RUNNING HEAD: RESPONSE BIAS IN THE ATTENTIONAL BLINK

Is the emotional modulation of the attentional blink driven by response bias?

Helen Tibboel

Bram Van Bockstaele

Jan De Houwer

Department of Experimental-Clinical and Health Psychology

Ghent University, Belgium

mailing address: Helen Tibboel

Department of Psychology

Ghent University

Henri Dunantlaan 2

B-9000 Ghent

Belgium

Email: Helen.Tibboel@UGent.be

Phone: 0032 9 264 86 18

Fax: 0032 9 264 64 89

Abstract

Several studies have shown that the attentional blink (AB; Raymond, Shapiro, & Arnell, 1992) is diminished for highly arousing T2 stimuli (e.g., Anderson, 2005). Whereas this effect is most often interpreted as evidence for a more efficient processing of arousing information, it could be due also to a bias to report more arousing stimuli than neutral stimuli. We introduce a paradigm that allows one to control for such a response bias. Using this paradigm, we obtained evidence that the diminished AB for taboo words cannot be explained by a response bias. This supports the idea that the emotional modulation of the AB is caused by attentional processes.

Several researchers have used the Attentional Blink (AB; Raymond, Shapiro & Arnell, 1992) task to examine whether emotional information is processed more efficiently than neutral information (e.g., Anderson, 2005; Keil & Ihssen, 2004). In a typical AB task, participants are required to identify two targets (T1 and T2) that are embedded in a rapid serial visual presentation (RSVP) stream of distractors. The common finding is that T1 is identified well, whereas T2 performance depends on the temporal lag between the targets. The AB refers to this effect: when the lag is short (i.e., less than 500 ms), T2 performance is poorer than when the lag is long (e.g., Raymond et al., 1992; but see the literature on Lag-1 sparing for the effects with SOAs shorter than 100 ms; e.g., Hommel & Akyurek, 2005). It was suggested that attentional resources are not sufficient to deal with all RSVP items and that these items compete for the attentional resources needed to gain access to consciousness (e.g., Isaak, Shapiro, & Martin, 1999; Potter, Staub, & O'Connor, 2002; Raymond et al., 1992; but for an alternative account see Olivers & Meeter, 2008). In an emotional version of the AB, usually two types of T2 stimuli are presented: neutral and highly arousing T2 stimuli (e.g., Anderson, 2005). For arousing stimuli, the AB is commonly smaller than for neutral stimuli. This suggests that highly arousing stimuli require less attentional resources to gain access into conscious awareness and are thus processed more efficiently (for other types of emotional modulation of the AB, see Ihssen & Keil, 2009; Stein, Zwickel, Ritter, Kitzmantel, & Schneider, 2009; Vermeulen, 2010).

However, it is possible that the decreased AB for emotional T2 stimuli is not caused by attentional processes but by a response bias. For instance, in Anderson's (2005) design, half of the trials contained a taboo T2 word and the other half of the trials contained a random neutral T2 word. It is likely that participants noticed that many trials contained a taboo word and that they used this information to improve their performance on the task. They may have adopted the strategy to report more taboo words than they would otherwise (i.e., in an experiment that does not involve taboo words) whenever they were unsure about their response. For instance, when participants only identify some letters of T2 such as “h…y”, they may tend to type in “hobby” when the experiment contains only neutral words. In an experiment in which half of the T2s are taboo, they may type in “horny” instead. This could lead to an improvement in performance for taboo words that is most apparent at short lags, where participants are more often unsure about their response than for the long lags. This would lead to an emotional modulation of the AB: better performance for taboo words than for neutral words at short compared to long lags.

A similar overrepresentation of emotional stimuli (i.e., at least half of the trials contained an emotional word) was present also in other studies (e.g., Keil & Ihssen, 2004). Existing evidence for the emotional modulation of the AB can thus be explained without assuming that taboo words are processed more efficiently than neutral words. Anderson tried to exclude the possibility of a response bias by coding incorrect answers as being either taboo or neutral on the basis of their meaning. He reasoned that a response bias would lead to more guesses that referred to taboo words. In contrast, he found that there were significantly more neutral guesses than taboo guesses and he concluded that there was no response bias.

Unfortunately, the evidence against a response bias that was provided by Anderson (2005) is not conclusive. Because there are many more neutral words than taboo words, it seems reasonable to assume that participants will always provide more neutral guesses than taboo guesses, even when the frequency of taboo guesses is increased relative to an experiment without taboo words. An analysis that focuses solely on the number of incorrect guesses may thus not be sensitive enough to detect a response bias. A possible solution for this conundrum is provided by Signal Detection Theory (SDT). This theory is used to estimate observers’ sensitivity to detect a specific signal and observers’ bias to report the signal even when they are uncertain (e.g., Wickens, 2002) on the basis of the number of hits (i.e., the participant correctly identifies the target) and false alarms (i.e., the participant reports that a target was presented when in fact another target was presented). D', the index of sensitivity, is based on the hit rate, but controls for the false alarm rate. Log β, the index of response bias, is based on the false alarm rate, but controls for the hit rate.

We therefore conducted a study that allowed us to implement signal detection analyses. We used an AB task that was comparable to the one used by Anderson (2005), with some exceptions. Most importantly, on each trial, participants had to select a response from a limited set of alternatives. Thus, whereas in Anderson's study, participants could refrain from entering a response and had the option to enter any word they thought of, this was not the case in our experiment. The advantage of our procedure is that each response can be coded as being either a hit or a false alarm, thus allowing for signal detection analyses.

Method

Participants

Twenty-nine psychology students at Ghent University (five men) participated in this experiment in exchange for course credits or a payment of eight euro. The mean age was 20.34 (*SD* = 2.35, range 18-28). All participants gave their informed consent and the appropriate ethical guidelines were followed.

Stimuli and Materials

Because we used a forced choice decision task, we had to limit the number of possible T2 stimuli. We therefore selected only six taboo words and six neutral words as T2 stimuli (see Appendix). This is a smaller number of T2 stimuli than is typically used in other studies (e.g., Anderson, 2005) but AB effects have been reported with even fewer T2 stimuli (e.g., Jackson & Raymond, 2006; Shapiro, Caldwell, & Sorensen, 1997). The taboo and neutral words did not differ in word length (*M* = 4.83, *SD* = .75 and *M* = 4.83, *SD* = .75, respectively). According to Dutch word frequency norms (Duyck, Desmet, Verbeke, &

Brysbaert, 2004) they did not differ in word frequency per million either (*M* = 7.33, *SD* = 8.33 and *M* = 7.00, *SD* = 9.06, respectively), all *t*s < 1.

There were 30 neutral T1 stimuli and 79 neutral distractors (word length: *M* = 5.70, *SD* = 1.18, and *M* = 12.73, *SE* = 2.07, respectively). Distractors were adapted from stimuli used by Anderson (2005). All words were Dutch.

Procedure

Participants were tested in a room that contained three separate cubicles in which computers were set up. One, two, or three participant(s) were tested during each session. They were seated in front of a 19 inch CRT-monitor with a refresh rate of 85 Hz, at a distance of approximately 60 cm. For stimulus presentation and response registration, we used the E-Prime software package (Schneider, Eschman, & Zuccolotto, 2002a, 2002b).

Each trial started with the presentation of a red fixation cross in the center of the screen for 1000 ms. This was followed by the RSVP stream, consisting of 13 white distractor words, and T1 and T2 in green. Each stimulus in the sequence was presented for 94 ms (equalling 8 screen refreshes), in 16 point bold Courier New font, in the center of the screen, against a black background. Participants were instructed to monitor the stream and to report the green words. At the end of each trial, the question: “What was the first green word?” appeared. Underneath the question, all 30 T1 stimuli were presented in 18 point bold Courier New font, arranged in three columns, ordered alphabetically. Participants were required to click the word that they thought they had seen. After this, the question: “What was the second green word?” appeared. This time, all T2 targets were presented on the screen, in 18 point bold Courier New font, arranged in three columns and ordered alphabetically. Again participants were required to click the word that they thought was presented. The experiment continued after the participant clicked a word. There was no response deadline.

T1 and the distractors were randomly selected from the list of T1 stimuli and the list of distractor stimuli respectively. T2 was randomly selected from the list of taboo T2 stimuli on half of the trials, and from the list of neutral T2 stimuli on the other half of the trials. The only constraint was that each T2 stimulus was presented equally often for each trial type. T1 could appear at the third or fifth position in the stream, and T2 could appear two or eight lags after T1 (i.e., with one or seven intervening distractors), reflecting a stimulus onset asynchrony (SOA) of 188 and 752 ms respectively. There were three experimental blocks. In each block, each of the eight trial types (2 T2 categories * 2 lags * 2 T1 positions) was repeated six times, yielding 48 trials per block. Each T2 stimulus was thus repeated 12 times. The relatively high number of repetitions was needed to yield stable means in each cell of the design. Trials were presented in a random order. At the beginning of the experiment, there was a practice block consisting of four trials that contained different neutral targets.

Data analysis

The proportion of correct responses was calculated for each of the experimental conditions for both targets. For the analysis of T2, only trials with a correct T1 identification were taken into account. We calculated the proportion of hits for each T2 stimulus, by dividing the number of times the participant correctly indicated that a specific T2 was presented by the number of times that this T2 was presented. We calculated the proportion of false alarms by dividing the number of times that a participant incorrectly indicated that this T2 was presented by the number of times that this T2 was not presented.

We then examined the hits and false alarms to see if there were any scores of 0 or 1. For technical reasons, when the score was 0, $^{1}/_{1000}$ was added and when the score was 1, $^{1}/_{1000}$ was subtracted.[1] On the basis of these hits and false alarms, we calculated d’ and log β for each stimulus. D’ was calculated using the following formula: $d' = Z(h) - Z(f)$ where “h” stands for hits and “f” for false alarms. D’ provides an index of the strength of a signal (i.e., in this case the strength of the T2 stimulus). We calculated log β by using the following formula: $\log \beta = ½[Z^2(f) - Z^2(h)]$. Positive log β scores indicate a bias to say that another signal was presented than the one that was actually presented. Negative log β scores reflect a bias to say that the signal was present when it was in fact not present (Wickens, 2002).[2]

Finally, we averaged the hits, false alarms, d' and log β for both categories of words. We performed four separate repeated measures ANOVAs (on hits, false alarms, d', and log β) with T2 type (taboo or neutral) and lag (2 or 8) as within-subjects factors.[3]

Results

We excluded the data of two participants from our analyses because their proportion of correct T1 identifications was more than 2.5 standard deviations below the group mean (M = .90, SD = .11). The identification of T1 did not differ between conditions, all Fs < 1.28. Relevant means of the analyses of T2 data can be found in Table 1.

Hits

Most importantly, the interaction between T2 type and lag was significant, $F(1, 26) = 8.83$, $p < .01$, $f^2 = .34$, indicating that the lag effect was weaker for taboo T2 stimuli than for neutral T2 stimuli. T-tests showed that performance was better for taboo T2 stimuli than for neutral T2 stimuli at Lag 2, $t(26) = 3.61$, $p < .005$. This difference was smaller but remained significant at Lag 8, $t(26) = 2.96$, $p < .01$. For both the taboo words and the neutral words, performance was better at Lag 8 than at Lag 2, $t(26) = 8.26$, $p < .001$, and $t(26) = 11.50$, $p < .001$, respectively. Second, a main effect for lag, $F(1, 26) = 110.40$, $p < .001$, showed better performance at Lag 8 compared to Lag 2. Finally, a main effect for T2 type, $F(1, 26) = 14.62$, revealed better performance for taboo than for neutral T2 stimuli.

False alarms

The interaction between T2 type and lag was significant, $F(1, 26) = 42.17$, $p < .001$, $f^2 = 1.62$. There were more false alarms for the neutral T2 stimuli than for taboo T2 stimuli. This difference was significant at Lag 2, $t(26) = 6.38$, $p < .001$, but not at Lag 8, $t < 1$. Furthermore, a main effect for lag, $F(1, 26) = 116.55$, $p < .001$, showed that there were more false alarms at Lag 2 than at Lag 8. Finally, a main effect for T2 type, $F(1, 26) = 34.62$, $p < .001$, revealed more false alarms for neutral than for taboo T2 stimuli.[4]

D’

Our analyses of d’ scores mirrored the analyses of the hits. Most importantly, the interaction between T2 type and lag was significant, $F(1, 26) = 17.92$, $p < .001$, $f^2 = .69$. The lag effect was stronger for neutral than for taboo T2 stimuli. Paired samples t-tests revealed that performance was better for taboo words at Lag 2, $t(26) = 5.62$, $p < .001$, and at Lag 8, $t(26) = 3.98$, $p < .001$. For both the taboo words and the neutral words, d’ was higher at Lag 8 than at Lag 2, $t(26) = 12.20$, $p < .001$, and $t(26) = 15.52$, $p < .001$. A main effect for lag, $F(1, 26) = 221.27$, $p < .001$, revealed a higher d’ at Lag 8 than at Lag 2, and a main effect for T2 type, $F(1, 26) = 35.84$, $p < .001$, revealed a higher d’ for taboo T2 stimuli than for neutral T2 stimuli.

Log β

The ANOVA for the log β scores revealed also an interaction between T2 type and lag, $F(1, 26) = 12.40$, $p < .005$, $f^2 = .48$. Paired samples t-tests showed that there was a significant difference between log β for neutral compared to taboo T2 stimuli at Lag 2, $t(26) = 2.59$, $p < .05$. When the presented T2 stimulus was a taboo word, participants were more biased to say that a different stimulus was presented than when the presented T2 stimulus was a neutral word. At Lag 8 there was also a significant difference in log β for taboo T2 stimuli and neutral T2 stimuli, $t(26) = 2.44$, $p < .05$, but the direction of the effect was reversed. When a neutral T2 stimulus was presented, participants were more biased to say that the stimulus was not present than when a taboo stimulus was presented. Furthermore, there was a difference between Lag 2 and Lag 8 for the taboo T2 stimuli, $t(26) = 4.25$, $p < .001$, but not for the neutral T2 stimuli, $t < 1$. Finally, a main effect for lag, $F(1, 26) = 9.55$, $p < .01$, showed that there was a strong bias to say the target was absent on Lag 2, but less so at Lag 8. There was no effect for T2 type, $F < 1$.

Discussion

The primary aim of this study was to examine whether the decreased AB for taboo T2 stimuli could be explained by a bias to report more taboo than neutral T2 stimuli. First, our data clearly show that the AB is diminished for taboo compared to neutral T2 stimuli. We found this pattern of results both when we analysed only the hits and when we analysed d’. We thus managed to replicate the finding that the AB is modulated by arousing stimuli (e.g., Anderson, 2005) even when controlling for response bias. These results are in line with theories stating that emotionally arousing stimuli are preferentially attended to and processed more efficiently than neutral information (e.g., Anderson, 2005; Öhman, Flykt, & Esteves, 2001).

Second, when we analysed the false alarms and log β, we found that there was a bias *against* reporting taboo words at short lags. Whereas Anderson’s analyses did not allow one to estimate the size and direction of the response bias, nor its effect on the emotional modulation of the AB, our results conclusively demonstrate that there is a bias against reporting taboo words at short lags which counteracts the emotional modulation of the AB. As such, our results suggest that the modulation of the AB by taboo T2 stimuli is based on genuine attentional processes involved in accessing consciousness, and that this effect might actually have been underestimated in previous studies. In line with this conclusion, we observed that the effect size of the modulation of the AB in the analysis of the sensitivity (d’) scores was twice the effect size yielded by the analysis of the hits. This suggests that our modification of the AB task allows one to optimize the magnitude of the emotional modulation of the AB and thus offers substantial benefits for future research.

In sum, our findings confirm that the modulatory effects of taboo T2 stimuli are based on attentional processes involved in accessing consciousness. The design of our study allowed for more in-depth analyses of the mechanisms underlying the emotional modulation of the AB. We thus provide a more solid basis for drawing the conclusion that the diminished AB for taboo words cannot be explained by a response bias.

The fact that the participants in our study were biased not to report taboo T2 stimuli is also interesting as such. First, it needs to be noted that according to the logic of signal detection, there is no contradiction between the bias against reporting taboo words and the increased sensitivity to detect taboo words. The aim of signal detection is to disentangle response bias and sensitivity. These two components need not be consistent with each other. Second, the bias can be linked previous research in other fields. For instance, McGinnies (1949) has shown that participants have higher identification thresholds for taboo than for neutral words, whereas their galvanic skin response (GSR) preceding identification of taboo words was increased compared to the GSR preceding identification of neutral words. This was taken as support for the “perceptual defense hypothesis”, which assumes that the affective content of arousing stimuli can be processed unconsciously and causes identification thresholds to be raised as a means to “protect” the individual from negatively reinforced information. Later studies (e.g., Eriksen & Browne, 1956) have criticized McGinnies for testing participants in a context were they were embarrassed to overtly identify taboo words. The slower identification of taboo words may have been due to a response bias instead. Our data indeed suggest that participants are able to process taboo words very efficiently (i.e., thresholds are low), but they use a rather conservative criterion to report these words. When they in doubt, they tend to choose the “safe” neutral option.

Even though the modulation of the AB by arousing T2s does not seem to be due to a response bias, the question remains whether it is actually due to the arousing nature of the stimuli. A potential confound in previous studies is that the arousing stimuli usually form a coherent category (e.g., Anderson, 2005; Keil & Ihssen, 2004), whereas the control stimuli are randomly selected neutral words from various semantic categories. The fact that the arousing stimuli stand out because of their coherence could account for the reduced AB for these stimuli. Nevertheless, some researchers did take coherence into account. Anderson (2005, Experiment 2) and Keil and Ihssen (2004, Experiment 3), for instance, have used tools and verbs denoting tool use as neutral T2 stimuli and still found a significantly smaller AB for emotional T2 stimuli. It is thus unlikely that our findings can be explained entirely by the fact that the taboo words formed a coherent category, whereas the neutral words did not.

Finally, it is still possible that a response bias accounts for modulatory effects in other versions of the AB in which the salience of T2 is manipulated. In an increasing number of studies the AB has been used to examine the efficiency with which specific “special” stimuli are processed, such as participants’ own name (Shapiro, Caldwell, & Sorensen, 1997) and famous faces (Jackson & Raymond, 2006). Finally, the AB is used frequently in (sub-)clinical contexts to examine addiction (Liu, Li, Ma, & Sun, 2008; Tibboel, De Houwer, & Field, in press), specific phobias (Trippe, Hewig, Heydel, Hecht, & Miltner, 2007) and anxiety (Fox, Russo, & Georgiou, 2005). We suggest that researchers who want to make a serious claim about the special attentional status of any type of stimuli should perform more meticulous analyses to exclude the possibility that these effects are driven by a response bias. As we have shown, a design such as the one we have introduced in this paper allows for such analyses.

References

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General, 134,* 258-281.

Duyck, W., Desmet, T., Verbeke, L. P. C., & Brysbaert, M. (2004). WordGen: A tool for word selection and nonword generation in Dutch, English, German, and French. *Behavior Research Methods, Instruments, & Computers, 36*, 488-499.

Eriksen, C. W., & Browne, C. T. (1956). An Experimental and Theoretical-Analysis of Perceptual Defense. *Journal of Abnormal and Social Psychology, 52*, 224-230.

Fox, E., Russo, R., & Georgiou, G. A. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. *Cognitive, Affective, & Behavioral Neuroscience, 5*, 396-404.

Hommel, B., & Akyurek, E. G. (2005). Lag-1 sparing in the attentional blink: Benefits and costs of integrating two events into a single episode. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 58*, 1415-1433.

Ihssen, N., & Keil, A. (2009). The costs and benefits of processing emotional stimuli during rapid serial visual presentation. *Cognition & Emotion*, *23*, 296-326.

Isaak, M. I., Shapiro, K. L., & Martin, J. (1999). The attentional blink reflects retrieval competition among multiple rapid serial visual presentation items: Tests of an interference model. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1774-1792.

Jackson, M. C., & Raymond, J. E. (2006). The role of attention and familiarity in face identification. *Perception & Psychophysics, 68*, 543-557.

Keil, A., & Ihssen, N. (2004). Identification facilitation for emotionally arousing verbs during the Attentional Blink. *Emotion, 4*, 23-35.

Liu, N., Li, B., Sun, N., & Ma, Y. (2008). Effects of addiction-associated and affective stimuli on the attentional blink in a sample of abstinent opiate dependent patients. *Journal of Psychopharmacology*, *22,* 64-70.

McGinnies, E. M. (1949). Emotionality and perceptual defense. *Psychological Review, 56,* 471-482.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*, 466-478.

Olivers, C. N. L., & Meeter, M. (2008). A Boost and Bounce Theory of Temporal Attention. *Psychological Review, 115*, 836-863.

Potter, M. C., Staub, A., & O'Connor, D. H. (2002). The time course of competition for attention: Attention is initially labile. *Journal of Experimental Psychology-Human Perception and Performance, 28,* 1149-1162.

Raymond, J. E., Shapiro, K., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18,* 849-860.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002a). *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools Inc.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002b). *E-Prime Reference Guide*. Pittsburgh: Psychology Software Tools Inc.

Shapiro, K. L., Caldwell, J., & Sorensen, R. E. (1997). Personal names and the attentional blink: A visual "cocktail party" effect. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 504-514.

Stein, T., Zwickel, J., Ritter, J., Kitzmantel, M., & Schneider, W. X. (2009). The effect of fearful faces on the attentional blink is task dependent. *Psychonomic Bulletin & Review, 16,* 104-109.

Tibboel, H., De Houwer, J., & Field, M. (2009). Reduced attentional blink for alcohol-related stimuli in heavy social drinkers. *Journal of Psychopharmacology*, 0269881109106977.

Trippe, R. H., Hewig, J., Heydel, C., Hecht, H., & Miltner, W. H. R. (2007). Attentional Blink to emotional and threatening pictures in spider phobics: Electrophysiology and behavior. *Brain Research*, *1148*, 149-160.

Vermeulen, N. Current positive and negative affective states modulate attention: An attentional blink study. *Personality and Individual Differences*, *49*, 542-545.

Wickens, T. D. (2002). *Elementary Signal Detection Theory*. Oxford: University Press.

Author note

Helen Tibboel, Bram Van Bockstaele, and Jan De Houwer, Department of Experimental-Clinical and Health Psychology, Ghent University, Ghent, Belgium.

Helen Tibboel is a Research Assistant of the Flemish Research Foundation (FWO - Vlaanderen). The preparation of this manuscript was supported by Grant BOF/GOA2006/001 of Ghent University. Correspondence regarding this article should be addressed to Helen Tibboel, Department of Experimental-Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, 9000 Ghent, Belgium. Email: helen.tibboel@ugent.be

Footnotes

[1] Scores of 0 and 1 needed to be adjusted because these values cannot be normalized. When the proportion of hits for a specific stimulus was 0, this stimulus was never identified correctly. When the proportion of false alarms was 0, this stimulus was never incorrectly chosen. When the proportion of hits was 1, this stimulus was always identified correctly. When the proportion of false alarms was 1, this stimulus was always incorrectly chosen when in fact another stimulus was presented. For the false alarms there were no scores of 1. At Lag 2, the percentage of scores of 0 was 13.22 for the neutral words (*SD* = 9.91), and 26.44 (*SD* = 7.12) for the taboo words. At Lag 8, the percentage of 0 scores was considerably higher: 78.16 percent for the neutral words (*SD* = 4.18) and 79.89 percent for the taboo words (*SD* = 5.93). For the hits, the percentage of scores of 1 at Lag 2 was 12.64 (*SD* = 12.08) for neutral words, and 19.54 for taboo words (*SD* = 13.21). At Lag 8, this percentage was higher: 73.56 (*SD* = 8.06) and 84.48 (*SD* = 3.62) respectively. The percentage of 0 scores at Lag 2 was 14.37 (*SD* = 6.69) for the neutral words, and 5.17 (*SD* = 1.89) for the taboo words. There were no scores of 0 at Lag 8.

Note that both scores of 0 and scores of 1 are valid data points, that were replaced solely for the purpose of normalization. As Wickens (2002) points out, it is important to realize that the addition or subtraction of a value like $^{1}/_{1000}$ is arbitrary. But as we substitute these values for both the neutral and the taboo hits and false alarms, the effect of the substitutions is equal for both categories and can thus not explain our effects. Furthermore, we also performed the same ANOVAs on the data after adding (subtracting) $^{1}/_{100}$ to (from) the 0 (1) scores. Results were virtually the same.

[2] Our results show that for both neutral and taboo T2 stimuli, participants are biased to select an alternative other than the target. We must note that log β is usually used in tasks where there are only two response alternatives. However, in our study 12 response

alternatives. This decreases the proportion of false alarms per stimulus. If a participant makes an incorrect response on a two-alternative forced choice task, the one alternative response is chosen. In our task, there is one correct and 11 incorrect answers. If a participant is incorrect, and each alternative response has an equal chance of being chosen, there is a false alarm for each stimulus in 1/11 of trials. Because the low number of false alarms distorts log β, we will focus on the difference in bias between neutral and taboo T2 stimuli instead of focussing on absolute values.

[3] An ANOVA with block as an additional within-subjects factor yielded the same results.

[4] Note that an "apple" false alarm can occur both when a neutral word was presented (i.e., "delta") and when a taboo word (i.e., "anal") was presented. In these analyses we do not make a distinction between these two situations. However, we analysed the false alarms also with an ANOVA with three within-subjects factors: response type (neutral or taboo), target type (neutral or taboo), and lag (2 or 8). We found only a main effect of target type, $F(1, 26) = 21.34$, $p < .001$, showing that there were more false alarms when a neutral target was presented. This mirrors the main effect of T2 type in the analyses of hits (i.e., more incorrect answers when a neutral T2 was presented). Target type did not have a main effect and did not affect any of the higher order interactions, *Fs* < 1.

Table 1

Proportion of Hits, False Alarms, D', and Log β given Correct Identification of T1

	Lag 2		Lag 8	
T2 type	*M*	*SD*	*M*	*SD*
Hits				
Neutral	.54	.21	.94	.05
Taboo	.65	.21	.97	.06
False alarms				
Neutral	.05	.03	.00	.01
Taboo	.02	.01	.00	.01
D'				
Neutral	1.97	1.36	5.37	.64
Taboo	2.95	1.24	5.66	.67
Log β				
Neutral	.55	1.19	.63	.60
Taboo	1.35	1.28	.03	.82

Appendix

T2 stimuli

Taboo words

ANAAL (anal), DILDO (dildo), GEIL (horny), ORGIE (orgy), SEKS (sex), SPERMA (sperm)

Neutral words

APPEL (apple), DELTA (delta), GRIL (whim), OPTIE (option), SPRAAK (speech), ZEIS (scythe)