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Murder, She Wrote: Enhanced Sensitivity to Negative Word Valence

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Enhanced sensitivity to information of negative (compared to positive) valence has an adaptive value, for example, by expediting the correct choice of avoidance behavior. However, previous evidence for such enhanced sensitivity has been inconclusive. Here we report a clear advantage for negative over positive words in categorizing them as emotional. In 3 experiments, participants classified briefly presented (33 ms or 22 ms) masked words as emotional or neutral. Categorization accuracy and valence-detection sensitivity were both higher for negative than for positive words. The results were not due to differences between emotion categories in either lexical frequency, extremeness of valence ratings, or arousal. These results conclusively establish enhanced sensitivity for negative over positive words, supporting the hypothesis that negative stimuli enjoy preferential access to perceptual processing.

Keywords: emotion, awareness, negative valence detection

Rapid and accurate detection of information of negative emotional valence has a clear adaptive value from both biological and psychological perspectives (e.g., for engaging in avoidance behavior to prevent potential harm or unpleasant social exchanges). However, the evidence to date for an advantage in detecting negative (over positive) valence remains inconclusive. Furthermore, detection of valence has typically been inferred indirectly from the effects of valence in tasks requiring attention and/or stimulus detection, in which stimuli could carry positive, negative, or neutral information. However, what matters for rapid responses to negative valence is detection of the valence itself. Therefore, in the present study, we sought to establish whether the presence of emotional valence in word stimuli is better detected in negative than in positive words, with an explicit direct measure for detection of valence.

Previous research (reviewed below) on the link between valence and perception raises three major issues: First, are effects of negative valence due to valence per se, or could they instead be due to higher arousal, which can be conceptualized as an independent stimulus dimension but tends to be more associated with negative than positive valence (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Bradley, Codispoti, Cuthbert, & Lang, 2001; Hamann, Ely, Grafton, & Kilts, 1999)? Second, is there indeed an enhancement of perceptual sensitivity to information of negative valence, or do the effects of negative valence reflect biases due to response prioritization or criterion differences? And third, do the effects of negative valence require full conscious awareness?

In the present study, we demonstrate that the negative valence of verbal information is detected with both better accuracy and higher sensitivity, compared to positive information. Moreover, we find that these effects do not reflect a response bias, can be found even when the negative information does not correlate with higher arousal and extend to reports that do not involve full conscious awareness of the information.

We focus on the perception of valence in verbal information (written words, rather than pictorial representations such as facial expressions or snakes and spiders) for a number of reasons. First, orthographic verbal stimuli convey rich and meaningful emotional information pertaining to the complex social environment of human interaction, beyond immediate implications for survival. Second, unlike pictorial stimuli, any effects of emotional content in words cannot be attributed to a difference in their low-level visual properties. Finally, level of familiarity for words (measured by lexical frequency) can be equated for different valences.

Below we briefly review the previous research on this topic, highlighting studies using attentional tasks that have raised the issues of arousal and response prioritization as possible factors in the preferential processing of negative stimuli; and studies using word detection and naming tasks that have raised the issues of whether negative stimulus advantages could result from response biases and whether full conscious awareness of the stimuli is necessary for such advantages to emerge. In line with our current focus, we restrict our review to studies of word processing.

Attention and Arousal

Negative (compared to neutral or positive) words have been found to produce greater reaction time (RT) interference effects

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(McKenna & Sharma, 1995; Pratto & John, 1991), as well as larger event-related potential (ERP) amplitudes (Thomas, Johnstone, & Gonsalvez, 2007) in the emotional Stroop task, in which participants attempt to ignore the semantic content of a word and respond to some other stimulus dimension (e.g., reporting the color in which the word is written). As the emotional content of the words is supposed to be unattended, such effects may at first sight appear to suggest an early, preattentive perceptual processing advantage for the negative words (e.g., in the form of "automatic vigilance"; see Pratto & John, 1991). However, much attention research indicates that the mere instruction to ignore stimuli or any of their attributes does not render them unattended (e.g., Lavie, 1995; Lavie & Cox, 1997; Lavie & Fox, 1998; Lavie, Hirst, De Fockert, & Viding, 2004). In situations that do not overload attentional capacity (such as those typically employed in the emotional and other Stroop-like tasks), there is now much evidence that task-irrelevant stimuli are in fact attended (see Lavie & Tsal, 1994; Lavie, 2005 for reviews). In such cases, the greater interference caused by negative words may therefore implicate other processes rather than early, preattentive perceptual sensitivity. For example, negative stimuli may engage attention or semantic processing for longer, or recruit additional processes, such as working memory (e.g., see a related recent suggestion in the case of short term memory for faces; Jackson, Wolf, Johnston, Raymond, & Linden, 2008; Jackson, Wu, Linden, & Raymond, in press).

In addition, the interference effects of valence may, at least under some conditions, be due to arousal rather than valence; a recent study (Aquino & Arnell, 2007) found that only highly arousing sexual taboo words, but not less arousing threatening words or nonarousing neutral words, produced longer RTs in a version of the emotional Stroop task that required making number parity judgments while ignoring an irrelevant word. These findings are reminiscent of the "perceptual defense" effects whereby taboo words produce longer RTs (e.g., McGinnies, 1949) and may result from greater attentional engagement as well as the recruitment of additional processes such as executive control by highly arousing words.

To investigate whether stimuli with emotional valence engage attention, some studies have used the attentional blink paradigm, where the allocation of attention to a first target in a rapid serial visual presentation (RSVP) of stimuli leads to impaired detection of a second target presented shortly afterward (Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1997). When the valence and arousal of distracter words appearing before the target (and therefore serving as an equivalent of the first target in the attentional blink paradigm) were manipulated, only highly arousing sexual taboo (but not negative, positive, threatening, or neutral) words caused reduced identification of targets (color names) that followed shortly after them (Arnell, Killman, & Fijavs, 2007). Furthermore, a recent study (Huang, Baddeley, & Young, 2008) found that negative words appearing before a target impaired the subsequent detection of the target more than neutral words did, but only when target detection required semantic processing—not when it required shape-based or phonological processing. Negative stimuli may therefore engage attention, but it seems that such engagement is limited to an attentional set requiring semantic processing, and the effects found may at least in some cases be due to arousal rather than valence.

More relevant to the present investigation are demonstrations that negative words are less susceptible to the attentional blink—that is, that they are more likely than neutral words to be detected when they are presented as the second target in the in a rapid serial visual stream (e.g., Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004; Ogawa & Suzuki, 2004). Some studies clearly indicate such a processing advantage for negative over positive valence (e.g., Ogawa & Suzuki, 2004), which can be found even when arousal levels are matched for the negative and positive words (Kihara & Osaka, 2008). However, other studies have found both negative and positive words to be less vulnerable than neutral words to the attentional blink (e.g., Anderson, 2005; Keil & Ihssen, 2004) as long as both the positive and negative words were associated with higher arousal than the neutral words (Anderson, 2005). It must be noted that findings from attentional blink experiments may be mainly relevant to situations in which the allocation of attentional resources to one target or another must be managed: As with any dual-task paradigm, a sequential two-target task like that used to observe the attentional blink is highly susceptible to effects of processing prioritization. Therefore, it is possible that subjects prioritize the second-target task when it involves emotional words. Finally, as the RSVP employed in the attentional blink paradigm places high demands on attention, it is not clear whether any effects of valence found are due to valence-dependent differences in prioritization when attentional requirements approach capacity limits, or whether such effects are more fundamental and can be found with measures of perceptual processing that do not impose such high demands on attention.

Awareness and Response Bias

Few studies have measured the effects of valence on word perception, as measured with naming or presence (vs. absence) detection of briefly presented masked words. The hypothesis tested was that if negative emotional valence enjoys an early (and perhaps even unconscious) processing advantage, then it should facilitate word naming or detection. The results of these studies present an inconsistent picture. Gaillard, Del Cul, Naccache, Vinckier, Cohen, and Dehaene (2006) found that the duration threshold for accurately naming briefly presented, masked words was shorter for negative than for neutral words, and that participants subjectively rated negative words as more visible than neutral ones. Gaillard et al. (2006) interpreted this finding as implying that the semantic content (including valence) of written words can be unconsciously processed. Further support for this suggestion comes from neurophysiological studies in which subliminally presented negative words led to larger ERP amplitudes (Bernat, Bunce, & Shevrin, 2001), single-unit responses from amygdala neurons in awake humans (Naccache, Gaillard, Adam, Hasboun, Clémenceau, et al., 2005), and skin conductance responses (Silvert, Delplanque, Bouwalerh, Verpoort, & Sequeira, 2004) than neutral or positive words. Gaillard et al. (2006), however, did not examine positive words. Therefore, no conclusions can be drawn regarding valence-detection differences between positive and negative words.

Dijksterhuis and Aarts (2003) used brief presentations of either a word or a blank screen followed by a mask, and asked participants to report whether or not a word had been shown. Positive and negative words were used, and results showed better word-detection for negative than positive words. However, the use of both word categories in the same experimental blocks made it impossible to assess false alarm rates separately for each valence, preventing the adoption of a signal-detection approach that would allow for the calculation of sensitivity and criterion measures. Thus, the results may have been due to response biases, such as a more lax criterion for reporting negative words (Labiouse, 2004; but see response by Dijksterhuis, Corneille, Aarts, Vermeulen, & Luminet, 2004, which mentions unpublished research by Corneille, Vermeulen, Luminet, and Dijksterhuis indicating that negative valence can affect word-detection sensitivity, not just response bias).

Zeelenberg, Wagenmakers, and Rotteveel (2006) used a two-alternative forced choice task, where on each trial participants were presented with a brief masked word, were then shown the target and a foil and had to choose which one they thought they had just been presented with. Results showed more accurate choices of both negative and positive words compared to neutral words, but no difference between positive and negative words. The valence of foils in the forced choice task was manipulated to assess response bias, and no such bias was found. Though the logic underlying the measures of accuracy and bias used in this study is sound, these measures may have been too crude to detect subtle effects that a signal detection approach may have been able to pick up.

Snodgrass and Harring (2005) did adopt such an approach in a task requiring participants to identify brief masked stimuli as words or random letter strings. Positive and negative words were presented in separate blocks. Somewhat surprisingly, results showed better sensitivity (measured by d' scores) to positive than to negative words. No analysis of whether this sensitivity difference was accompanied by a difference in response bias was reported, though.

The discrepancies between the results of these three studies, despite their use of similar measures, may be due to their use of small word sets. Dijksterhuis and Aarts (2003) used only 15 words of each valence, Snodgrass and Harring (2005) used only 14, and Zeelenberg et al. (2006) used only 16 words in each condition. Such small sets could be heavily influenced by some word-specific effects (e.g., one category being more orthographically cohesive than the other, allowing for priming based on letter shapes; Abrams & Greenwald, 2000). Moreover, valence ratings in these studies were obtained either from separate pilot studies or published databases. Individual, idiosyncratic differences in valence attribution may therefore have either biased the results or reduced the experimental power to find an effect (e.g., in the case of Zeelenberg et al., 2006).

Finally, arousal levels were not measured in these studies, despite the important role of arousal (highlighted in the above review) in the effects of emotion. Differences in arousal between the valence categories used in the different studies may have thus accounted for the difference in the results.

The Present Study

In the present study, we sought to establish whether the emotional valence of negative words is better detected than that of positive words. To investigate whether or not processing of the valence itself (rather than the specific identity of each word) differed for negative and positive valence, the task in all the experiments reported below was to report on each trial whether a briefly presented word, preceded and followed by masks, was emotional or neutral. Note that the task did not require word detection per se; words were presented on all trials. Rather, to report whether the word was emotional or neutral, participants had to detect its emotional valence. Thus, we refer to this task throughout the paper as valence detection (as opposed to word detection). We used a large corpus of words and controlled for the possibility that participants may have idiosyncratic valence ratings (Experiments 1–3) as well as for differences in arousal between the different word categories (Experiment 3).

In Experiments 1 and 2, we employed a signal-detection approach and measured both sensitivity (d' scores) and response bias (beta scores) to assess whether any valence-detection advantage reflects enhanced sensitivity, rather than a mere response bias. Each block of trials comprised presentations of neutral words and one type of emotional word (either positive or negative), thus allowing the separate measurement of hits and false alarm rates (misclassifying neutral words as emotional) for each valence. In Experiment 3, we addressed the potential role of arousal differences both between the specific words presented (by equating arousal for the different valence categories on the basis of the participants' own ratings) and overall, across whole blocks, by using a mixed-block design, in which positive, negative, and neutral words were presented in the same blocks.

Experiment 1

Method

Participants

Twenty-seven participants (mean age 26, range 18–44; 20 females), recruited from University College London's online subject pool, took part in Experiment 1 and were paid £5 for their participation. All participants in all three experiments were native English speakers and had normal or corrected-to-normal vision.

Stimuli and Procedure

Eighty-eight negative, 88 positive, and 176 neutral words were selected from the Handbook of Semantic Word Norms (Toglia & Battig, 1978). Words were chosen such that on a scale of 1 (most negative) to 7 (most positive) ratings were lower than 2.5 for negative words ($M = 2.24$, $SD = 0.18$); higher than 5.5 for positive words ($M = 5.75$, $SD = 0.2$); and midrange for neutral words ($M = 4$, $SD = 0.11$, range = 3.82–4.19). Word length ranged between three and eight letters. Mean word lengths were 5.43 ($SD = 1.39$), 5.31 ($SD = 1.51$), and 5.15 ($SD = 1.27$) letters for negative, positive and neutral words, respectively.

The experiment took place in a dimly lit room. E-Prime 1 (Psychological Software Tools) was used to run the experiment on a personal computer with a 15" CRT screen (90-Hz refresh rate). A chin rest was used to maintain a viewing distance of 60 cm. Each trial began with a fixation cross, presented for 500 ms. A mask (eight hash characters) was then presented for 67 ms, followed immediately by a word, presented for either 22 ms or 33 ms (in different blocks). The word was replaced by another mask, again presented for 67 ms (Figure 1). All stimuli were presented in the

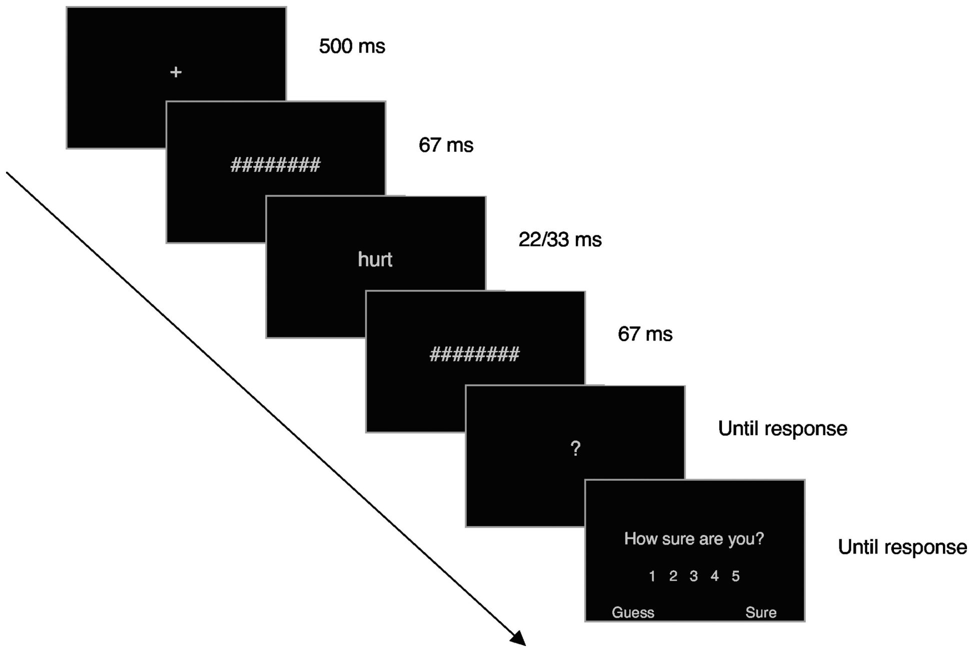

Figure 1. Trial sequence in Experiment 1. Trial onset was indicated by a fixation cross. The presentation of a word (in this example, a negative one) was preceded and followed by masks. Participants then indicated by key presses first whether the word had been emotional or neutral, and then how confident they were of that response.

center of the screen in light gray (target word = 3.45 cd/m^2, mask = 5.58 cd/m^2) on a black background (0.014 cd/m^2). The words were presented in lower-case Arial Narrow font. Word length ranged between 0.67° and 3.15°, and height ranged between 0.47° and 0.86°.

Valence and word exposure duration were blocked. Participants were informed of the type of block before each block, and were requested to press one key if a word had emotional connotations (positive or negative, depending on the block), and another to report a neutral word. Following each response, participants were asked to rate their confidence by pressing one of the 1 (*pure guess*) to 5 (*absolutely sure*) keys. Each block consisted of 44 trials (22 emotional and 22 neutral words, presented in random order). Each word was presented once during the experiment. The assignation of neutral words to negative or positive blocks was counterbalanced across participants.

Participants completed four practice blocks of 12 trials each (different words were used in the practice and experiment). This was followed by eight experimental blocks (four each for positive and negative valence; for each valence there were two blocks with 33-ms and two with 22-ms presentation durations). Block order was counterbalanced across participants for both valence and exposure duration. Half of the words in each category (positive, negative, and neutral) were used in each of the duration conditions; the combinations of word-list pairings (which neutral words were presented with which positive or negative words, for each duration) were also counterbalanced.

Upon completion of the experiment, participants provided subjective valence ratings for the words used in the experiment using a 1 (*very negative*) to 7 (*very positive*) scale. These ratings were used to ensure that the valence of each emotional word category was comparable, by equating their average distance from the extreme. For each individual, whenever the mean for one category was closer to the extreme than the mean for the other category, the most extreme words from that category and least extreme words from the other category were removed from any further analysis, until the mean valence ratings of the word categories were at an equal distance from the relevant extreme and standard deviations were similar. This resulted in the removal of six (33 ms) and seven (22 ms) negative words, and seven (33 ms) and six (22 ms) positive words on average per participant. The remaining word lists had mean ratings of 2.19 for the negative words (SD = .87), and 5.76 for the positive words (SD = .84). No neutral words were excluded as their mean ratings did not significantly differ from 4 (M = 3.93, SD = .29).

Results

The results of Experiment 1 are summarized in Table 1. Correct categorizations were defined as hits, and used to calculate accuracy rates for each valence. The hit and false alarm (categorizing a neutral word as emotional) rates were used to calculate d' and beta scores. Percentage accuracy (hit) rates, and d' and beta scores were entered into 2 (valence: positive or negative) × 2 (duration: 22 or 33 ms) repeated measures analysis of variance (ANOVA). These analyses reveled a main effect of duration both for hit rates ($F(1, 26) = 10.17$, $MSE = 351.21$, $p = .004$) and d' scores ($F(1, 26) = 50.15$, $MSE = .263$, $p < .001$): Both accuracy and sensitivity were better under the 33 ms exposure than the 22 ms conditions. Importantly, there was also a main effect of valence for both hit rates ($F(1, 26) = 27.75$, $MSE = 248.51$, $p < .001$) and d' scores ($F(1, 26) = 9.04$, $MSE = .465$, $p = .006$), indicating that valence

Table 1
Experiment 1: Mean Percentages of Hits (False Alarms), Mean d′ and Beta scores, and Mean Confidence Ratings as a Function of Presentation Duration and Word Valence

	Duration			
	22 ms		33 ms	
Variable	Negative	Positive	Negative	Positive
Hit % (false alarms)	64 (21)	50 (20)	77 (14)	59 (12)
d′	1.37	1.08	2.18	1.68
Beta	2.11	2.76	2.24	4.36
Confidence	3.06	2.95	3.93	3.97

detection and sensitivity were better for negative than for positive valence. This result supports the hypothesis of an emotional categorization advantage (or better detection of emotional valence) for negative words. The effect of valence did not interact with duration ($F(1, 26) = 1.37$, $MSE = 95.66$, $p = .252$ for the hits; $F(1, 26) = 1.34$, $MSE = .221$, $p = .257$ for the d' scores).

Response criterion tended to be higher in the longer duration (although this effect was only marginally significant; $F(1, 26) = 3.35$, $MSE = 5.96$, $p = .079$) and lower for negative compared to positive judgments ($F(1, 26) = 9.02$, $MSE = 5.94$, $p = .006$). As Table 1 shows, the effect of valence on criterion was larger for the 33-ms than the 22-ms duration. Indeed, it was significant in the 33-ms duration ($t(26) = 3.08$, $SEM = .69$, $p = .005$), but not in the 22-ms duration ($t(26) = 1.3$, $SEM = .5$, $p = .202$). The interaction of duration and valence, however, only reached marginal significance ($F(1, 26) = 3.77$, $MSE = 3.88$, $p = .063$).

Confidence Ratings

Overall confidence ratings were significantly lower in the 22-ms conditions ($M = 2.83$) than in the 33-ms conditions ($M = 3.75$; Wilcoxon signed-ranks test, $Z = 4.43$, $p < .001$). However, even at the 22-ms duration the mean confidence ratings were nowhere near the "pure guess" score of 1. A closer inspection of the confidence rating data indicated that participants rated their responses as a pure guess (i.e., a response of "1") on 33% of trials in the 22-ms condition, and on only 12% of trials in the 33-ms condition. Thus, viewing conditions were not reliably subliminal under either exposure duration.

Experiment 2

The results of the confidence ratings in Experiment 1 revealed that the shorter presentation duration used did not result in potentially subliminal effects. In this experiment, we therefore attempted to investigate whether the advantage for negative valence detection would occur under subliminal presentation conditions, by degrading stimulus visibility. To this end, we reduced the luminance of the words and presented them all for 22 ms.

Method

Participants

Twenty-three new participants (mean age 21 years, range 18–27; 17 females) participated in Experiment 2 and were paid £5 for their participation.

Stimuli and Procedure

The stimuli and procedure of Experiment 2 were similar to those of Experiment 1 with the exceptions that the words were all presented for 22 ms and their luminance was reduced to 1.29 cd/m^2. Participants completed two practice blocks of 24 trials each before the experimental blocks.

Individual valence ratings were also collected in this experiment, and the same procedure used in Experiment 1 to equate extremeness of valence was followed again here. This resulted in the removal of 10 negative and seven positive words on average per participant. The remaining word list ratings were 2.05 ($SD = .65$) for the negative words, and 5.95 ($SD = .65$) for the positive words. No neutral words were excluded since their mean rating was 4 ($SD = .2$).

Results

The results of Experiment 2 are summarized in Table 2. Both accuracy (hit) rates and valence detection sensitivity (d' scores) were again higher for negative than for positive words ($t(22) = 2.43$, $SEM = 2.04$, $p = .024$ for hits; $t(22) = 2.2$, $SEM = .07$, $p = .039$ for d' scores). In addition, sensitivity to negative valence was higher than chance (d' scores were significantly higher than zero; $t(22) = 3.87$, $SEM = .048$, $p = .001$), but sensitivity to positive words did not differ significantly from zero ($t < 1$).

Critically, the enhanced accuracy and sensitivity for negative (compared to positive) words was not accompanied by a difference in response bias. Beta scores were identical for negative and positive words (see Table 2).

Confidence Ratings

Confidence ratings were low overall (see Table 2), and indicate that participants felt they were guessing on nearly all trials. Wilcoxon signed-ranks test showed no differences between the overall confidence ratings for neutral ($M = 1.55$) versus negative ($Z = 1.14$, $p = .254$) and neutral versus positive ($Z = 1.3$, $p = .194$) words. Participants did, however, report slightly but significantly higher confidence for negative compared to positive words ($Z = 2.96$, $p = .003$). To rule out the possibility that the enhanced hit rate and sensitivity were due to a differential residual awareness between negative and positive words, we compared sensitivity only for responses with a confidence rating of 1 ("pure guess"). Indeed, this comparison still showed an advantage in sensitivity to

Table 2
Experiment 2: Mean Percentages of Hits (False Alarms), Mean d′ and Beta scores, and Mean Confidence Ratings as a Function of Word Valence

	Word valence	
Variable	Negative	Positive
Hit % (false alarms)	52 (45)	47 (46)
d′	.18	.03
Beta	1	1
Confidence	1.62	1.54

the negative (vs. positive) valence (mean d' scores were .14 for negative words and −.07 for positive words; $t(22) = 2.21$, $SEM =$ .09, $p = .038$ for the difference). Moreover, the d' scores of the "pure guess" negative words remained significantly above the zero chance level ($t(22) = 2.14$, $SEM = .06$, $p = .043$), unlike the d' scores of the positive words ($t < 1$). The response criterion remained 1 for both valence categories.

Finally, for all word types there was no difference between confidence ratings reported on correct and incorrect trials (negative: M correct = 1.75, M incorrect = 1.54; $Z = 1.61$, $p = .107$; positive: M correct = 1.64, M incorrect = 1.48; $Z = 1.62$, $p =$ .104; neutral: M correct = 1.59, M incorrect = 1.55; $Z = .51$, $p =$ .614). It should be acknowledged that confidence ratings are not a foolproof way to assess awareness or its complete absence; self-reported confidence may be low for reasons unrelated to awareness (e.g., Pleyers, Corneille, Luminet, & Yzerbyt, 2007). Thus, one cannot rule out the possibility that some residual awareness remained under conditions of very brief presentation and self-reported guessing. Even with this caveat, however, the main result of this experiment is that a valence detection advantage for negative words was still evident under conditions in which participants reported they were guessing, and did not show a difference in confidence between correct and incorrect trials. Subliminal perception, construed in this limited sense, can therefore influence affective categorization despite the absence of subjective awareness.

Experiment 3

As detailed in the Introduction, a major factor that has often been found to mediate the effects of valence is the level of arousal. In this experiment, we sought to examine whether any processing advantage for negative words would still be apparent independently of arousal. As in the previous experiments, participants were requested to classify the words into emotional or neutral. We controlled for the effects of arousal in two ways: First, it is possible that presenting positive and negative words in different blocks in the previous experiments caused a difference in the average level of arousal throughout blocks containing different valences. Therefore, in Experiment 3 we used a mixed-block design in which positive, negative and neutral words were presented within the same blocks. Second, to control for any specific effects potentially induced within a block by the more arousing words, we collected participants' individual arousal ratings of each word (in addition to their valence ratings, as in the previous experiments) and matched the word categories for each participant for both attributes.

Method

Participants

Eight new volunteers (5 females, mean age 27, range 22–34) were recruited from the University College London's online subject pool and paid £7 for participation.

Stimuli and Procedure

The stimuli, procedure, and experimental parameters were similar to Experiment 1, except words were presented for 22 ms in all blocks and all word categories (negative, positive, and neutral) were intermixed within each block. Participants were required to press a button on the keyboard if the word presented was neutral, or another button if the word was emotional (the same response was used for negative and positive words both to preserve the response characteristics of the previous experiments, and because our main interest in this study is whether the presence of emotional valence itself was better detected for negative than for positive words). Following this response, they were again required to rate their confidence level on a scale of 1 to 5, as in Experiments 1 and 2.

Participants first completed a practice block consisting of 36 trials (12 of each word type; these words were not used again in the experiment). This was followed by four blocks of 88 trials, each consisting of 22 negative-word, 22 positive-word, and 44 neutral-word trials.

Following completion of the categorization task, participants were asked to provide subjective valence ratings for the words used, as in Experiments 1 and 2. Some words were then excluded from the negative and positive word lists to equate the two categories for extremeness of valence ratings. This resulted in the removal of an average of 10 negative and 9 positive words per participant.

Following the valence rating blocks, participants were asked to rate how arousing they found each of the words used in the experiment. The words were again presented in random order, in four blocks of 88 trials preceded by one practice block (using new words) of 12 trials. Each trial began with a word presented in light gray over a black background until the participant pressed the Space bar, after which the Self-Assessment Mannequin (a widely used rating scale with pictures displaying the relative emotion; Lang, 1980) was displayed on screen for the participants to use as a rating scale. The scale ranged from 1 (*very calm*) to 9 (*very aroused*), with 5 being neither calm nor aroused. Once participants pressed the corresponding number, the next trial began.

After equating the word-sets for valence, only three out of the eight participants rated the negative words as higher in arousal than the positive words, on average, making it unlikely that an advantage for negative words would be the result of higher arousal caused by such words. However, to ensure that the word-sets were matched for arousal as well as valence, additional words were excluded from the negative and positive word lists for all participants until the mean arousal ratings for these word categories were equal. This resulted in the exclusion of a further 31 negative and 31 positive words, on average, in addition to the words excluded to match valence (note that even after excluding these words, the average numbers of words were still 47 and 48 for negative and positive words, respectively; about three times the number of words used in the previous studies of Dijksterhuis & Aarts, 2003; Snodgrass & Harring, 2005; and Zeelenberg et al., 2006). After matching the word categories for both valence and arousal the final mean valence ratings were 2.54 (SD = .81) and 5.41 (SD = .78) for negative and positive words, respectively. No neutral words had to be excluded as their mean valence ratings did not differ significantly from 4 (M = 3.95, SD = .32). The mean arousal ratings across all participants were 4.7 (SD = 1.11), 4.7 (SD = 1.09), and 3.49 (SD = 1.21) for the negative, positive, and neutral words, respectively.

Results

The intermixed-block design employed in this experiment precluded the calculation of d' scores (because false alarms—misclassifying a neutral word as emotional—could not be assigned to a specific valence). Therefore, the dependent measure used in this experiment was percentage accuracy (hit rates). Importantly, even after matching the two categories for valence and arousal, the mean hit rate for categorizing negative words as emotional (66%) was significantly higher than for positive words (50%; $t(7) = 2.86$, $SEM = .058$, $p = .024$). Interestingly, participants were significantly more accurate in categorizing the neutral words (77%) compared to both positive ($t(7) = 3.73$, $SEM = .074$, $p = .007$) and negative words ($t(7) = 2.46$, $SEM = .045$, $p = .044$). The higher hit rates for neutral than for emotional words most likely indicate that participants adopted a conservative criterion for reporting emotional valence, which resulted in a high hit rate for neutral words. The fact that negative words had a higher hit rate than positive ones indicates negative valence was more likely to overcome this strict criterion.

Confidence Ratings

Wilcoxon signed-ranks test revealed that confidence ratings did not differ significantly between the negative ($M = 3.3$) and the neutral ($M = 3.05$) words, or between the positive ($M = 3.08$) and the neutral words (both p values >1). However, the difference between the confidence ratings of the negative and positive words was significant ($Z = 2.03$, $p = .042$). Participants were therefore slightly more confident when reporting negative valence.

It should be noted that presentation conditions in Experiment 3 were not designed to be subliminal; therefore, our conclusion that the valence-detection advantage for negative words is evident when controlling for arousal is limited to consciously perceived words. Attempting to assess whether the conclusion can be generalized to words that participants reported no subjective awareness of, we examined only trials with a confidence rating of 1 ("guess"). The power of this analysis, however, was severely curtailed by the small number of guess trials: one participant had no such trials; the remaining seven participants had an average of 9 negative ($SD = 3.4$) and 12 positive ($SD = 4.98$) guess trials. There was a trend toward better valence detection for negative than positive words ($M = 26\%$ and 20%, respectively), though unsurprisingly this trend did not reach statistical significance ($t(6) < 1$, *ns*).

Lexical Frequency

The Celex database (Baayen, Piepenbrock, & Gulikers, 1995) was used to assess the lexical frequency of the words used in this study. The positive words were found to have a higher average frequency ($M = 1{,}529$ per million) than the negative words ($M = 720$ per million), ruling out the possibility that the negative-word advantage found in all three experiments could have resulted from such words being more familiar. To rule out an alternative account in terms of potential effects of uniqueness (i.e., the frequencies of the neutral words being closer to those of the positive than of the negative words) we removed the neutral and positive words with the highest frequencies, so that the remaining words had similar frequencies to the negative words (Neutral words: $M = 729$, $SD = 1062$; Positive words: $M = 724$, $SD = 646$). This did not alter the direction of the results for either Experiment 1, 2, or 3, or their significance in Experiments 1 and 2. The significance of the negative-positive and negative-neutral hit-rate differences in Experiment 3 was somewhat reduced ($p = .055$ and $p = .057$, respectively).

General Discussion

An advantage in detecting the emotional valence of negative (compared to positive) words was found in all three experiments. In an emotional categorization task that required that participants decide whether a word was neutral or emotional, Experiment 1 showed better accuracy (hit rates) a well as higher sensitivity (measured with criterion-free d' scores) for briefly presented negative (compared to positive) words. Experiment 2 extended this result to conditions under which participants reported they were guessing and so showed no subjective awareness of the words' valence. The negative-word advantage was found despite positive and negative words being equated for extremeness of emotional valence (as assessed by the participants' postexperiment ratings), and despite comparing the negative words with positive words of the same or higher lexical frequency. An effect of negative valence on a measure of response bias was found under the long-duration presentation conditions of Experiment 1, but not under the short-duration conditions of that experiment or the reported guessing conditions of Experiment 2. Finally, Experiment 3 verified that an advantage for detecting emotional valence in negative (compared to positive) words is evident even when differences in the arousal induced by negative and positive words are ruled out as an alternative account: Higher accuracy was still found for negative words when controlling for individual participants' arousal (in addition to valence) ratings, and despite negative and positive words appearing in the same blocks, ruling out both differences in individual words' arousal ratings and differences in the overall levels of arousal in different blocks as alternative accounts for the negative valence detection advantage.

The intermixed block design of Experiment 3 also allows us to rule out another potential alternative account for the effects of negative valence. When valence was blocked (as in Experiments 1 and 2) one might suggest that the enhanced accuracy and sensitivity found for negative valence was in fact the result of emotionally neutral words being better categorized as such when the choice was between them and negative, rather than positive, words. If neutral words were more distinct from negative than from positive words, this implies that in the context of negative words they were perceived as being further away from that category—that is, more positive; in contrast, in the context of positive words they were not perceived as more negative (or if they were, this difference was not as extreme as the difference in a negative-word context). This, however, cannot explain the negative valence advantage found in Experiment 3, in which neutral words were intermixed with positive and negative words in the same block. Furthermore, any general (noncontext driven) bias toward perceiving neutral words as more positive (and for such words to therefore stand out more among negative than positive words) may have also been manifested in the subjective valence ratings that our participants provided at the end of the experiment.

Across all three experiments, however, all our participants consistently rated all of the neutral words as neutral (rather than as somewhat more positive). Our exclusion procedure, based on the individual subjective valence ratings, also ensured that neither the positive nor negative valence categories used in our analysis was closer to the neutral category. We note, however, that as Experiment 3 required detection of emotional valence without specifying valence identity (positive or negative), our conclusion, when arousal is controlled for, is limited to the presence of emotional valence being better detected in negative than in positive words. It remains for future work to clarify whether, when controlling for arousal, identification of valence identity is better for negative than for positive words.

The present findings resolve the previous discrepancies in the results of previous studies investigating the effects of word valence on perceptual processing (Dijksterhuis & Aarts, 2003; Snodgrass & Harring, 2005; Zeelenberg et al., 2006). Using a large corpus of words (more than five times as many words as were used in each condition than in any of the previous studies), and ruling out alternative accounts in terms of idiosyncratic valence ratings, words frequency, uniqueness and arousal, a clear negative valence detection advantage emerges.

Our findings are consistent with previous demonstrations that negative words (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004; Ogawa & Suzuki, 2004), as well as nonverbal, fearful face stimuli (e.g., Milders, Sahraie, Logan, & Donnellon, 2006) are more likely than the corresponding neutral stimuli to escape the attentional blink (Shapiro et al., 1997), indicating that negative stimuli may have preferential access to processing resources. Similarly, in a different task requiring word naming, negative words were found to have a lower duration threshold for accurate naming than neutral words (Gaillard et al., 2006). The question of whether this advantage was due to the negative valence or whether it could be accounted for by emotional valence in general (in which case a similar advantage should be found for positive word valence as well) has not been answered conclusively by attentional blink studies: Ogawa and Suzuki (2004) found no advantage for positive over neutral words, whereas Anderson (2005) did, but showed that this advantage was attributable to arousal. Importantly, note that none of the above studies compared positive and negative words within the same experiment. Recently, Kihara and Osaka (2008) equated the arousal of negative and positive words within the same attentional blink experiments, and found an advantage (i.e., the attentional blink was reduced) for negative, compared to positive, words. Though differential arousal rates induced by different valences may contribute to differences in successful processing of emotional stimuli, the results of Kihara and Osaka (2008), as well as those of Experiment 3 of the present study, suggest that words with negative valence are preferentially processed, compared to positive words, independently of any effect of arousal. This clearly establishes an advantage for negative word processing rather than a general effect of emotional valence.

It is interesting to note that when Gaillard et al. (2006) found better naming accuracy for negative words, they also found that participants' naming errors were more likely than would be predicted by chance to consist of naming a (wrong) negative word after a negative than after a neutral target. This implies that even if the target word had not been perceived at a level that enabled naming, its valence was nonetheless processed and influenced the subsequent response. The absence of positive words in that study, however, precludes any conclusions regarding the present issue of sensitivity to negative valence rather than to any emotion. Like Gaillard et al. (2006), in the present study we also find that negative valence can be extracted from a written word even if participants claim to be guessing what the target valence was. Unlike Gaillard et al. (2006), however, we used positive words as well and found that the ability to extract valence information, distinguishing an emotional word from a neutral one, is specific to negative words.

Further research will have to elucidate the mechanism underlying the present findings. Speculatively, the present results suggest that there may be a relationship between word valence and the speed of information accrual, leading to differences in valence detection for different valences. Categorization of stimuli as negative or positive is made based on very little information (e.g., Murphy & Zajonc, 1993). Assuming that the amount of information available about a stimulus is a monotonic function of exposure duration, our findings suggest that negative (compared to positive) valence either increases the rate of information accrual or requires less information to be available for correct categorization. This conjecture is indirectly supported by the finding that attention speeds perceptual information processing (Carrasco & McElree, 2001) coupled with research showing that emotional stimuli attract attention (e.g., in emotional Stroop tasks; McKenna & Sharma, 1995; Pratto & John, 1991). For orthographic stimuli, the attention-grabbing effect of emotional stimuli may be limited to tasks requiring semantic analysis (rather than phonological or graphic analysis; Huang et al., 2008), implicating the lexical-semantic system in mediating the negative-word advantage. In the present study, however, attention was not manipulated and therefore the involvement of attentional processes in the negative-word advantage cannot be directly inferred from our results.

Alternative (though nonexclusive) possibilities include the idea that in accordance with the importance of swift judgments regarding potentially threatening information, the lexical system is organized so that negative words are more easily accessed than positive (or neutral) words. Postulating this, however, is insufficient to account for the present results as it still does not explain how valence information can be extracted from words even when full semantic information is not, as in Experiment 2 of the present study. A different possibility is that negative words are consolidated into working memory faster than positive or neutral ones; the stronger memory trace may lead to a greater likelihood of reporting negative emotional valence, even if the word itself is rapidly forgotten after very brief presentations.

The present findings may also have implications for understanding the neural mechanisms of emotion perception. An ongoing debate (Pessoa, 2005) concerns the question of whether emotional stimuli are processed automatically, and whether their processing may not even require awareness. Whereas some neuroimaging studies have found that emotional stimuli caused activation in brain regions known to process emotional information (e.g., the amygdala) regardless of attentional manipulations and even when participants were not aware of the stimuli (Etkin et al., 2004; Morris, Ohman, & Dolan, 1998; Vuilleumier, Armony, Driver, & Dolan, 2001; Vuilleumier, Armony, Clarke, Husain, Driver, & Dolan, 2002; Whalen et al., 1998), others have not found such activity in the absence of awareness and have in fact shown that the availability of attention is required for such activity to arise (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Pessoa, Japee, Sturman, & Ungerleider, 2006). Here we have shown that emotional valence information can affect guessing behavior such that performance can exceed chance despite participants claiming they are unaware of the stimulus valence. The apparent discrepancy between these results and those demonstrating a dependence of emotional processing on the availability of attentional resources may be resolved by recent findings from our lab, which showed that attention can affect both neural activity (Bahrami, Lavie, & Rees, 2007) and behavioral measures (Bahrami, Carmel, Walsh, Rees, & Lavie, 2008a, 2008b) induced by stimuli that participants were entirely unaware of. This suggests that the negative words of the present study may have captured attention even in the absence of awareness, leading to enhanced processing of the relevant stimulus dimension—valence. Future work will have to address this possibility by manipulating the attention directed at unconscious emotional stimuli.

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