSATION	INESBUSSMAN	SEVOUNDLEL
HOORAY	HATE	GREGCONATION	INTDISEGRATE	SHADFOREOW
HOOSIER	HERPES	CONTIONTORIST	IRREOACHPRABL	SITHOUSETER
KIMONO	HORROR	CYCLOPENEDIA	JUSTATIONIFIC	TAMENTOURN
BALLYHOO	INCEST	DEIFYMYST	KERCHHANDIEF	TERIDELEOUS
NIBBLE	KILL	DELISENCATES	LAEMUTION	TEWABLARES
PAGODA	LESBIAN	DENSACONTION	LECTUALINTELIS	THERFURMORE
PIGSKIN	MURDER	DICARYTION	LINGROLLOG	THETHYPOICAL
PIMPLE	ORGY	DIFFIATIONEREN	MANNEYJOUR	THOUGHOURLY
PINKIE	PANIC	DISEARAPPANCE	MERNGOVENT	TILFERIZER
QUIBBLE	RAPE	DISUATEAMBIG	MOTOCLERCY	TRIMERECIOUS
RUFFLE	SCREAM	EIDOKALESCOP	MULTSIANEOUS	UCINHALLATION
SIZZLE	SHIT	ERALIZGENATION	NALIZINTERATIO	URBPERTATIONS
SKIMPY	SLAVE	FEDERCONATION	NENSICOMPREHIB	USOIDSINAL
SNIFFLE	STAB	FICACLASSITION	OGLYPHHIERIC	WERINTLAND
SWAHILI	SUICIDE	GANIZORATION	PIFICURATION	WINILDEDSH
SWANKY	TERROR	GRAPHBIOY	PINGBOSTRAPOT	
WHOOSH	TUMOR			
ZIPPER	WHORE			

Note. T2 = Second target.

(*Appendixes continue*)

Appendix F

T2 and Distractor Words From Experiment 3C

T2			Distractors: Neutral		Distractors: Arousing	
ABOARD	INSIST	STEM	ABSENT	HURRIED	PENIS	KILL
ACQUIRE	JERSEY	STORM	ACADEMY	LUXURY	ASSHOLE	MISERY
ALLIED	JUSTIFY	STRETCH	ACTOR	INPUT	CLITORIS	ORGY
ADULT	LANDING	SUBTLE	BARN	IRISH	FAILURE	PAIN
AMATEUR	LEGEND	SUITE	BARREL	JOURNEY	PLAGUE	PANIC
ASSIST	LIVELY	SUMMARY	BASES	JUMP	SORROW	PISS
BATH	LONELY	SURPLUS	BEAM	JUNGLE	SPITE	RAGE
BEARD	MARSHAL	SWING	BEHALF	KINGDOM	TENSE	SHOCK
BEARING	MINIMAL	TACTICS	BELT	LANE	SLUT	SIN
BILLY	MIRROR	TANGENT	BEND	LEATHER	DANGER	SUFFER
BUTTER	MOUNT	TEXTILE	BORDER	LOCK	DILDO	THREAT
CADY	MUTUAL	THEATRE	BOSS	LOOP	TRAGIC	MISERABLE
CLOCK	NOON	TIRE	BOTHER	MANAGE	WASTE	FATAL
CAVALRY	OBSERVE	TORN	CABIN	MARBLE	WEEP	DEADLY
CELLAR	OURS	TRACE	CAFE	MARS	WOUND	DISMEMBER
CHIN	OUTCOME	TRACTOR	CARBON	MEAL	SHIT	AMPUTATE
CLIMATE	OUTDOOR	TRADING	CARD	MELODY	COCK	INFECTIOUS
CONTEST	PACK	TREAT	CASUAL	MOVIE	BARF	PUSSY
CRITIC	PARADE	UPWARD	CHAPEL	NETWORK	ORGASM	DISGUST
DEALER	PATROL	URGE	CHART	ORANGE	NIPPLE	SURGERY
DEFINE	PENNY	UTILITY	CHEEK	PALM	BEATEN	BASTARD
DISK	PILE	UTTERLY	COMPARE	PAUSE	BURNED	BITCH
DULL	POND	VAGUE	DARE	PERFORM	FART	BLOOD
EAGER	PREFER	VEIN	DAWN	PLANET	LESBIAN	CANCER
ENTRY	PREMIER	VERSE	DEALT	PLASTER	LUST	GRAVE
EXACT	RANCH	VETERAN	DISCUSS	REFORM	FRIGHT	HERPES
EXCUSE	REFLECT	VIVID	DRYING	REPAIR	GUILT	HORROR
EXHIBIT	REPEAT	VOTING	EIGHTH	RHYTHM	ANUS	INCEST
FEEDING	RITUAL	WARD	EMPIRE	SCREW	FIRE	MURDER
FLEW	SADDLE	WARRANT	ENABLE	SILVER	STAB	EJACULATE
FORTUNE	SCOPE	WEEKLY	EXPERT	SLIM	AFRAID	RAPE
FROZEN	SHIRT	WHISKY	ETERNAL	SPONSOR	ANGRY	SCREAM
GEAR	SIXTH	WITNESS	FAINT	TAIL	CRASH	SEMEN
GRAIN	SLEPT	WORN	FARMER	TOOTH	CRISIS	SLAVE
HANDLED	STABLE	WORTHY	FAULT	TRIBUTE	DOOM	DESTROY
HOLDER	STADIUM	YOURS	FENCE	TRIM	EVIL	SUICIDE
HONEY	STAR	ZERO	GARAGE	VALID	FEAR	TERROR
HORIZON			GATHER	VERBAL	HATE	TUMOR
			HEATING	WAKE	HELL	VAGINA
			HERD	WORKER	HURT	WHORE

Note. T2 = Second target.

Appendix G

T2 Words From Experiment 4A

Neutral	Arousing
ALLERGY	ANUS
AVID	ASSHOLE
BOAR	BARF
CARRIER	BASTARD
CEDAR	BITCH
CLAP	COCK
EPITOME	CUNT
EVOKE	DILDO
FERN	EJACULATE
HELMET	FART
INVENT	FUCK
KEY	HERPES
LINT	INCEST
MAID	LESBIAN
MEND	NIPPLE
MIGRATE	ORGASM
OCTET	ORGY
OMIT	PENIS
PADDLE	PISS
PEAL	PUSSY
PEPPER	RAPE
PERCH	SEMEN
SPILL	SEX
SURF	SHIT
SWAP	SLUT
TILT	TITS
UNTIE	VAGINA
VEILED	WHORE

Note. T2 = Second target.

Received December 11, 2000
Revision received February 11, 2005
Accepted February 14, 2005 ■