Research Article

Emotion-Induced Impairments in Speeded Word Recognition Tasks

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Abstract. Recent studies show that emotional stimuli impair the identification of subsequently presented, briefly flashed stimuli. In the present study, we investigated whether emotional distractors (primes) impaired target processing when presentation of the target stimulus was not impoverished. In lexical decision, animacy decision, rhyme decision, and nonword naming, targets were presented in such a manner that they were clearly visible (i.e., targets were not masked and presented until participants responded). In all tasks taboo-sexual distractors caused a slowdown in responding to the subsequent neutral target. Our results indicate that the detrimental effects of emotional distractors are not confined to paradigms in which visibility of the target is limited. Moreover, impairments were obtained even when semantic processing of stimuli was not required.

Keywords: emotion, taboo words, attention capture, word recognition, semantic processing, perception

Stimuli such as pictures and words that are emotionally significant attract attention and are better perceived than stimuli that are emotionally neutral. Anderson and Phelps (2001), for example, investigated the identification of emotional words in a rapid serial visual presentation (RSVP) paradigm. In this paradigm, the second of two targets presented in a stream of distractors is often not identified if it is presented shortly (≈100–600 ms) after the first target. This effect is referred to as the attentional blink (Raymond, Shapiro, & Arnell, 1992). Anderson and Phelps (also see Anderson, 2005; Keil & Ihssen, 2004) demonstrated that the attentional blink was reduced for emotional stimuli. In their study, second targets (T2) were more often correctly identified when they were emotional words than when they were neutral words (the first targets in this study were always neutral words). Notably, subjects with damage to the left amygdala showed no evidence of enhanced identification of emotional targets.

Evidence for the enhanced processing of emotional words has also been obtained in other paradigms. For example, Zeelenberg, Wagenmakers, and Rotteveel (2006) obtained evidence for enhanced identification of briefly presented and masked emotional words in a two-alternative forced-choice procedure in which only one target word was presented on each trial. Studies with pictures and faces have also obtained evidence for emotion-induced enhanced identification (Maratos, Mogg, & Bradley, 2008; Milders, Sahraie, Logan, & Donnellon, 2006).

The studies mentioned above indicate that emotionally significant stimuli are more often correctly identified than emotionally neutral stimuli. In addition, when emotionally significant stimuli are presented prior to emotionally neutral targets they tend to harm identification of the subsequently presented neutral target. For example, Most, Chun, Widders, and Zald (2005) presented a stream of distractor pictures with one target picture embedded in the stream. The target was rotated 90° to either the left or the right. Most et al. showed that participants were worse at detecting the orientation of the target picture if an emotionally negative distractor picture was presented previously in the stream, compared to a neutral-distractor picture.[1] This so-called "emotion-induced blindness" effect has now been obtained in several RSVP studies using both pictures and words (e.g., Arnell, Killman, & Fijavz, 2007; Mathewson, Arnell, & Mansfield, 2008; Most, Smith, Cooter, Levy, & Zald, 2007) and with different task requirements (e.g., identification of a target word rather than orientation detection of a target picture).

It has been suggested that emotion-induced effects in visual perception may be due to attentional processes (e.g., Anderson, 2005; Most et al., 2005). Emotion-induced attentional processes may explain why an emotional stimulus impairs performance to a subsequently presented neutral target in an RSVP paradigm. If attentional resources are limited, an increase in the allocation of resources to the emotional stimulus will result in fewer resources remaining available for the processing of the subsequently presented neutral target stimulus, impairing its identification.

According to two-stage models of the attentional blink (e.g., Chun & Potter, 1995), high-capacity stage 1 processing results in a transient representation of the presented stimuli. Subsequently, multiple stimulus representations compete for limited-capacity stage 2 processing which turns a

[1] This finding was obtained at lag 2 (i.e., when one neutral-distractor picture intervened between the presentation of the emotional distractor and the target picture), but not at lag 8.

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transient representation into a more stable one that is available for conscious report. Emotional stimuli are presumed to engage stage 2 processing at the cost of other stimuli. That is, because stage 2 processing is limited in capacity, other transient stimulus representations may fade before stage 2 processing can be directed to them thereby making these representations unavailable for conscious report. Because the allocation of processing resources to emotional stimuli happens reflexively, detrimental carry-over effects may be obtained even when emotional stimuli are task irrelevant (Arnell et al., 2007; Most et al., 2005).

So far, little is known about whether effects similar to those obtained in the RSVP paradigm can be obtained when target presentation is not impoverished. In the RSVP paradigm the target is briefly presented (usually of the order of 75–120 ms) and masked (i.e., the target is usually preceded and followed by multiple distractors presented at the same location as the target stimulus). Furthermore, because the target is embedded in a stream of many distractors and can occur on any of multiple positions there is a high degree of temporal uncertainty. Because of the short presentation duration of the target, the masking, and the temporal uncertainty it is difficult to focus attention on the target in order to select it for further processing. These conditions may make the target especially vulnerable to detrimental influences of emotional distractors. Presenting the target in a clearly visible fashion by eliminating the masking and increasing the presentation time might eliminate the emotion-induced impairment caused by task-irrelevant distractors. That is, the longer presentation duration of the target might facilitate its access to stage 2 processing thereby eliminating the detrimental effect of an emotional distractor. In addition, the effect of an emotional distractor might be eliminated by presenting the distractor and target in a predictable fashion, thereby removing the temporal uncertainty that is associated with the RSVP paradigm. Presenting the distractor and target in a predictable fashion may allow participants to ignore the emotional distractor and focus on the target stimulus.

In the present study we investigated whether presenting distractors and targets in the way just sketched eliminates the detrimental effect of emotional distractors. On each trial a single emotional distractor (or prime) was presented prior to a single target stimulus that was not masked and remained on the screen until the participant responded. In the first two experiments targets were presented in a lexical decision task (Experiment 1) or an animacy decision task (Experiment 2). The question of interest was whether performance in these tasks would be harmed by the prior presentation of an emotional distractor. Although lexical decision and semantic categorization tasks, such as animacy decision, are widely used in the memory and language literature, we are aware of only one study that has investigated the effect of an emotional distractor on performance to a subsequently presented neutral target stimulus in a speeded word recognition task. In this study, Calvo and Castillo (2005) showed that an emotional distractor word impaired performance to a subsequently presented neutral target word; lexical decisions were slower to target words that were preceded by a threat distractor than to target words that were preceded by a neutral distractor. The Calvo and Castillo study, however, differs from the above-mentioned RSVP studies in that on each trial two different distractor words were presented simultaneously at different locations. That is, on each trial one foveal distractor and one parafoveal distractor were presented. In the RSVP paradigm, however, all stimuli are presented at the same location. Possibly more important, on half of the trials in the Calvo and Castillo study, one of the two distractors was an identity prime. Because identity primes had a large positive effect on performance that, averaged over all conditions, outweighed the negative effect of emotional distractors by a factor 7, participants in this study may have been motivated to pay attention to the distractor. In the present study there was no such motivation because all distractors were unrelated to the targets.

A second question that we addressed in the present study is whether emotion-induced impairments can be obtained even when semantic processing of the stimuli is not required. In a recent study using the RSVP paradigm, Huang, Baddeley, and Young (2008) reported an impairment in target identification when semantic processing of the stimuli was required but not when perceptual or phonological processing was required. Processing of the stimuli was manipulated by varying the dimension on which targets had to be selected from distractors in the RSVP stream. When targets had to be selected on the basis of a semantic dimension (i.e., when participants searched for a fruit word such as *pear* in a stream of nonfruit distractor words) an emotion-induced impairment was found. When targets had to be selected on the basis of a more superficial dimension (i.e., when participants searched for an uppercase word in a stream of lowercase distractor words or when they searched for a word that rhymed with the word *pear* in a stream of words that did not) no emotion-induced impairment was found. If, as the data of Huang et al. suggest, emotion-induced impairments are only found when semantic processing is required, no effect of emotional distractors should be obtained in a speeded rhyme decision task (in which the participant's task is to decide whether the target word rhymes with *pear*) or a nonword naming task (in which the participant's task is to simply read the target letter string aloud as fast as possible). This was investigated in Experiments 3 and 4.

Experiment 1

In the first experiment of the present study, we investigated whether emotional distractors impair lexical decisions to subsequently presented neutral targets. On each trial only one distractor was presented and both the distractor and target were presented on the same (central) location on the screen. To further extend the findings of Calvo and Castillo (2005) we used taboo-sexual words rather than threat words. Recent findings with the RSVP paradigm suggest that taboo-sexual words may be especially effective in capturing attention (Mathewson et al., 2008). All distractors were either taboo-sexual words or neutral words and none of the distractors were identical or related to the target. Finally, in the present experiment both word and nonword targets

were preceded by taboo-sexual words. If emotional distractors attract attention at the expense of the target, detrimental effects should be observed for nonword targets as well as word targets.[2]

Method

Participants

Forty-eight students from the University of California, San Diego participated for course credit. The participants in all experiments of the present study reported normal or corrected-to-normal vision and gave informed consent. The data of one participant were discarded because of excessive error rates. We replaced this participant while keeping the counterbalanced design intact.

Stimulus Materials

Forty-four taboo-sexual words selected from Mathewson et al. (2008) and forty-four neutral words[3] were chosen to serve as distractors in the lexical decision task. The taboo-sexual words and neutral words were rated on 9-point scales by a separate group of subjects ($n = 20$) in terms of their arousal (1 = low arousal, 9 = high arousal) and by another group of subjects ($n = 20$) in terms of their valence (1 = negative, 9 = positive) using the Self-Assessment Manikin (Bradley & Lang, 1999). Taboo-sexual and neutral words differed in terms of their arousal ratings ($M = 5.32$, $SD = 0.57$ vs. $M = 2.72$, $SD = 0.47$), $t(86) = 23.40$, $p < .0001$, but not in terms of their valence ratings ($M = 5.47$, $SD = 1.12$ vs. $M = 5.23$, $SD = 0.54$), $t(62.35) = 1.29$, $p > .15$. Taboo-sexual and neutral words were matched on word length ($M = 5.59$, $SD = 1.35$ vs. $M = 5.59$, $SD = 1.35$) and word frequency (occurrences per million in the CELEX database, Baayen, Piepenbrock, & van Rijn, 1993) ($M = 10.46$, $SD = 16.91$ vs. $M = 10.27$, $SD = 10.36$), both ps $> .75$. A complete listing of the taboo-sexual distractors is provided in the Appendix.

A set of 44 neutral words (e.g., *frog, tool, glacier*) and 44 pronounceable nonwords (e.g., *faw, gambo, recloim*) were selected to serve as targets in the lexical decision task. The nonwords were taken from previously published lexical decision studies (Wagenmakers et al., 2004; Zeelenberg, Wagenmakers, & Shiffrin, 2004). Two counterbalanced lists were created so that across lists each word target and each nonword target were preceded by both a taboo-sexual distractor and a neutral distractor. An additional set of six taboo words and six neutral words was selected to serve as distractors on the practice trials, and another set of six words and six nonwords was selected to serve as targets on the practice trials. In this and all subsequent experiments, the composition of practice trials (i.e., the proportion of taboo-sexual distractors and neutral distractors, the proportion of trials requiring a "yes" and "no" response, and the pairing of distractors and targets) mirrored that of the experiment proper.

Each subject received one of the two counterbalanced lists. All distractor-target pairs were semantically unrelated. No stimuli were repeated in the experiment.

Procedure

Participants received written instructions to make a "word" decision if the letter string was an existing English word and to make a "nonword" decision if the letter string was not an existing English word. Examples of words and nonwords were provided. Participants were instructed to respond as quickly and accurately as possible.

The experiment started with 12 practice trials that were immediately followed by the 88 experimental trials. The 88 experimental trials consisted of 22 taboo-distractor word-target trials, 22 neutral-distractor word-target trials, 22 taboo-distractor nonword-target trials, and 22 neutral-distractor nonword-target trials. Thus, the emotional status of the distractor was not predictive of the lexical status of the target. Distractor-target pairs were presented in a random order. A different random order was generated for each participant.

Each trial consisted of the following events: a warning signal consisting of eight dash characters (450 ms), a blank screen (50 ms), the distractor (150 ms), a blank screen (150 ms), and the target. The warning signal, distractor, and target were presented on the same location in the center of the computer screen. The presentation procedure is illustrated schematically in Figure 1. The target remained on the screen until the participant had made a response by pressing the *m* key for a "word" response or the *z* key for a "nonword" response. If the participant made an error, the word "Incorrect" was presented for 1,000 ms. If the response was correct but slower than 2,000 ms, the words "Too slow" were presented for 1,000 ms. The next trial started 1,000 ms after the response or, in case of an erroneous or slow response, 1,000 ms after presentation of the feedback.

[2] Although Calvo and Castillo (2005) reported that emotional distractors slowed down responding to word targets, they did not report RTs for nonword targets. Thus, it remains to be seen whether emotional distractors affect decisions to nonword targets.

[3] Emotional words (in our case taboo-sexual words) tend to be more tightly related to each other than a "random" set of neutral words. One could wonder whether distractors that are part of a semantic cluster capture attention, thereby harming performance to the target. Aquino and Arnell (2007) investigated this in a digit parity test and found no effect of semantic interrelatedness, thereby providing evidence that emotion-induced impairments are not due to emotional distractors forming a tighter semantic cluster than neutral distractors. To test whether differences in semantic relatedness between the distractors might affect performance in a lexical decision test, we did an experiment in which the distractors either formed a tightly related semantic cluster (i.e., animal names) or not. The results showed no differences in either RTs or percent errors between targets preceded by distractors from the related set (mean RT = 678 ms, PE = 6.5% averaged over word and nonword targets) and targets preceded by distractors from the unrelated set (mean RT = 674 ms, PE = 7.6%), $F(1, 35) = 1.45$, $p > .20$ and $F(1, 35) = 1.32$, $p > .20$, respectively.

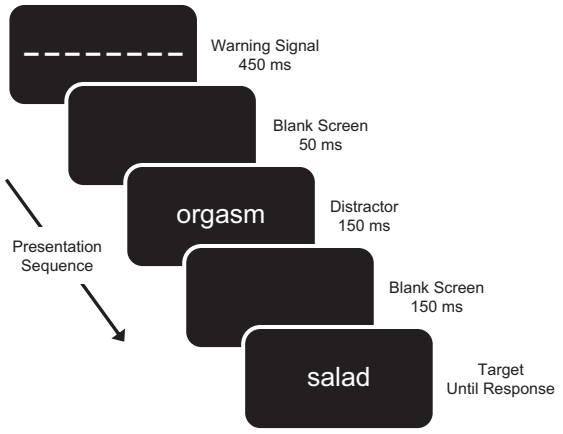

Figure 1. Illustration of the presentation procedure used in Experiments 1–4.

In this and all subsequent experiments, stimuli were presented in light gray on a black background in Courier New font, point size 18. Stimulus presentation and data collection were controlled by E-prime software v1.1.

Results and Discussion

Mean reaction times for correct responses were calculated for each condition. Responses more than two standard deviations above or below each participant's condition mean were excluded from the analyses (4.8% of the observations were removed due to outlier reaction times). Table 1 shows the mean reaction times for correct responses and the percent errors. As can be seen, reaction times were slower to targets preceded by a taboo-sexual distractor than to targets preceded by an emotionally neutral distractor.

This conclusion was confirmed by a 2 (taboo distractor vs. neutral distractor) by 2 (word vs. nonword) repeated measures ANOVA on the mean reaction times. The ANOVA showed a significant main effect of distractor status, $F(1, 47) = 64.91$, $p < .0001$, partial $\eta^2 = .58$, indicating that participants responded slower to targets preceded by a taboo distractor than to targets preceded by a neutral distractor. The main effect of lexical status was also significant, $F(1, 47) = 82.61$, $p < .0001$, partial $\eta^2 = .64$; participants responded slower to nonword targets than to word targets. Finally, the interaction was not significant, $F(1, 47) < 1$. Although the interaction was not significant we did perform follow-up *t*-tests because we wanted to know whether the emotion-induced deficits were significant for both classes of stimuli (i.e., words and nonwords). The *t*-tests showed that the impairment in performance due to taboo-sexual distractors was significant for both words, $t(47) = 6.29$, $p < .0001$, and nonwords, $t(47) = 5.32$, $p < .0001$.

Table 1. Reaction times (in ms) and percent errors to word and nonword targets in the lexical decision task of Experiment 1

	Word		Nonword	
Distractor	RT	PE	RT	PE
Taboo-sexual	714 (16)	5.7 (0.9)	811 (21)	9.3 (1.7)
Neutral	657 (16)	4.4 (0.8)	765 (19)	8.5 (1.3)
Impairment	57 (9)	1.3 (0.9)	45 (9)	0.8 (1.3)

Note. RT = reaction time, PE = percent errors. Standard errors of the mean are provided in parentheses.

An ANOVA on the percent errors showed no main effect of distractor status, $F(1, 47) = 2.33$, $p > .10$. The main effect of lexical status was significant, $F(1, 47) = 7.14$, $p < .01$, partial $\eta^2 = .13$; participants made more errors to nonword targets than to word targets. Finally, the interaction was not significant, $F(1, 47) < 1$.

The results of Experiment 1 extend those of Calvo and Castillo (2005) in three ways. First, we show emotion-induced impairments for both word and nonword targets. This is consistent with an attention capture explanation and excludes the possibility that the emotional-induced deficit was due to a decisional bias that favors nonwords over words. Second, Calvo and Castillo showed impairments with threat-related distractors. In the present experiment we showed impairments with taboo-sexual distractors, showing that the impairments are not limited to threat-related distractor stimuli. Third, and most important, because distractors were never related to the targets participants had no reason to attend to the distractors. Yet, an emotion-induced impairment was found. In Experiment 2 we wanted to extend these findings to animacy decision, another speeded decision task that is often used in word recognition studies.

Experiment 2

Method

Participants

Forty-eight students from the University of California, San Diego participated for course credit. None of them had participated in Experiment 1. The data from two participants were discarded because of excessive error rates. We replaced these participants while keeping the counterbalanced design intact.

Stimulus Materials, Apparatus, and Procedure

The taboo-sexual distractors and neutral distractors from Experiment 1 were used again. A set of 44 animate words (e.g., *oak, salmon, cowboy*) and 44 inanimate words (e.g., *jet, pudding, umbrella*) were selected to serve as targets in the present experiment. The majority of targets were selected from a previously published animacy decision study (Pecher, Zeelenberg, & Wagenmakers, 2005).

The experiment started with 12 practice trials that were immediately followed by the 88 experimental trials. The 88 experimental trials consisted of 22 taboo-distractor animate-target trials, 22 neutral-distractor animate-target trials, 22 taboo-distractor inanimate-target trials, and 22 neutral-distractor inanimate-target trials. Thus, the emotional status of the distractor was not predictive of the semantic status (i.e., animate vs. inanimate) of the target. Two counterbalanced lists were created so that across lists each animate target and each inanimate target were preceded by both a taboo-sexual distractor and a neutral distractor. Each subject received one of the two counterbalanced lists. All distractor-target pairs were semantically unrelated. No stimuli were repeated in the experiment. A different random presentation order was generated for each participant.

Participants received written instructions to make an "animate" decision if the word represented something living (i.e., a human being, animal, or plant), or part of a living thing and to make an "inanimate" decision if the word represented something not living. Examples of animate and inanimate things were provided. The presentation procedure and timing for trials were identical to that of Experiment 1. Participants made a response by pressing the *m* key for an "animate" response or the *z* key for an "inanimate" response.

Results and Discussion

Mean reaction times for correct responses were calculated for each condition. Responses more than two standard deviations above or below each participant's condition mean were excluded from the analyses (4.9% of the observations were removed due to outlier reaction times). Table 2 shows the mean reaction times for correct responses and the percent errors. As can be seen, reaction times were slower to target words preceded by a taboo-sexual distractor than to target words preceded by an emotionally neutral distractor.

This conclusion was confirmed by a 2 (taboo distractor vs. neutral distractor) by 2 (animate vs. inanimate target) repeated measures ANOVA on the mean reaction times. The ANOVA showed a significant main effect of distractor status, $F(1, 47) = 21.07$, $p < .0001$, partial $\eta^2 = .32$, indicating that participants responded slower to targets preceded by a taboo distractor than to targets preceded by a neutral distractor. The main effect of animacy was also significant, $F(1, 47) = 38.72$, $p < .0001$, partial $\eta^2 = .45$; participants responded slower to inanimate targets than to animate targets. Finally, the interaction was not significant, $F(1, 47) = 2.25$, $p > .10$. Follow-up *t*-tests showed that the impairment in performance due to taboo-sexual distractors was significant for both animate targets, $t(47) = 4.93$, $p < .0001$, and inanimate targets, $t(47) = 2.51$, $p < .05$.

Table 2. Reaction times (in ms) and percent errors to animate and inanimate target words in the animacy decision task of Experiment 2

	Animate		Inanimate	
Distractor	RT	PE	RT	PE
Taboo-sexual	705 (13)	14.2 (1.2)	745 (16)	8.6 (0.9)
Neutral	671 (13)	10.8 (1.2)	725 (14)	7.4 (1.0)
Impairment	34 (7)	3.4 (1.2)	20 (8)	1.2 (1.3)

Note. RT = reaction time, PE = percent errors. Standard errors of the mean are provided in parentheses.

An ANOVA on the percent errors showed a main effect of distractor status that approached conventional levels of statistical significance, $F(1, 47) = 3.97$, $p = .056$, partial $\eta^2 = .08$; participants made more errors to targets preceded by taboo distractors than to targets preceded by neutral distractors. The main effect of animacy was significant, $F(1, 47) = 16.36$, $p < .0001$, partial $\eta^2 = .26$; participants made more errors to inanimate targets than to animate targets. Finally, the interaction was not significant, $F(1, 47) = 1.99$, $p > .10$.

The results from Experiments 1 and 2 showed that taboo-sexual words cause a slowdown in responding to subsequently presented target words. Both lexical decisions and animacy decisions were impaired, indicating that the effects are robust and found across different speeded word recognition tasks.

As we mentioned in the Introduction, in a recent study using the RSVP paradigm Huang et al. (2008) obtained an emotion-induced impairment when participants searched for a target in a stream of distractors on the basis of a semantic dimension, but not when they searched for a target on the basis of a nonsemantic dimension. This suggests that emotion-induced impairments are restricted to conditions in which semantic processing of the stimuli is required. This raises the question whether emotion-induced effects in speeded word recognition tasks are also limited to conditions in which semantic processing is required.

Obviously, in the animacy decision task of our Experiment 2 semantic processing of the targets was necessary. Note, however, that semantic processing of the distractors (which caused the emotion-induced impairment) was not necessary because they were task irrelevant. In the RSVP paradigm the situation is different because the position of the target in the stream of distractors is uncertain (i.e., the position varies from trial to trial) and participants need to process each item in the stream to check whether it is a target or not. In the present experiments the target is always the second word and the distractor word could in principle always be ignored. Nevertheless, it may be that in the animacy task participants were in a semantic "mode" because semantic processing of the targets was required.

For the lexical decision task the situation is less clear. In principle, lexical decisions do not require that semantic knowledge is accessed. Models of lexical decision such as MROM (Grainger & Jacobs, 1996) show that lexical decisions can be made on the basis of word form representations even when nonwords are orthographically legal and similar in spelling to words (also see Wagenmakers et al., 2004). Moreover, several empirical studies suggest that lexical decisions are often made without accessing the meaning of the target word (Becker, Moscovitch, Behrmann, & Joordens, 1997; Borowsky & Masson, 1996; Joordens &

Becker, 1997; Kirsner, Brown, Abrol, Chadna, & Sharma, 1980; Zeelenberg & Pecher, 2002, 2003). For example, no long-term cross-language repetition priming is found in lexical decision (e.g., Kirsner et al, 1980; Zeelenberg & Pecher, 2003). Zeelenberg and Pecher (2003) observed that prior presentation of the Dutch word *kikker* did not facilitate lexical decisions to its English translation equivalent *frog*. When participants performed animacy decision, however, there was long-term cross-language repetition priming. These results support the idea that animacy decision requires semantic processing but lexical decision does not. Nevertheless, one could argue that participants may have engaged in meaning access; because words refer to meaningful concepts, and nonwords do not, semantic processing may facilitate making lexical decisions.

In Experiments 3 and 4 we therefore examined whether the effects obtained in Experiments 1 and 2 generalize to tasks that do not require semantic processing. Experiment 3 tested whether sexual-taboo words slow down responding in a speeded rhyme decision task. This task was chosen as a close analog of the RSVP task used by Huang et al. (2008) in which subjects had to report words that rhymed with *pear*. As mentioned in the Introduction, emotional distractor words did not impair performance in an RSVP task when participants were searching for a subsequently presented target word that rhymed with *pear*. According to Huang et al. (2008) no emotion-induced deficit was obtained in rhyme decision because this task does not require semantic access. The same logic would predict no effect in our rhyme decision task. In the present experiment, rather than asking subjects to search for a target word in an RSVP stream, we asked subjects to simply decide as quickly and accurately as possible whether the target word rhymed with *pear*.

Experiment 3

Method

Participants

Forty-six students from the University of California, San Diego participated for course credit. None of them had participated in Experiment 1 or 2. The data from five participants were discarded because of excessive error rates or response times. We replaced these participants while keeping the counterbalanced design intact.

Stimulus Materials, Apparatus, and Procedure

The taboo-sexual distractors and neutral distractors from Experiment 1 were used again. A set of 22 words that rhymed with *pear* was selected from an online rhyme dictionary (www.rhymezone.com). Two native speakers of American English verified that the 22 selected words indeed rhymed with *pear*. Twenty-two additional words that did not rhyme with *pear* were also selected.

The experiment started with 12 practice trials that were immediately followed by the 88 experimental trials. The 88 experimental trials consisted of 22 taboo-distractor rhyme-target trials, 22 neutral-distractor rhyme-target trials, 22 taboo-distractor nonrhyme-target trials, and 22 neutral-distractor nonrhyme-target trials. Each target was presented twice in the experiment (once with a taboo distractor and once with a neutral distractor) and each distractor was presented once. Two counterbalanced lists were created so that across lists each taboo distractor was presented once with a rhyme target and once with a nonrhyme target. Each subject received one of the two counterbalanced lists. A different random presentation order was generated for each participant.

Participants received written instructions to make a "rhyme" decision if the target rhymed with *pear* and to make a "nonrhyme" decision if the target did not rhyme with *pear*. The presentation procedure and timing for trials were identical to that of Experiments 1 and 2. Participants made a response by pressing the *m* key for a "rhyme" response or the *z* key for an "nonrhyme" response.

Results and Discussion

Mean reaction times for correct responses were calculated for each condition. Responses more than two standard deviations above or below each participant's condition mean were excluded from the analyses (5.2% of the observations were removed due to outlier reaction times). Table 3 shows the mean reaction times for correct responses and the percent errors. As can be seen, reaction times were slower to targets preceded by a taboo-sexual distractor than to targets preceded by an emotionally neutral distractor.

This conclusion was confirmed by a 2 (taboo distractor vs. neutral distractor) by 2 (rhyme vs. nonrhyme target) repeated measures ANOVA on the mean reaction times. The ANOVA showed a significant main effect of distractor status, $F(1, 45) = 29.55$, $p < .0001$, partial $\eta^2 = .40$, indicating that participants responded slower to targets preceded by a taboo distractor than to targets preceded by a neutral distractor. The main effect of rhyme status approached conventional levels of statistical significance, $F(1, 45) = 3.91$, $p = .054$, partial $\eta^2 = .08$; participants responded somewhat slower to nonrhyme targets than to rhyme targets. Finally, the interaction was marginally significant, $F(1, 45) = 2.88$,

Table 3. Reaction times (in ms) and percent errors to target words in the rhyme decision task of Experiment 3

	Rhyme word		Nonrhyme word	
Distractor	RT	PE	RT	PE
Taboo-sexual	634 (15)	3.1 (0.7)	642 (16)	5.8 (0.7)
Neutral	597 (14)	3.7 (0.6)	621 (14)	6.9 (0.9)
Impairment	37 (5)	−0.6 (0.6)	22 (8)	−1.1 (0.9)

Note. Subjects decided whether or not target words rhymed with *pear*. See text for details. RT = reaction time, PE = percent errors. Standard errors of the mean are provided in parentheses.

$p = .096$, partial $\eta^2 = .06$, indicating that the emotion-induced deficits tended to be somewhat larger for rhyme targets than for nonrhyme targets. Follow-up *t*-tests showed that the impairment in performance due to taboo-sexual distractors was significant for both words that rhymed with *pear*, $t(45) = 6.95$, $p < .0001$, and words that did not rhyme with *pear*, $t(45) = 2.58$, $p < .05$.

An ANOVA on the percent errors showed no main effect of distractor status, $F(1, 45) = 2.42$, $p > .10$. The main effect of rhyme status was significant, $F(1, 45) = 18.01$, $p < .01$, partial $\eta^2 = .29$; participants made more errors to nonrhyme targets than to rhyme targets. Finally, the interaction was not significant, $F(1, 45) < 1$.

In the next experiment we tested whether taboo-sexual words slow down responding in a speeded naming task. Rather than asking subjects to name words, which is a more commonly used task, we asked them to name pronounceable nonwords. Nonwords are unfamiliar meaningless letter strings that have not been encountered by the subjects prior to the experiment. In our nonword naming task participants were simply asked to say aloud as quickly as possible a nonword that was presented on the screen. Naming requires subjects to convert graphemes in phonemes but does not require semantic processing. Moreover, unlike words, nonwords do not refer to meaningful concepts. If taboo-sexual words capture attention even if the task requires no semantic processing we should observe that taboo-sexual distractors slow down performance in a nonword naming task.

Experiment 4

Method

Participants

Thirty-eight students from the Erasmus University Rotterdam participated for course credit.

Stimulus Materials

Experiments 1–3 were conducted with native speakers of English and English stimuli. Because participants in the present experiment were native speakers of Dutch a new set of Dutch words was used in Experiment 4. Thirty-two taboo-sexual words and 32 neutral words were selected to serve as distractors in the naming task. The taboo-sexual words and neutral words were rated on 9-point scales by a separate group of participants ($n = 20$) in terms of their arousal (1 = low arousal, 9 = high arousal) and by another group of subjects ($n = 20$) in terms of their valence (1 = negative, 9 = positive) using the Self-Assessment Manikin (Bradley & Lang, 1999). The taboo-sexual and neutral words differed in terms of their arousal ratings ($M = 5.30$, $SD = 0.84$ vs. $M = 2.69$, $SD = 0.49$), $t(62) = 15.27$, $p < .0001$, but not in terms of their valence ratings ($M = 5.13$, $SD = 1.70$ vs. $M = 5.22$, $SD = 0.46$), $t(35.60) = 0.28$, $p > .75$. Taboo-sexual and neutral words were matched on word length ($M = 6.19$, $SD = 2.16$ vs. $M = 6.19$, $SD = 2.16$) and word frequency (occurrences per million in the CELEX database, Baayen et al., 1993) ($M = 8.03$, $SD = 7.20$ vs. $M = 8.03$, $SD = 6.17$), both ps > .75. A complete listing of the taboo-sexual distractors is provided in the Appendix.

A set of 64 pronounceable nonwords (length: $M = 6.0$, $SD = 1.76$) was selected to serve as targets in the naming task. Pronunciation of the nonword targets was straightforward because of the close correspondence between orthography and phonology in the Dutch language (Martensen, Maris, & Dijkstra, 2003); for this reason there was no ambiguity as to the correct pronunciation of the nonword targets.

Two counterbalanced lists were created so that across lists each nonword was preceded by both a taboo-sexual distractor and a neutral distractor. Each subject received one of the two counterbalanced lists. No stimuli were repeated in the experiment.

Procedure

Participants received written instructions to name the second stimulus as fast as possible while ignoring the first word. They were informed that the targets consisted of nonwords that were not part of the Dutch language. Participants were instructed to respond as quickly and accurately as possible. The experiment started with eight practice trials. After the practice trials, the 64 experimental nonwords were presented, 32 nonwords were preceded by a taboo-sexual distractor and 32 nonwords were preceded by a neutral distractor. A different random presentation order was generated for each participant.

The presentation procedure (i.e., timing of warning signal, distractor, and target) was identical to that of Experiments 1–3. Participants were asked to read the target aloud as quickly and as accurately as possible. A voice key was used to measure the time between the onset of the target and the onset of the vocal response. After the response the experimenter entered a code to indicate whether the response was correct, incorrect, or a voice-key error had occurred (failure to trigger the voice key, or delayed or premature triggering of voice key). The next trial started immediately after the experimenter entered the code.

Results and Discussion

Reaction times for errors, voice-key failures, or responses more than two standard deviations above or below each participant's condition mean were excluded from the analyses. This resulted in the removal of 3.5% of the reaction times because of voice-key failures and removal of 4.5% of the correct reaction times because they were outliers. Table 4 shows the mean reaction times for correct responses and the percent errors. As can be seen, reaction times were slower to targets preceded by a taboo-sexual distractor than to targets preceded by an emotionally neutral distractor. This conclusion was confirmed by a *t*-test, showing that the impairment in performance due to taboo-sexual distractors

Table 4. Reaction times (in ms) and percent errors to nonword targets in the naming task of Experiment 4

Distractor	RT	PE
Taboo-sexual	570 (12)	3.3 (0.6)
Neutral	559 (11)	3.6 (0.9)
Impairment	11 (3)	−0.3 (0.8)

Note. RT = reaction time, PE = percent errors. Standard errors of the mean are provided in parentheses.

was significant, $t(37) = 3.44$, $p < .001$, partial $\eta^2 = .24$. Error rates were low and showed no significant effect, $t(37) < 1$.

The results of the present experiment generalize the findings from Experiments 1–3 to a new set of stimuli and, more important, to a new task, naming, in which semantic processing of the stimuli is not required. In fact, the target stimuli did not refer to meaningful concepts because they consisted of nonwords.

General Discussion

In the present study we showed that taboo-sexual distractors slow down responding to a subsequently presented neutral target in four different word recognition tasks. In Experiment 1 we showed that taboo-sexual distractors slow down lexical decisions to both word and nonword targets thereby extending previously obtained findings of Calvo and Castillo (2005). Similarly, in Experiment 2 we showed that taboo-sexual distractors slow down responding to both animate- and inanimate-target words in an animacy decision task. Experiment 3 showed that taboo-sexual distractors slow down rhyme decisions to target words, a task that does not require semantic processing. Finally, in Experiment 4 we showed that taboo-sexual distractors slow down speeded naming of target letter strings in a nonword naming task, a task that used meaningless stimuli.

These emotion-induced impairments were obtained across different sets of target stimuli, different sets of emotional distractors (English and Dutch language words), and different tasks, showing that the effect is robust. Perhaps most surprising, emotion-induced impairments were obtained despite the fact that several measures were taken that could have precluded the impact of the emotional distractor on performance to the target. In all four experiments of the present study target stimuli were not masked and presented until participants responded. Despite the fact that the target stimulus was clearly visible, the emotional distractor caused an impairment in responding to the target. Moreover, the emotional distractor had an effect even though it was presented for a much shorter duration than the target stimulus. Thus, it is not the case that the longer presentation of the target resulted in an elimination of the detrimental effect of the emotional distractor. In addition, the distractor and target were presented in a predictable manner thereby eliminating the temporal uncertainty that is associated with the RSVP paradigm. In the RSVP paradigm the target is presented at an unpredictable position in the stream of distractors. Therefore, it is impossible to focus attention on the target on the basis of temporal information alone. Rather, targets must be selected from the stream of stimuli on the basis of some stimulus dimension (meaning, color, letter case, or some other dimension), requiring that the content of all stimuli in the stream be processed to some degree. In the present study, however, there was no need to process the content of the distractor, because the target could be selected on the basis of its relative temporal position alone.

Previous findings in the RSVP paradigm have been attributed to limited-capacity stage 2 processing which turns transient stimulus representations into more stable ones (Bachmann & Hommuk, 2005; Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998; Mathewson et al., 2008). If emotional distractors capture attention and direct stage 2 processing to themselves, the transient representation of the target stimulus may have faded before stage 2 processing can be directed to it, thereby making the target unavailable for conscious report. In the RSVP paradigm, stimuli are briefly presented (usually between 75 and 120 ms) and masked (i.e., target stimuli are immediately followed by distractors). In the experiments of the present study, however, target stimuli remained on the screen until the participant responded. Thus, attention capture by emotional stimuli did not make the targets unavailable for conscious report. Nevertheless, performance was affected by emotional distractors suggesting that emotional distractors may have delayed stage 2 processing. This may have delayed awareness of the target and subsequent processing of the target resulting in delayed responding.

Our findings and those of others show that emotional stimuli interfere with the processing of subsequently presented neutral target stimuli. One interpretation of these results is that emotional distractors attract attention away from the target stimulus. An alternative account is that emotional stimuli cause a temporary freezing response by suppressing motor activity (cf. Azevedo et al., 2005; Fox, Russo, Bowels, & Dutton, 2001; Wilkowski & Robinson, 2006; for an elaborate discussion of this account see Estes & Verges, 2008). A motor suppression mechanism, however, does not account for several findings relevant to the present paper. For example, emotional distractors impair target processing not only in paradigms that measure speed of responding, but also in RSVP tasks (Arnell et al., 2007; Mathewson et al., 2008; Most et al., 2005) and other tasks that measure perceptual accuracy (Bocanegra & Zeelenberg, 2009; Zeelenberg & Bocanegra, 2010). If the effect of emotional distractors were simply to temporarily suppress motor activity the effect should be present in tasks that measure speed of responding but not necessarily in tasks that measure perceptual accuracy. Also, freezing has been proposed to account for behavioral changes when negative stimuli are present; freezing is supposed to prevent detection by predators. However, positive emotional distractors also impair subsequent target processing (Most et al., 2007). Finally, in a recent study, De Houwer and Tibboel (2010) showed that emotional distractor pictures impaired performance on no-go trials. That is, subjects more often erroneously emitted

a response to a no-go target when the target was preceded by an emotionally arousing picture compared to when it was preceded by a neutral picture. If emotional distractors suppress motor activity they should have resulted in a decrease in responding on no-go trials rather than an increase. We therefore consider a general motor suppression explanation of our results and related findings reported in the literature unlikely.

The finding of an emotion-induced impairment in the rhyme decision task of Experiment 3 and the nonword naming task of Experiment 4 indicates that such impairments can be found even when semantic processing of the stimuli is not required. This finding contrasts with that of Huang et al. (2008) who found emotion-induced impairments in the RSVP paradigm only when semantic processing of the stimuli was required. A possible explanation for the apparent differences is that the reaction time tasks used in the present study were more sensitive than the RSVP paradigm. Emotion-induced impairments may be driven by (at least partly) different processes in different tasks. In the tasks used in the present study emotional distractors may have delayed awareness of the target, but they may also have affected multiple post-perceptual processing stages (e.g., retrieval processes, decision making, response selection). Reaction time measures may be especially sensitive to these influences.

Another factor that may have contributed to the difference in results between the Huang et al. (2008) study and the present one lies in the stimuli used in these studies. Whereas Huang et al. used negative, mostly threat-related emotional words, we used taboo-sexual words in the present study. Some studies have suggested that threat-related words are less effective in capturing attention than taboo-sexual words (Aquino & Arnell, 2007; Mathewson et al., 2008). If it is indeed the case that taboo-sexual words are more effective in capturing attention than threat words, taboo-sexual words might cause an impairment in the RSVP paradigm even when no semantic processing of the stimuli is required.

It is worth noting that although our Experiments 3 and 4 did not require semantic processing of target stimuli, phonological processing was required both in Experiment 3 (rhyme decision) and Experiment 4 (nonword naming). What are the boundary conditions under which emotion-induced impairments are obtained? Would similar findings be found in tasks in which no or only a very limited amount of linguistic processing is needed? This could be investigated in tasks in which only superficial processing of target stimuli is required, for example, by asking subjects whether targets are presented in lowercase or uppercase letters, a task that involves only a limited degree of orthographic processing, or by asking subjects to make decisions about the color of a target stimulus, a task that requires no linguistic processing at all. On the one hand one might argue that emotion-induced impairments could be eliminated in situations in which no linguistic processing is required at all. On the other hand, reading and meaning activation are largely automatic processes and taboo-sexual words may capture attention even in situations that do not demand linguistic processing.

Another interesting question for future studies would be whether the effects of emotional distractors on speeded word recognition are driven by arousal, valence, or both. Mathewson et al. (2008) performed regression analyses to determine whether distractor arousal, distractor valence, or both predicted target performance in an RSVP task. They found that arousal ratings of distractors predicted accuracy on subsequent targets in RSVP tasks. Valence ratings did not predict target performance. Aquino and Arnell (2007) obtained similar results in a digit parity task. The present study was not designed to answer the question of which dimension, arousal or valence, causes emotion-induced impairments in the tasks we used. Our set of taboo-sexual distractors consisted of a relatively homogeneous set of highly arousing words. The fact that we obtained emotion-induced impairments suggests that arousal is an important factor because our taboo-sexual distractors were more arousing than our neutral stimuli but taboo-sexual distractors and neutral distractors did not differ in valence.[4] However, additional experiments using distractors with a much wider range of arousal and valence ratings are needed to obtain more definitive insights into the relative role of arousal, valence, and valence extremity in the emotion-induced deficits due to distractors in the speeded word recognition tasks used in the present study.

Effects of attention grabbing by emotional stimuli have been observed in a number of other tasks, such as the Stroop task (e.g., Pratto & John, 1991; Wentura, Rothermund, & Bak, 2000), the digit parity task (Aquino & Arnell, 2007) and, perhaps most notably, the dot probe task (Mogg & Bradley, 1999). In the standard version of the dot probe task, the target stimulus, a dot, can be presented on one of the two locations (usually to the left and right of fixation). In the valid condition, an emotional stimulus is presented on the same side as the dot and a neutral stimulus is presented on the opposite side. In the invalid condition, a neutral stimulus is presented on the same side as the dot and an emotional stimulus is presented on the opposite side. Subjects typically respond faster in the valid condition than in the invalid condition (e.g., Brosch, Sander, & Scherer, 2007; Mogg & Bradley, 1999). Emotional modulations in the dot probe task likely reflect the orienting of attention to the location of the emotional stimulus (as well as a failure to disengage from that location; Fox et al., 2001).

It is important to note that the tasks used in the present study as well as the RSVP tasks differ from the dot probe paradigm in several aspects (also see Zeelenberg & Bocanegra, 2010). Whereas spatial uncertainty is a key aspect of the dot probe task, stimuli were always presented on the same central location of the screen in the present experiment. Consistent with other studies (e.g., Mathewson et al., 2008; Most et al., 2005, 2007) in which the distractor and target are presented on the same location throughout the

[4] Taboo-sexual distractors tended to be somewhat more extreme in valence than neutral distractors. Nevertheless, valence extremity scores, defined as the absolute difference from the midpoint of the valence scale (5), were not significantly different for taboo-sexual distractors and neutral distractors.

experiment we obtained impairments for targets preceded by emotional distractors (as compared to neutral distractors). Note that this contrasts with findings from the dot probe task where the presentation of an emotional cue on the same location as the target enhances performance.

Although the underlying mechanisms and behavioral consequences of emotional cues are likely different in different types of paradigms, it is still possible that the same dimensions of emotional stimuli drive these emotion-induced effects. What are these dimensions? As we noted earlier, studies (Mathewson et al., 2008) suggest that the emotion-induced impairments in the RSVP paradigm are driven by arousal rather than valence. Likewise, Brosch et al. (2007) found that arousal, but not pleasantness ratings predicted reaction times on valid trials in a dot probe paradigm. The stimuli showing attentional capture effects in their experiment consisted of infant faces. Brosch et al. attributed their findings to the biological significance of these stimuli. In a Stroop task, Wentura et al. (2000) found that other-relevant trait adjectives produced longer response latencies than possessor-relevant adjectives. They reasoned that negative and positive other-relevant traits (e.g., *brutal, honest*) have a stronger tendency to grab attention because they are more relevant than possessor-relevant traits (e.g., *happy, depressive*). After all, traits such as *brutal* or *honest* may signal dangers or opportunities in the environment. In a similar way, our findings of attentional capture by taboo-sexual distractor words may be due to their biological relevance. Sex-related words have also shown effects on memory performance (e.g., MacKay et al., 2004). Moreover, ERP studies (Schupp, Junghöfer, Weike, & Hamm, 2003) have shown that erotic pictures modulate relatively early activations over temporo-occipital sites suggesting that their emotional content affects perceptual encoding. However, the links between biological relevance, arousal, and performance are still not entirely clear. For example, threat-related stimuli, which are clearly biologically relevant, affect behavior in some cases (e.g., Calvo & Castillo, 2005; Fox et al., 2001; Öhman, Flykt, & Esteves, 2001) but only under very limited circumstances or not at all in other cases (Aquino & Arnell, 2007; Harris & Pashler, 2004; Mathewson et al., 2008). Thus, the question of what type of emotional stimuli affects behavior in what kinds of tasks is clearly a topic that deserves more attention in future research.

To summarize, the results of the present study indicate that task-irrelevant emotional distractors impair performance to subsequently presented neutral target stimuli in a variety of speeded word recognition tasks (i.e., lexical decision, animacy decision, rhyme decision, and nonword naming). These effects were obtained even though the target stimuli were clearly visible, presented in a predictable manner and even when semantic processing of the stimuli was not required indicating that the detrimental effects of emotional distractors are more pervasive than indicated by previous studies.

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Appendix

Table A1. Taboo-sexual distractors used in Experiments 1–3

Word	Valence	Arousal
anus	4.70	4.85
arousal	6.25	5.35
ass	5.05	5.75
bastard	3.30	4.80
bitch	3.10	5.45
blowjob	6.00	5.80
boobs	6.60	5.55
breast	6.60	4.85
climax	6.70	6.20
clitoris	5.95	5.80
cock	5.40	4.60
condom	5.50	5.10
dildo	4.85	4.75
erotic	6.45	5.95
fetish	6.25	5.10
fondle	6.25	5.55
foreplay	6.95	5.35
fuck	5.15	6.65
gay	5.40	4.65
horny	6.05	5.85
incest	2.85	5.70
kinky	6.25	4.95
lesbian	5.55	4.40
libido	5.20	4.30
lust	5.40	6.10
naked	6.05	5.35
naughty	5.60	5.35
nipples	6.10	5.80
orgasm	7.10	6.40
orgy	5.80	5.25
penis	5.55	5.00
piss	3.75	4.35
pussy	5.90	6.15
scrotum	5.50	4.50
seduce	6.05	5.20
sexual	6.85	5.85
shit	3.55	4.85
slut	3.25	5.20
testicle	5.20	4.85
tits	5.75	5.70
vagina	6.15	5.50
vibrator	5.65	5.50
virgin	6.20	4.85
whore	3.05	5.05

Table A2. Taboo-sexual distractors used in Experiment 4

Dutch	English	Valence	Arousal
abortus	abortion	3.25	6.05
aftrekken	jerk off	5.45	5.05
anaal	anal	4.00	5.50
beffen	go down on	5.55	5.75
clitoris	clitoris	5.85	5.35
dildo	dildo	4.70	4.20
eikel	glans	4.00	4.40
erectie	erection	5.85	5.45
flikker	queer	3.65	3.30
geil	horny	6.90	6.05
hitsig	excited	6.30	5.35
hoer	whore	3.45	5.00
homo	gay	5.10	3.80
incest	incest	2.00	5.65
kut	cunt	4.80	4.45
lul	dick	4.35	4.50
masturberen	masturbate	5.75	5.60
neuken	fuck	6.75	6.00
opgewonden	aroused	7.15	6.10
orgasme	orgasm	7.70	6.05
pedofiel	pedophile	1.40	5.65
penis	penis	5.70	5.15
pijpen	give a blowjob	6.25	5.45
porno	porn	4.65	5.10
seks	sex	7.75	6.60
teef	bitch	3.65	4.15
tepel	nipple	5.60	5.05
tieten	tits	6.25	4.60
vagina	vagina	6.15	5.25
verkrachting	rape	1.15	7.25
vingeren	finger	5.95	5.55
vrijen	make love	7.25	6.25