Affective Priming With Subliminally Presented Pictures

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Abstract Affective priming studies have demonstrated that subliminally presented prime words can exert an influence on responses towards positive or negative target stimuli. In the present series of experiments, it was investigated whether these findings can be extended to pictorial stimuli. Ideographically selected positive, neutral, and negative picture primes that were sandwich-masked immediately preceded positive or negative target pictures (Experiment 1) or words (Experiments 2 & 3). Evaluative categorization responses to these target stimuli were significantly influenced by the valence of the prime. First, it was demonstrated that high anxious participants were selectively slowed when the subliminally presented prime was negative (Experiments 1 & 2). Second, the affective congruence between primes and targets also exerted an influence on the responses, but in a direction that is opposite to what is typically observed in affective priming research. These reverse priming effects are situated within a series of recent similar findings, and implications for theories of affective priming are discussed.

The idea that human organisms evaluate their environment constantly and unconsciously in terms of "positive/pleasant" and "negative/unpleasant" is the essence of an hypothesis with a long tradition in the history of psychology (Hermans & Eelen, 1997). Nevertheless, it was only in the last two decades that experimental evidence started to accumulate to support it. The most compelling and direct support for the *automatic evaluation hypothesis* stems from the seminal work of Russell Fazio and his colleagues (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). These authors employed a modified version of the standard sequential priming paradigm (Neely, 1991) in which the affective/evaluative relation of the prime-target pairs was manipulated. This procedure has become known as the *affective priming paradigm* (Hermans, De Houwer, & Eelen, 1994) and forms the basis of an extensive series of studies (for a recent overview, see Klauer, 1998; Klauer & Musch, 2003).

In a typical affective priming study, positive and negative prime stimuli (words or pictures) are presented for 200 ms and are followed by a positive or negative target stimulus after an interstimulus interval of 100 ms. This results in a stimulus onset asynchrony of 300 ms (SOA; i.e., the interval between the onset of the prime and the onset of the target). Results show that the time needed to evaluate the target stimuli as either "positive" or "negative" is significantly shorter when prime and target share the same valence (positive-positive or negative-negative; affectively congruent) as compared to trials on which prime and target are of opposite valence (positive-negative or negative-positive; affectively incongruent). These data can only be explained if one assumes that the affective valence of the prime is processed, even though this is not necessary for the task at hand.

The automatic character of this priming effect is supported by several lines of research, of which a) the *subliminal presentation studies* and b) the *SOA-manipulation studies* most clearly elucidate this point. With respect to the latter line of research, in a number of studies the interval between the onset of the prime and the onset of the target (SOA) was manipulated (De Houwer, Hermans, & Eelen, 1998; Fazio et al., 1986, Experiment 2; Hermans et al., 1994, Experiment 1; Hermans, Spruyt, & Eelen, 2003). In these studies, for half of the trials, the interval between the onset of the prime and the onset of the target was 300 ms, whereas for the other half the SOA was 1,000 ms. If the priming effects observed at SOA 300 are based on consciously controlled processes rather than on automatic processes, one would expect stronger, or at least similar, results if participants are given more time to process the prime-target relation, because controlled processes are generally assumed to be more time-consuming than automatic processes. Nevertheless, although in all three studies strong affective congruency effects could be observed at SOA 300, no effects were present at the longer SOA of 1,000 ms. This provides an indirect but rather strong indication of the automatic nature of the affective priming effect.

Other studies have provided a more fine-grained analysis of the temporal characteristics of the affective priming effect. Hermans, De Houwer, & Eelen (2001) manipulated the SOA on a within-subjects basis over five levels (SOA -150, 0, 150, 300, and 450). They were able to demonstrate affective priming effects for the two shortest, nonnegative SOAs (SOA 0 and SOA 150). For the longer SOAs (e.g., SOA 450), the priming effect disappeared. Similar research has been reported by Klauer and his co-workers (Klauer, Roßnagel, & Musch, 1997). Almost simultaneous with, and independent of the study by Hermans et al. (2001), they varied the SOA with levels of -100 ms, 0 ms, 100 ms, 200 ms, 600 ms, and 1,200 ms, and obtained an affective priming effect for the two shortest nonnegative SOAs (SOA 0 and SOA 100). Based on these studies, Hermans et al. (2001) concluded that the activation curve of affective priming has a rather quick onset (SOA 0), with a maximum around SOA 150, after which the effect rather quickly dissipates. Most probably, an SOA of 300 ms is already located at the edge of the activation curve. Hence, the SOA manipulation studies allow for the conclusion that affective priming shows the signature of an automatic, fast-acting cognitive process.

A second line of research that strongly supports the automatic character of the affective priming effect is a series of studies in which the prime is presented *subliminally*. In this context, Greenwald, Klinger, and Liu (1989) reported three experiments in which primes were dichoptically masked by presenting a random letter-fragment pattern to the dominant eye, either rapidly following the prime (Experiment 1) or presented simultaneously with the prime (Experiments 2 & 3). The effectiveness of the masking procedure was demonstrated by the participants' inability to discriminate the left versus right position of a test series of similarly masked words. In all three experiments, significant masked priming effects were obtained: Evaluative decisions to evaluatively congruent masked prime-target combinations were significantly faster than those to incongruent combinations. Similar results have been reported by Croizet (1998) and by Otten and Wentura (1999).

Greenwald, Klinger, and Schuh (1995) compared visible and masked priming for evaluative decisions in an impressive series of experiments. However, using SOAs between 250 and 300 ms, there was only weak evidence for some amount of priming in the masked condition. Subsequently, Greenwald, Draine, and Abrams (1996) report research that suggests that subliminal affective priming is moderated substantially by SOA, being consistently strong only at a very short SOA (67 ms) and decreasing to low levels for SOAs longer than 100 ms. With SOAs between 34 and 67 ms and masked primes presented for 17 ms, 33 ms, or 50 ms, Draine and Greenwald (1998) were able to demonstrate replicable unconscious affective priming effects. Two elements of their study deserve some further consideration. First, Draine and Greenwald (1998) were able to demonstrate indirect priming effects of the subliminally presented stimuli in the absence of direct effects (i.e., Experiments 1-3: discriminating masked prime words from meaningless letter strings; Experiment 4: discriminating positive and negative masked prime words). This indirect-without-direct effect could also be demonstrated for the 17 ms prime duration trials and thereby provides one of the strongest examples of unconscious semantic processing. Second, the strength of these subliminal effects (effect sizes ranging from $d = 0.34$ to $d = 1.38$) are not only attributable to the short SOAs, but are likely increased by the *response window procedure* and the *sandwich-masking technique*. The response window procedure combines the two traditional priming indices (response speed and accuracy) into one index by instructing participants to respond within an interval of time that can be described as a response window. It has the major benefit of controlling for speed-accuracy trade-off problems by forcing all response latencies to be relatively similar, thereby avoiding the dilution of the priming effect amongst both response latency and accuracy. The dependent variable with this procedure is the percentage of correct responses, and the technique typically leads to a large increase in the size of accuracy priming (for an overview, see Klauer & Musch, 2003). The sandwich-masking technique simply entails that the prime is not only followed by a masking stimulus (backward masking), but is also preceded by the same mask. This technique is assumed to allow longer exposure durations of the prime.

Combining the response window procedure, the sandwich-masking technique and the use of short SOAs, other authors were able to successfully replicate the subliminal affective priming effects (Abrams & Greenwald, 2000; Abrams, Klinger, & Greenwald, 2002; Klauer, Mierke, & Musch, 2002; Klinger, Burton & Pitts, 2000; Musch, 2000, Experiment 5; Otten & Wentura, 1999, Experiment 2). Abrams et al. (2002) demonstrated that these subliminal priming effects are not based on the automatic activation of a stimulus-response mapping that was acquired during the practice phase, but in fact involve the unconscious categorization of the prime as either positive or negative (i.e., activation of the semantic category). Also, interesting dissociations between masked and unmasked affective priming could be established. Musch (2000) demonstrated that the consistency proportion effect, which refers to the observation that priming effects increase as the proportion of evaluatively congruent prime-target pairs increases relative to the proportion of incongruent trials (e.g., Klauer, Roßnagel, & Musch, 1997), can be demonstrated at a short SOA for supraliminally presented stimuli, but disappears when the primes are presented subliminally. Greenwald et al. (1996) reported another empirical pattern to differentiate subliminal from supraliminal priming. In their research, for supraliminal priming, magnitude of priming was affected by the relation between prime and target stimuli on the just-preceding trial. When the preceding trial was an incongruent prime-target pair, supraliminal priming was weaker than when the preceding trial was a congruent pair. This pattern indicates a form of memory for the preceding trial's prime-target configuration. The effect occurred with visible primes and an SOA of 150 ms. By contrast, magnitude of subliminal priming was unaffected by the congruency or incongruency of the preceding prime-target pair; that is, participants gave no evidence of retaining information about the most recent prime-target configuration.

Based on these data it can be concluded that affective priming for subliminally presented stimuli is a replicable phenomenon. Together with the data of the SOA manipulation studies, this provides clear evidence for the automatic character of the affective priming effects and supports the automatic stimulus evaluation hypothesis. A characteristic, however, of all studies on *subliminal* affective priming that have been published until now is that they all have employed word stimuli. This raises the question of whether these results can be generalized to other types of stimuli. For *supraliminal* affective priming, significant effects have not only been demonstrated for words, but also for stimuli as diverse as *simple line drawings* (Giner-Sorolla, Garcia, & Bargh, 1999), *complex real life colour pictures* (Fazio, Jackson, Dunton, & Williams, 1995; Hermans et al., 1994; Spruyt, Hermans, De Houwer, & Eelen, 2002), *regular versus atonal combinations of tones* (Reber, Haerter, & Sollberger, 1999), *odours* (Hermans, Baeyens, & Eelen, 1998), and *pictorial stimuli that acquired their evaluative meaning through a preceding conditioning phase* (e.g., Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002; Olson & Fazio, 2001; for an overview, see Hermans, Baeyens, & Eelen, 2003). In the present series of studies, it was investigated whether the subliminal priming effects can be generalized to real-life colour pictures of positively and negatively valenced objects, animals, and persons.

Experiment 1

In this first experiment, the influence of individually selected and subliminally presented positive, neutral and negative prime pictures on the evaluative categorization of positive and negative target pictures was investigated. Primes were "sandwich masked," by employing both a premask as well as a postmask. The masking technique was binocular in that primes and masks were presented to both eyes. Prime duration was fixed at 20 ms and awareness was assessed following the priming task. The set of pictures from which primes and targets were selected consisted of a series of complex real-life colour pictures, which has been successfully employed in supraliminal affective priming studies (e.g., Hermans, De Houwer, & Eelen, 1996; Hermans et al., 1994).

Method

Participants. Thirty-five first-year psychology students (6 men, 29 women) participated for partial fulfillment of course requirements. All had normal or corrected-to-normal vision.

Stimuli and apparatus. A set of 100 colour pictures and 100 identical colour slides were used for both primes and targets throughout the entire experiment. Stimuli were selected in order to obtain a very wide range of content as well as affective value (e.g., a mutilated face of a young woman, a typewriter on a blue background, two kittens sitting on a windowsill,...). During the priming procedure, 42 x 64 cm slides were presented, at a viewing distance of about 3 m. The masking stimulus consisted of a colour slide that was composed of irregular colour-patches on which a pattern of black nonsense figures was superimposed. The masking stimulus was presented 65 x 65 cm in order to mask all primes, of which some were presented in "landscape" style (64 x 42 cm), whereas others were presented in "portrait" style (42 x 64 cm).

The experiment was run in a dimly lit room. Primes and targets were backprojected on a translucent glass projection screen, which separated the experimenter's room from the subject's room. Two random-access slide projectors (Kodak Carousel S-RA 2000 and S-RA 2500) and a standard slide projector were installed in the former part. All three projectors were equipped with a Compur electronic m3 shutter. Response latencies were recorded by means of a microphone-activated voice key that stopped a highly accurate Turbo Pascal timer (Bovens & Brysbaert, 1990) upon registration of a sound. An IBM compatible XT computer registered the responses and controlled both slide presentation and exposure duration.

Procedure. The experiment consisted of three subsequent phases: the stimulus selection phase, the subliminal priming procedure, and a postexperimental assessment of awareness.

During the *stimulus selection phase* participants were handed over the 100 colour pictures, and were asked to evaluate them on a 21-category scale (-100 = very negative/very unpleasant; 0 = neutral; +100 = very positive/very pleasant). The experimenter stressed that they should rely on their first, spontaneous reaction towards the picture. To get an idea about the kind of pictures that were included in the set, participants took a quick look at the pictures before starting to rate them.

Next, participants were asked to fill out both parts of the Spielberger, Gorsuch, Lushene, Vagg, and Jacobs (1983) State Trait Anxiety Inventory (STAI; Dutch adaptation by Van der Ploeg, Defares, & Spielberger, 1980). Meanwhile, out of the participants' sight, the evaluative ratings were used to select 18 primes and 18 targets. For that purpose the 15 most negatively and the 15 most positively rated stimuli, together with 6 neutral pictures (rating = 0) were selected. At random, 6 positive, 6 negative and 6 neutral stimuli were designated as primes, the remaining 9 positively and 9 negatively valenced pictures were chosen as targets. The corresponding slides were placed in the proper projector, as one random access projector served for the presentation of the primes and the second for target presentation. The masking stimulus was placed in fixed position in the third projector.

Based on the data of 27 of the final 28 participants of this experiment (missing data for one participant), we checked the consistency with which specific stimuli were assigned to the positive, neutral or negative valence category. For the negative stimuli, 38 of the 100 pictures were used as a negative prime or target for at least one of the participants. Twelve of these pictures were selected for only a minority of the participants (one or two). For the remaining 26 pictures, 3 were employed for all participants, 10 for at least 70% of the participants, and an additional 5 for at least 60% of the participants. The final 11 pictures were employed for 11 to 33% of our sample. For the positive pictures, the consistency of selected stimuli was noticeably lower. A total of 68 of the 100 pictures was used as a positive prime or target for at least one of the participants. None of these pictures was employed for all participants. Twenty-five pictures were selected for only a minority of the participants (one or two). For the remaining 43 pictures, only 8 were used for at least half of the participants, and an additional 7 for at least 40% of the participants. The remainder (35 pictures) were selected for 11 to 33% of our sample. Although these figures might be a mere reflection of the characteristics of our stimulus set, we believe that they are also indicative of the fact that there exists a strong positive-negative asymmetry in human evaluations (Rozin & Royzman, 2001; Taylor, 1991) and that there exists a stronger consistency in ratings of negative stimuli as compared to positive stimuli (Peeters & Czapinski, 1990). An overall index of consistency makes this rather clear: Whereas the stimuli that were selected as a negative prime or target were used for a mean number of 10,7 participants (45%), this was only 5,9 (22%) for the positive stimuli. For the neutral stimuli, this overall consistency was also rather low. A total of 35 pictures were selected as a neutral prime for at least one participant. The mean number of participants for which these 35 pictures were selected was 5,8 (22%). This lower consistency is possibly the result of a broader range of choice, as only 6 stimuli had to be selected for the neutral category (as compared to 15 for the positive and negative categories).

The *subliminal priming procedure* consisted of a series of 18 practice trials and 126 experimental trials. For the practice trials, primes were randomly assigned to the targets with the restriction that there had to be equally large sets of affectively congruent (3 Positive-Positive, 3 Negative-Negative), affectively incongruent (3 Negative-Positive, 3 Positive-Negative), and control prime-target pairs (3 Neutral-Positive, 3 Neutral-Negative). The 126 experimental trials consisted of seven series of 18 trials for which the randomization rule was the same as for the practice trials. The experimental trials were subsequently subdivided in two blocks of 63 trials. Within each block the order of the trials was completely randomized.

It was explained that the experiment concerned the speed at which people are able to affectively categorize stimulus pictures. It was told that stimuli would be presented and that the participant's task consisted in evaluating each of these target stimuli as quickly as possible as either "positive" or "negative." Each trial started with the presentation of the masking stimulus during 500 ms (premask). This stimulus was immediately followed by the presentation of the prime for a duration of 20 ms and the masking stimulus (postmask) for 50 ms. Without delay the target was presented after the postmask, resulting in a stimulus onset asynchrony (SOA) of 70 ms. The target remained on the screen until the participant responded by saying "Positive" or "Negative." The inter trial interval was always 7 s.

The *postexperimental assessment of awareness* consisted of three subsequent phases. First, all spontaneous remarks from the participant concerning possible awareness of the primes were recorded during and immediately after the experiment. Second, a fixed set of questions was asked: 1) "Did you notice anything special about this experiment?", 2) "Did you notice anything special about the slide with the colour pattern (i.e., the mask)?", 3) "Did you notice that the slide with the colour pattern was interrupted by another slide for a short period?", and in case the participant responded positively to the last question, 4) "Which of those slides did you recognize?". In case the participants did not spontaneously mention the subliminally presented primes and did respond negatively to all five questions, the presentations could be regarded as "unconscious" following a subjective criterion for conscious perception. Nevertheless, it remains possible that some participants had consciously perceived some of the primes during the priming procedure, but had forgotten this by the time of the postexperimental awareness assessment. Hence, it was decided to include an identification task in this awareness assessment.

At the start of this identification task, the experimenter explained that there indeed had been a stimulus that was presented for such a short time that conscious perception was hampered. The experimenter gave details about the premask/prime/postmask/target sequence and even showed the three slide projectors to demonstrate that there had actually been a series of primes. It was explained that one of the reasons why the primes might not have been consciously perceived was that during the priming procedure the participant was asked to focus all attention to the targets. Subsequently, a new series of 18 trials was presented, during which each of the 18 primes was presented exactly once. The presentation parameters were the same as for the experimental trials. The participant was now asked to focus all attention to the masking stimulus. No response had to be given to the target, which was now presented for a fixed duration of 600 ms (which equals the mean response latency of previous studies; e.g., Hermans et al., 1994, Experiment 1). The experimenter explained that 18 different primes would be presented that were also presented during the priming phase, and that the participant had already seen during the stimulus selection phase. After each trial the participant was asked what the prime had been. It was stated that it was sufficient to indicate whether it had been an animal, a person or an object. For each new presentation the experimenter asked to closely attend to the masking stimulus. If the participant indicated that no prime was consciously perceived, this was written down by the experimenter who instructed to closely watch the following trial. Most participants indicated that they had not seen anything or merely a brief flash of light during the presentation of the masking stimulus. Participants who were able to consciously recognize one or more of the primes were considered as "aware" and were excluded from the analyses. It is important to note that this procedure did not entail a "forced choice" task to assess awareness. Given our procedure of assessment, the definition of "unawareness" within the present study is in line with the idea of "subjective unawareness" (Cheesman & Merikle, 1985). Within this context, Cheesman and Merikle (1986) have argued that the subjectively defined threshold captures the intuitive phenomenological quality of consciousness advocated by Bowers (1984), and that, therefore, this is a satisfactory way of delineating conscious from unconscious perceptual processing (Öhman, 1999).

Results

Awareness assessment. The data of four participants had to be excluded from the analyses because of technical problems during the experiment. None of the remaining 31 participants spontaneously mentioned something related to the presentation of the primes. Also, none of the participants indicated that they had noticed anything special about the presentation of the masking stimuli. Most of the participants were actually surprised that a prime had been presented during the presentation of the mask. In response to the identification task, three participants recognized one or more of the primes (the criterion being that the stimulus was at least correctly classified as animal, person or object). One participant correctly recognized one prime, a second participant correctly recognized two primes, and the third recognized four primes. These three participants were considered as "aware." Their data were excluded from the analyses. This left us with 28 participants (3 men, 25 women).

Response latencies. The data from trials on which a voice key failure occurred or on which an incorrect response was given were excluded from the analyses (2.75%), together with all response latencies shorter than 250 ms or longer than 1,500 ms (0.17%). The analyses are based on the remaining data (97.1% of all observations). The mean reaction times were subjected to a 2 (Block: trials 1-63 vs. trials 64-126) x 2 (Target: positive vs. negative) x 3 (Affective Congruence: congruent vs. control vs. incongruent) ANOVA with repeated measures on all three variables. As in all following experiments, the significance level was set at $p < .05$ (two-sided). p-Values will only be reported in the case of marginally significant ($.05 < p < .10$) effects. Greenhouse-Geiser correction of the *df* was applied whenever necessary. Means for the relevant variables of Experiments 1-3 can be found in Table 1.

Against expectation, the ANOVA revealed no main effect of affective congruence, $F(2, 54) < 1$, $MSE = 638$,

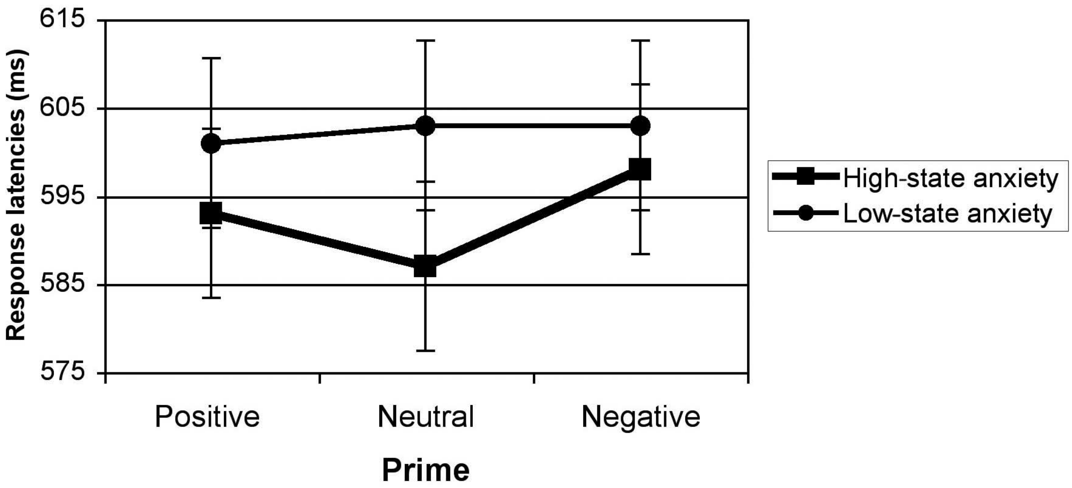

Figure 1. Mean response latencies as a function of prime valence (positive/neutral/negative) and state anxiety (high/low) (Experiment 1). Confidence intervals following Masson and Loftus (in press).

$M_{congruent}$ = 599, $M_{control}$ = 595, $M_{incongruent}$ = 599. A main effect of block, $F(1, 27) = 45.13$, $MSE = 3{,}114$, reflected a practice effect, $M_{block\ 1}$ = 618, $M_{block\ 2}$ = 577. None of the other main effects or interactions reached the level of significance.

Because of exploratory reasons, two variables were added to the design. Based on a median split of both the state and the trait scale of the STAI, participants were subdivided as low/high state anxious and as low/high trait anxious. The resulting 2 (State Anxiety: low vs. high) x 2 (Trait Anxiety: low vs. high) x 2 (Block: 1 vs. 2) x 2 (Target: positive vs. negative) x 3 (Affective Congruence: congruent vs. control vs. incongruent) ANOVA with repeated measures on the last three variables revealed a significant interaction involving state anxiety and affective congruence, $F(2, 48) = 3.29$, $MSE = 611$. Inspection of the means learns that high state anxious participants were relatively slower to respond to affectively congruent and incongruent trials, as compared to control trials, $M_{congruent}$ = 596, $M_{control}$ = 587, $M_{incongruent}$ = 596, whereas no such pattern was present for the low state anxious participants, $M_{congruent}$ = 602, $M_{control}$ = 603, $M_{incongruent}$ = 602.

Although these results seem inconsistent with our initial predictions, this pattern is fully compatible with an explanation in terms of the affective value of the stimuli. In fact, affectively congruent and incongruent trials differ from control trials essentially in that the primes in the former types of trials have a strong affective meaning, whereas primes in the control trials are selected because of their neutral affective meaning. In the context of research on the automatic processing of emotional stimuli by persons who are high or low anxious (e.g., Eysenck, 1992; Williams, Watts, MacLeod, & Matthews, 1997), effects like these would not be unexpected. In essence, this would mean that the observed effect of affective congruence would actually be based on an effect of prime valence.

To test this hypothesis, a separate ANOVA was conducted for the high state anxious group (N = 14), which now included prime valence as an additional within subjects variable. This 2 (Block) x 3 (Prime: positive vs. neutral vs. negative) x 2 (Target: positive vs. negative) analysis of variance indeed revealed a main effect of prime valence, $F(2, 26) = 3.38$, $MSE = 515$. Post hoc comparisons (Tukey HSD) revealed that high anxious participants were slower to respond to the target stimulus if this stimulus was preceded by a negative prime as compared to a neutral control prime, $M_{negative}$ = 598, $M_{neutral}$ = 587 (see Figure 1). Although the response latencies were also relatively slowed after a positive prime, the difference with the neutral controls did not reach significance, $M_{positive}$ = 593. A similar main effect was absent when the ANOVA was repeated for the low state anxious participants (N = 14), $F < 1$, $MSE = 900$, $M_{negative}$ = 603, $M_{neutral}$ = 603, $M_{positive}$ = 601.

Discussion

Although no overall affective congruence effect could be demonstrated, the present data did reveal a significant interaction between affective congruence and state anxiety. Further exploration of the data by means of simple main effect analyses showed that this interaction could be attributed to the fact that high state anxious participants were significantly slowed when the subliminally presented prime was of negative valence. This

TABLE 1
Mean Response Latencies (and Standard Errors) for Experiments 1-3, as a Function of Block (1/2), Anxiety (low/high), and Affective Congruence (congruent/incongruent/control).

	Block 1				Block 2			
	Low Anxious		High Anxious		Low Anxious		High Anxious	
Congruence	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Experiment 1								
Congruent	627	21	614	21	576	16	577	16
Incongruent	625	21	614	21	580	17	577	17
Control	627	21	600	21	578	15	574	15
Experiment 2								
Congruent	663	27	701	29	669	30	696	33
Incongruent	666	29	706	32	654	30	687	32
Control	673	28	702	31	660	31	674	34
Experiment 3								
Congruent	750	29	755	29	719	34	741	34
Incongruent	764	33	746	33	695	27	727	27
Control	743	37	760	37	748	32	733	33

Note. The anxiety variable refers to state anxiety in Experiment 1, and to trait anxiety in Experiments 2 and 3.

observation fits completely within a recent and empirically founded research tradition on attentional effects in anxiety disorders (for an overview, see Williams, Watts, MacLeod, & Mathews, 1997). Employing research paradigms like the emotional Stroop task (e.g., Mathews & MacLeod, 1985), the visual dot probe task (e.g., MacLeod, Mathews, & Tata,1986), and eye movement registration (e.g., Hermans, Vansteenwegen, & Eelen, 1999), it is now firmly established that high levels of anxiety are associated with a tendency to be distracted by, as well as to shift attention towards, threat-related stimuli. These phenomena are also known as *selective distractibility* and *attentional bias* (Eysenck, 1992) and are based on early phases of automatic information processing. Employing the emotional Stroop task, for instance, it has been repeatedly demonstrated that anxious individuals are relatively slowed in colour-naming threat-related words (e.g., for a spider anxious person: spider, cobweb, hairy, crawly) as compared to neutral control stimuli (e.g., table, train, kitchen). This selective distractibility or attentional bias has been observed in clinically diagnosed patients with an anxiety disorder (see Williams, Mathews, & MacLeod, 1996, for an overview) as well as in high trait anxious persons (e.g., Dawkins & Furnham, 1989), and persons who show increased levels of state anxiety (e.g., Mathews & MacLeod, 1985). Interestingly, research has shown that this emotional Stroop effect can also be observed when the negative words are presented subliminally (e.g., MacLeod & Hagan, 1992; MacLeod & Rutherford, 1992; Mogg, Bradley, Williams, & Mathews, 1993; Mogg, Kentish, & Bradley, 1993). The group (high anxious vs. low anxious) by stimulus valence (negative vs. neutral) interaction that is typically observed in these studies is identical to the one observed in the present experiment. In both cases the interaction witnesses an interfering influence of the negative valence of the irrelevant stimulus (component) on responses towards the relevant stimulus (component). In the present task the relevant stimulus is the target, whereas the colour of the word is the relevant stimulus in emotional Stroop research. Likewise, the irrelevant stimulus in the priming procedure is the prime, while this is the semantic meaning of the word in the emotional Stroop studies.

Hence, although the valence of the subliminally presented primes did not interact with the valence of the target in the present study (i.e., affective priming effect), it did produce a main effect for the high anxious participants, which is similar to the effect that is observed in subliminal emotional Stroop studies. This by itself provides evidence for the automatic evaluation of subliminally presented stimuli. Also, although comparable Stroop effects have been demonstrated before, it is the first time that this is demonstrated for subliminally presented pictorial stimuli. For reasons of clarity it is important to note that the emotional Stroop mechanism that is discussed here is different from the Stroop-like account of affective priming that was presented by Klauer and Musch (2003; see also, De Houwer, 2003).

The conclusions that can be drawn from the previous study are nevertheless limited. The crucial between-subjects factor (high vs. low anxious) was based on a post-hoc median split on the basis of the questionnaires that were administered at the end of the experiment. Therefore, in Experiment 2, participants were explicitly selected on the basis of their ratings on the State-Trait Anxiety Questionnaire. Based on the findings of Experiment 1, and in line with the results of emotional Stroop research, we predict that high anxious participants will demonstrate significantly slowed response latencies for trials on which the subliminally presented prime was negative as compared to trials on which the prime was neutral. A similar effect is not predicted for the low anxious group.

Experiment 2

In addition to the replication of this differential main effect of prime valence, it was also attempted to demonstrate a standard affective priming effect. One possible explanation for the absence of such a priming effect in Experiment 1 might be situated in the use of pictorial stimuli as *targets*. Possibly, the affective impact of these supraliminally presented positive and negative pictures was too strong for evaluative categorization responses to be influenced by the affective impact of the subliminally presented primes. In the subsequent study we therefore employed words instead of pictures as target stimuli.

As already mentioned, a second difference with Experiment 1 was that participants were now selected on the basis of their ratings on an anxiety questionnaire. More specifically, participants were selected on the basis of the trait anxiety subscale of the STAI. In addition, the experiment was run about three weeks before the start of their final exams. This was done because it can be reasonably assumed that at that moment most students also display heightened levels of state anxiety. Previous studies have shown that differential effects of trait anxiety are strongest when state anxiety is relatively high (e.g., MacLeod & Rutherford, 1992). This exam-stress procedure has been successfully employed in previous studies (MacLeod & Mathews, 1988; MacLeod & Rutherford, 1992).

Method

Participants. Participants were selected on the basis of the STAI-trait scores, which were obtained during a normative study for the whole group of first-year psychology students (N = 365; see also Hermans, 1994). Due to gender differences in trait anxiety as indexed by questionnaires like the STAI, 30 female students who had the highest score on this scale, and 30 female students who obtained the lowest score, were invited to participate in this study. Participation was completely voluntary. A total of 38 students (i.e., 63%) finally participated in the study.

Stimuli and apparatus. Primes were selected from the same set as in Experiment 1. Targets were selected from a series of 75 nouns, of which one-third was relatively positive (e.g., romance, wish, baby), one-third was relatively neutral (e.g., trumpet, bow, steel), and one-third was relatively negative (e.g., anxiety, cancer, war). The words were selected from existing normative studies (Bellezza, Greenwald, & Banaji, 1986; Brown & Ure, 1969; Toglia & Battig, 1978).

Procedure. The procedure was largely identical to that of Experiment 1. One of the differences was related to the use of words instead of pictures for the target stimuli. In the stimulus selection phase, a series of 75 words now also had to be evaluated employing the same procedure as described for the pictures in Experiment 1. This rating took place after the rating of the pictures. The cover story was also slightly different from Experiment 1. Because prime pictures were only presented subliminally during the priming phase, this part of the experiment was now introduced as a study on the evaluative processing of words (instead of pictures).

A second difference with the procedure of Experiment 1 was that the number of trials was reduced from 126 (7 x 18) to 108 (6 x 18). This allowed a more accurate comparison of priming effects within the first and second half of the experiment. Because of the uneven number of presentation series in Experiment 1, the first nine trials of the fourth presentation series were counted within the first experiment block, whereas trials 10 to 18 from that series were counted within the second experiment block. An even number of presentation series now allowed to divide the experiment in two blocks of three presentation series (3 x 18 trials), which were identical with respect to the number of trials within each of the different prime-target combinations.

Results

Awareness assessment. For one participant no data could be collected because of technical problems during the experiment. None of the remaining 37 participants spontaneously mentioned something related to the presentation of the primes. Also, none of the participants indicated that they had noticed anything special about the presentation of the masking stimuli. In response to the identification task, four participants recognized one or more of the primes (the criterion being that the stimulus was at least correctly classified as animal, person or object). Three participants correctly recognized one prime, a fourth participant correctly recognized two primes. These four participants were

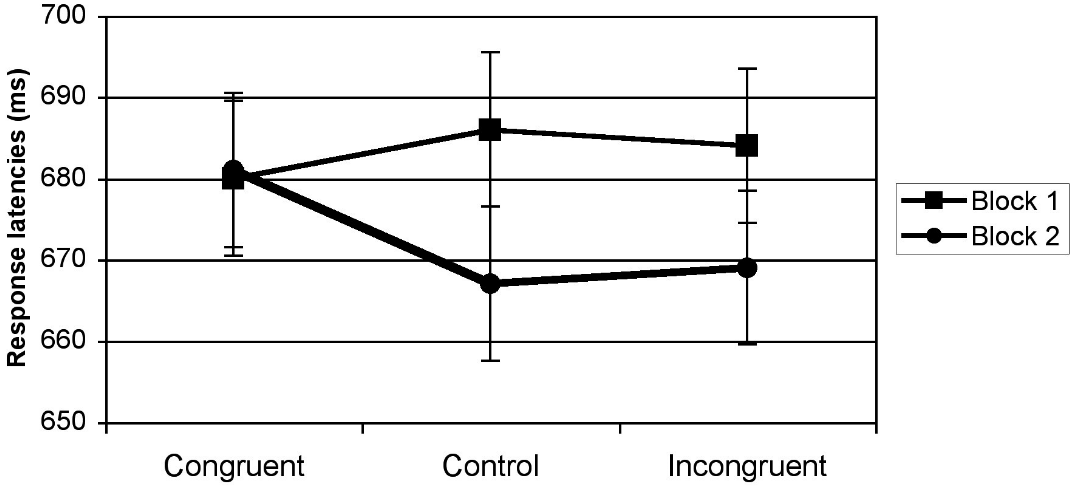

Figure 2. Mean response latencies (and 95% confidence intervals) as a function of affective congruence (congruent/control/incongruent) and block (1/2) (Experiment 2). Confidence intervals following Masson and Loftus (in press).

considered as "aware" and their data were excluded from the analyses. The final group consisted of 15 high trait anxious and 18 low trait anxious participants.

Response latencies. The data from trials on which a voice key failure occurred or on which an incorrect response was given were excluded from the analysis (3.45%), together with all response latencies shorter than 250 ms or longer than 1,500 ms (0.98%). The analyses are based on the remaining data (95.6% of all observations). The mean reaction times were subjected to a 2 (Trait Anxiety: low vs. high) x 2 (Block: 1 vs. 2) x 2 (Target: positive vs. negative) x 3 (Affective Congruence: congruent vs. control vs. incongruent) ANOVA with repeated measures for the last three variables.

As in Experiment 1, there was no main effect of affective congruence, $F(2, 62) < 1$, $MSE = 996$, $M_{congruent} = 682$, $M_{control} = 677$, $M_{incongruent} = 678$. There was, however, a significant Block x Affective Congruence interaction, $F(2, 62) = 4.33$, $MSE = 875$ (see Figure 2). Tukey *HSD* a posteriori contrasts revealed that in the second block of trials response latencies were significantly slower for affectively congruent trials as compared to neutral control trials, $M_{congruent} = 682$, $M_{control} = 667$. Contrasts involving incongruent trials did not reach the level of significance, $M_{incongruent} = 671$. Also, for the first experimental block none of the comparisons was significant, $M_{congruent} = 682$, $M_{control} = 687$, $M_{incongruent} = 686$.

Besides the Block x Affective Congruence interaction, the analysis revealed a significant interaction between trait anxiety and target valence, $F(1, 31) = 12.26$, $MSE = 2{,}540$. High trait anxious participants evaluated negative targets quicker than positive targets (Tukey *HSD*; $M_{positive} = 705$, $M_{negative} = 683$). A reverse, but only marginally significant, effect was observed for the low trait anxious participants, $M_{positive} = 657$, $M_{negative} = 671$.

Because of our a priori hypothesis concerning the differential processing of negatively valenced stimuli by high and low anxious persons, an additional 2 (Trait Anxiety) x 2 (Block) x 2 (Target) x 2 (Prime: neutral vs. negative) ANOVA with repeated measures for the last three variables was conducted. The crucial Trait Anxiety x Prime interaction was significant, $F(1, 31) = 4.23$, $MSE = 1{,}318$. For the high trait anxious group, a priori contrasts showed slower reaction times after subliminally presented negative primes as compared to neutral primes, $F(1, 31) = 5.75$, $MSE = 1{,}318$, $M_{negative} = 704$, $M_{neutral} = 688$ (see Figure 3). For the low trait anxious participants, no similar difference was found, $F < 1$, $M_{negative} = 664$, $M_{neutral} = 667$. It is also important to note that a similar ANOVA that included positive primes instead of negative primes did not reveal a comparable Prime x Trait Anxiety interaction ($F < 1$; for the high anxious participants: $M_{positive} = 691$, $M_{neutral} = 688$; for the low trait anxious group: $M_{positive} = 662$, $M_{neutral} = 667$). The effect of prime valence is thus specific for negatively valenced primes.

Discussion

First, the present data replicate the finding of Experiment 1 that high anxious participants are relatively slowed in responding to the target stimuli when this target is preceded by a subliminally presented neg-

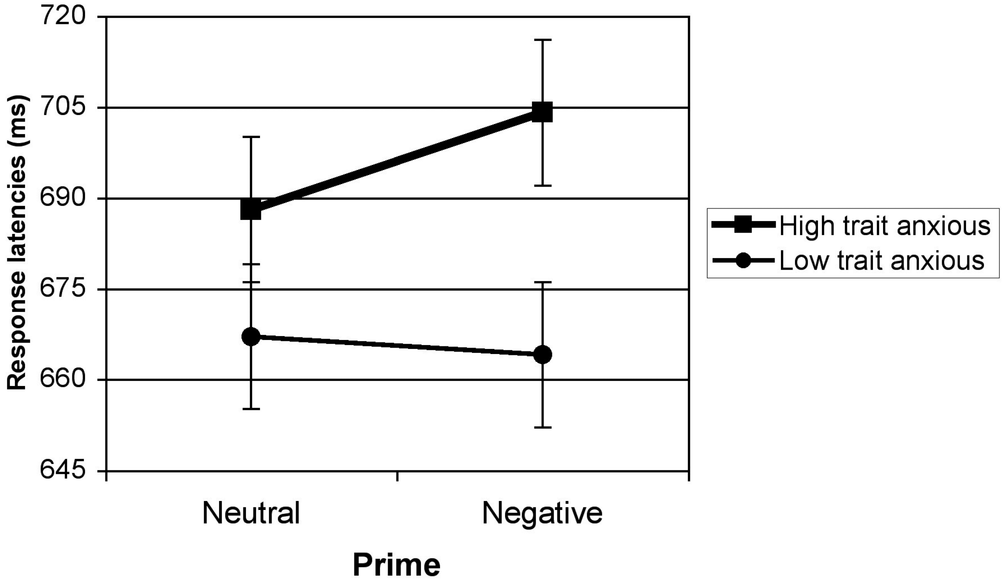

Figure 3. Mean response latencies as a function of prime valence (neutral/negative) and trait anxiety (high/low) (Experiment 2). Confidence intervals following Masson and Loftus (in press).

ative stimulus. This observation can be situated within the broader study of attentional bias and selective distractibility for negative/threatening stimuli in high anxious persons. An important aspect of our results is that the subliminal emotional Stroop effects that have been demonstrated for word stimuli (e.g., MacLeod & Rutherford, 1992) can be generalized to rather complex pictorial material. In a sense, these data do already support the idea that, at least by some individuals, subliminally presented pictorial stimuli are automatically evaluated.

In addition, a significant main effect of affective congruence could be observed for the second experimental block. Quite unexpectedly, however, the direction of this effect is opposite of what is typically observed in affective priming research, and is unpredicted on the basis of all present models of affective priming (e.g., De Houwer, Hermans, Rothermund, & Wentura, 2002; Klauer & Musch, 2003). Nevertheless, since 1997, similar reversed priming effects have been reported more than once for both subliminal (e.g., Banse, 2001; Wentura, 2001) and supraliminal (e.g., Glaser & Banaji, 1999; Klauer, Rossnagel, & Musch, 1997; Maier, Berner, & Pekrun, 2003) affective priming studies. But, given that no such contrast effects had been reported at the time Experiment 2 was conducted, the primary aim of Experiment 3 was to test whether this reversed priming effect could be replicated.

Experiment 3

The most important difference with the previous experiment was that a *dichoptical* masking procedure was used in Experiment 3, instead of a binocular procedure. In the dichoptical method, the prime and masking stimulus are no longer presented to both eyes. Rather, the masking stimulus is presented to the dominant eye, whereas the prime is presented to the nondominant eye. This method has been successfully employed in other subliminal affective priming studies (e.g., Croizet, 1998; Greenwald et al., 1989, 1995). It is assumed that masking effects employing the dichoptical procedure are based on binocular rivalry (e.g., Wolfe, 1986), with the dominant eye taking precedence in the perception of almost simultaneously presented stimuli, and that it leads to masking at a more central level, rather than at a peripheral level (e.g., at the level of the retina) (Holender, 1986). A pilot study with this method also revealed that the presentation of the prime could be extended from 20 to 30 ms. Because this study primarily aimed at testing whether the reversed priming effect could be replicated, selection of participants was no longer based on the scores of anxiety questionnaires.

Method

Participants. A total of 16 first-year psychology students (14 women) participated for partial fulfillment of course requirements. All had normal or corrected-to-normal vision.

Stimuli and apparatus. The stimulus material was identical to Experiment 2. Because of the dichoptical masking procedure, polarizing filters were screwed on the shutters of the slide projectors that were used to pre-

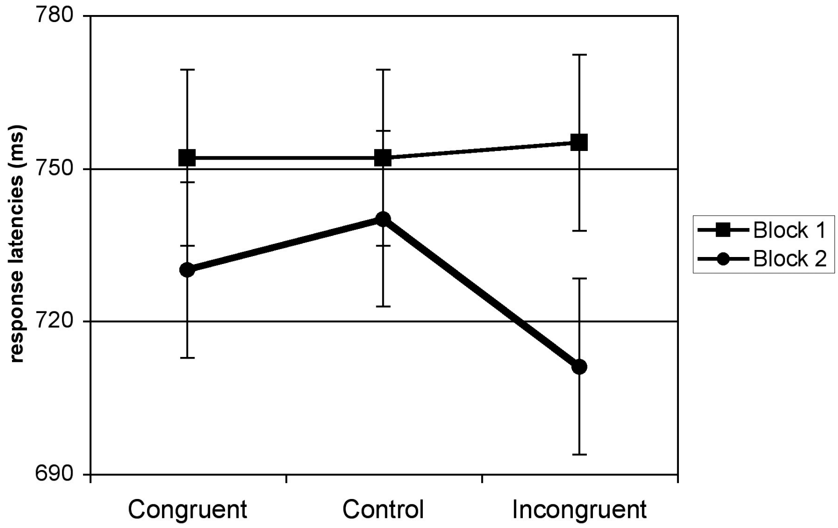

Figure 4. Mean response latencies as a function of affective congruence (congruent/control/incongruent) and Block (1/2) (Experiment 3). Confidence intervals following Masson and Loftus (in press).

sent the primes and the masking stimulus. Two similar filters were mounted in the apparatus behind which the participants placed their head. An in-height adjustable chin rest as well as an adaptable head rest assured that the participants' left and right eye were exactly in front of the two (left and right) polarizing filters. The filters were rotated so that the prime could be presented exclusively to the participant's nondominant eye, and the mask exclusively to the dominant eye.

Procedure. The procedure was largely identical to that of Experiment 2. After the stimulus selection phase, participants now filled out both parts of the STAI. Subsequently, they were asked to take their place behind the dichoptical apparatus and to adjust the height of the chair and chin rest, and to adapt the head rest so that they could sit comfortably and look straight through the left and right filter. Next, eye dominance was tested following a brief procedure described by Greenwald et al. (1989; p. 37), and the filters of the apparatus were oriented accordingly. Primes were now presented for 30 ms, in stead of 20 ms.

Results

Awareness assessment. The data of two participants were excluded from the analyses, because they were able to correctly identify three primes during the identification task. On the basis of their scores on the STAI-trait questionnaire, the remaining participants ($N = 14$) were subdivided in two equally large groups of low and high trait anxious participants.

Response latencies. The data from trials on which a voice key failure occurred or on which an incorrect response was given were excluded from the analysis, together with all response latencies shorter than 250 ms or longer than 1,500 ms. The analyses are based on the remaining data (97.9% of all observations). The mean reaction times were subjected to a 2 (Trait Anxiety: low vs. high) x 2 (Block: 1 vs. 2) x 2 (Target: positive vs. negative) x 3 (Affective Congruence: congruent vs. control vs. incongruent) ANOVA with repeated measures on the last three variables. Again, the main effect of affective congruence failed to reach the level of significance, $F(2, 24) = 1.17$, $MSE = 2{,}014$, $M_{\text{congruent}} = 741$, $M_{\text{control}} = 746$, $M_{\text{incongruent}} = 733$. None of the three a priori contrasts concerning the affective congruence variable revealed a significant difference.

In line with Experiment 2, however, in the present study a Block x Affective Congruence interaction could again be observed, $F(2, 24) = 4.03$, $MSE = 979$ (see Figure 4). For the second experimental block, the contrasts revealed faster responses for affectively incongruent trials as compared to the neutral control trials, $F(1, 12) = 8.92$, $MSE = 1{,}349$, $M_{\text{control}} = 740$, $M_{\text{incongruent}} = 711$. Also, as compared to the affectively congruent trials, the incongruent trials revealed marginally significant faster response latencies, $F(1, 12) = 3.76$, $p = .076$, $MSE = 1{,}333$, $M_{\text{congruent}} = 730$. The congruent trials did not differ from the control trials, $F(1, 12) = 1.48$, *n.s.*. Also, for the first experimental block, none of the three comparisons between the levels of the affective congruence variable was significant, $Fs < 1$, $M_{congruent} = 752$, $M_{control} = 752$, $M_{incongruent} = 755$.

The interaction between block and affective congruence was mediated by trait anxiety in a triple interaction, $F(2, 24) = 5.80$, $MSE = 979$. Simple interactions at each of both levels of the trait anxiety variable revealed that the interaction between block and affective congruence was restricted to the low trait anxious participants, $F(2, 12) = 11.47$, $MSE = 815$, and was absent for the high trait anxious, $F < 1$ [means for the relevant conditions in Block 2 were $M_{incongruent} = 695$, $M_{control} = 748$ (low trait anxious), and $M_{incongruent} = 727$, $M_{control} = 733$ (high trait anxious)].

To assess the impact of prime valence, the data were analyzed using a 2 (Trait Anxiety: low vs. high) x 2 (Block: 1 vs. 2) x 2 (Target: positive vs. negative) x 3 (Prime: positive vs. neutral vs. negative) ANOVA with repeated measures on the last three variables. The analysis revealed a reliable interaction between block and prime valence, $F(2, 24) = 4.09$, $MSE = 621$. Supplementary contrasts indicate that in the second experimental block responses are faster when the subliminally presented prime was positive as compared to when the prime was neutral, $F(1, 12) = 5.69$, $MSE = 993$, $M_{positive} = 720$, $M_{neutral} = 740$, $M_{negative} = 721$. No similar differences were observed for the first 54 experimental trials, $M_{positive} = 749$, $M_{neutral} = 752$, $M_{negative} = 759$.

As was the case for the previously mentioned Block x Affective Congruence interaction, this Block x Prime interaction also interacted with the trait anxiety variable, $F(2, 24) = 7.82$, $MSE = 621$. Additional simple interactions revealed that the significant interaction between block and prime was present for the low trait anxious participants, $F(2, 12) = 10.52$, $MSE = 646$, but not for the high trait anxious participants, $F(1, 12) = 1.01$, $MSE = 596$. The pattern of results for the low trait anxious was similar to the pattern that was revealed by the overall Block x Prime interaction.

Discussion

The results of the present experiment replicated the data of Experiment 2, in that a reversed priming effect was again observed. Affectively incongruent trials resulted in shorter response latencies as compared to neutral control trials. Like in Experiment 2, this contrast effect emerged in the second experimental block. Although the direction of this priming effect is completely opposite to what is predicted by most affective priming models, the data can nevertheless be interpreted as direct support for the hypothesis that subliminally presented pictorial stimuli can be automatically evaluated. In fact, irrespective of their direction, these priming effects can only be explained if one accepts that the affective meaning of the prime has selectively influenced responding to the positive or negative targets.

Unlike Experiment 2, this effect now also interacted with trait anxiety. Although the priming effect was in the same direction for the high trait anxious participants, the facilitated responses for incongruent trials were particularly present in the low trait anxious group. Similarly, the main effect of prime valence was also only present in the low anxious group. Although not incompatible with what is typically observed in research on affective processing in persons high or low in trait anxiety, the slowed responding after negative primes for high anxious participants (see Experiments 1 and 2) could not be replicated here.

General Discussion

Previous affective priming studies demonstrated that the affective meaning of subliminally presented prime *words* can facilitate (inhibit) responses to affectively congruent (incongruent) target stimuli (e.g., Draine & Greenwald, 1998). The results of the present series of experiments indicate that this finding can be extended to subliminally presented *pictorial stimulus materials*. The primes that were used in Experiments 1-3 consisted of colour pictures that varied in content, complexity, and affective meaning (e.g., a guitar, a corpse with a slit throat, a fish with beautiful colours). The conclusion that the affective meaning of these subliminally presented stimuli was processed by the participants, stems from two lines of observations.

First, the results of Experiments 1 and 2 reveal an emotional Stroop-like effect. High anxious participants responded significantly slower to the target stimuli, when the prime had a negative valence. For Experiment 1, this effect was based on a post-hoc analysis of the data. This pattern could, however, be fully replicated when, in Experiment 2, high and low anxious participants were invited on the basis of their scores on the trait anxiety subscale of the STAI. This effect can be interpreted as an instance of selective distractibility for negatively valenced stimulus materials in high anxious participants (Eysenck, 1992) and fits seamless within a related line of research on subliminal emotional Stroop studies (for an overview, see Williams et al., 1996, 1997). Although these data clearly demonstrate that subliminally presented pictures can be affectively processed, this conclusion should obviously be limited to the group of high anxious participants. It might nevertheless be quite possible that the primes were affectively processed by *all* participants, but only resulted in a selective response inhibition for the high anxious participants. On the basis of the present studies, this can, however, not be confirmed.

A second series of observations that leads to the conclusion that the affective valence of the prime stimuli was processed relates to the effects of affective congruence that were observed in Experiments 2 and 3. Quite surprisingly, the direction of these effects was opposite to what is typically observed in affective priming research, and to what could be expected on the basis of most models of affective priming effects. Irrespective of the theoretical implications of these findings, which we come to discuss in a moment, it is important to note that conclusions with respect to the affective processing of the primes are, in principle, independent of the precise direction of the affective congruency effect. The fact that the evaluative response latencies to positive and negative target stimuli are significantly influenced by the affective relation between the prime and the target, reveals that the affective meaning of the primes must have been processed. In contrast to the previously discussed selective distractibility effect, this effect was not mediated by trait anxiety (Experiment 2). Moreover, in Experiment 3, where trait anxiety was introduced on a post-hoc basis, the effect of affective congruence was particularly present for the low anxious participants. Taken together with the data of Experiment 2, this indicates that the affective influence of the subliminally presented pictures should not be restricted to the high anxious participants.

With respect to the generalizability of our data, it has to be noted that there was an overrepresentation of female participants in our samples. Given gender differences in trait anxiety and the incomparability of scores on the trait anxiety questionnaire, for Experiment 2 it was even decided to only include female participants. To date, however, there exist no empirical data that would suggest that gender is a moderator of affective priming effects.

Another aspect that deserves some attention is related to the stimulus selection procedure that was employed in the present experiments. Unlike most other studies on subliminal (affective) priming, the prime stimuli were individually selected before the actual masked presentation phase. This procedure might have familiarized our participants with the stimulus materials. It did not, however, hinder the success of our masking procedure. Future studies could nevertheless be aimed at investigating the effects of this feature of our procedure. We will return to this issue when we discuss the reversed character of the priming effects that were obtained in Experiments 2 and 3.

Aside from these general conclusions with respect to the affective processing of subliminally presented pictures, the question remains how the observed contrast-effect should be interpreted. The last five years, several other researchers have reported reversed affective priming effects (e.g., Banse, 2001; Glaser & Banaji, 1999; Klauer et al., 1997; Maier, Berner, & Pekrun, 2003; Wentura, 2001). For instance, Banse (2001; Experiments 1 & 2) reported standard congruence priming effects for *supraliminally* presented names and pictures of friends, romantic partners, and disliked persons, but observed reverse priming effects for backward masked primes. Using supraliminally presented primes and targets, Glaser and Banaji (1999) reported a consecutive series of six studies that demonstrated reversed priming effects. A factor that was persistently associated with the reversed effects in their studies was prime extremity. Whereas standard priming effects were observed for affectively "moderate" primes, all six studies revealed reversed priming for affectively "extreme" stimuli. In analogy to similar contrast effects in controlled judgment research, the authors argued that these reversed effects reflect an automatic correction for the biasing influence of the prime. It is, however, not easy to see how this "correction-model" could account for the reverse priming effects that are found for subliminally presented primes. Besides the present studies and the experiments reported by Banse (2001), Wentura (2001) also reported a similar contrast effect for subliminally presented primes.

According to Wentura, the sign of the priming effect might be dependent upon the instructions that are given with respect to the reaction time task. If participants are asked to react as fast as possible (emphasis on speed), their responses will be based on any evidence that is available, including the valence of the (subliminally presented) prime. Hence a congruent prime will facilitate and an incongruent prime will hamper the correct response (i.e., a congruency effect emerges). In contrast, when participants are asked to react as accurately as possible, they will employ a strategy in which responses are based solely on the target. In that strategy, the ease of discrimination between prime and target becomes a crucial variable. For incongruent prime-target pairs, the valence of the stimuli can be (implicitly) used to discriminate both stimuli. For congruent trials, it becomes much harder to discriminate both stimuli, because they share the same affective quality, which is actually the most prominent feature of stimuli in the evaluation task. Hence, in case the participant bases his responses on an accuracy strategy, contrast effects are predicted because it is time-consuming to disentangle the activated representation of affectively congruent prime and target and to arrive at a decision. By manipulating the instructions, Wentura induced either an accuracy-based or a speed-based strategy. This between-subjects manipulation indeed resulted in a standard congruency-effect for the "emphasis-on-speed" group, but also in a significant reversed priming effect for the "emphasis-on-accuracy" group. Although these results are clearly in line with the reasoning of Wentura (2001) as well as with the more general temporal discrimination theory presented by Milliken, Joordens, Merikle, and Seiffert (1998) on which the model of Wentura was based, it is not easy to see how they would explain the contrast effects that were observed in the present experiments. In all three studies, participants were asked "to respond as quickly as possible, while trying to keep the number of mistakes as small as possible" and were additionally informed that "they should nevertheless let speed prevail over accuracy." Moreover, between presentation blocks, participants were instructed to continue to respond as fast as possible. Given the emphasis on speed, one should have expected a standard priming effect, which we did find in other studies that have included the same instructions (e.g., Hermans et al., 1994, 2000, 2001).

In addition to the explanations in terms of "correction for bias" (Glaser & Banaji, 1999) and "speed versus accuracy strategies" (Wentura, 2001), a third possible explanation for the obtained contrast effects can be situated within the literature on masked repetition and semantic priming. In a study on masked priming of lexical decisions, Dagenbach, Carr, and Wilhelmson (1989) observed significant standard or reversed semantic priming effects, depending upon different threshold-setting procedures that preceded the priming task. In two groups, the threshold-setting consisted of *nonsemantic* forced-choice judgments concerning the masked primes that was presented during this phase of the experiment (detection and repetition judgments respectively). A third group made *semantic* judgments to set the threshold for the subsequent masked priming procedure. In this group, participants were required to indicate which of two words was semantically related to masked words that had been presented on that trial. For the two groups that had completed the nonsemantic threshold task prior to the priming task, standard priming effects of 32 and 39 ms were observed. For the semantic group, however, a reliable reversed priming effect of -23 ms was demonstrated. The processes they proposed as being responsible for this counterintuitive inhibitory effect were the basis for proposing the Center-Surround theory (Dagenbach & Carr, 1994). The basic idea behind this theory is that when the memory code of a concept is only weakly activated, the activation that stems from related items will additionally interfere with the processing of that concept. An example would be the situation where, in search of a specific name, the answer is on the tip of your tongue, but is impeded by "related" person names. The function of the center-surround mechanism would then consist of inhibiting the activation of these related names. In the studies by Dagenbach et al. (1989) the memory representation of the presented primes was most probably only weakly activated due to the masking procedure. Center-surround inhibition then helps the processing of the prime, by keeping up the activation of its memory representation (centre), while simultaneously inhibiting the activation of all related concepts (surround). The slowed response latencies for related prime-target pairs that were observed in their study would reflect this center-surround process. According to Dagenbach et al. (1994) this spreading of inhibition to semantically related items particularly comes into play when the participants are in some way focused on the extraction of semantic information. This would explain why, in their study, the reversed priming effect in the lexical decision task was only present for the group that had first completed a semantic threshold task. Following their original proposal, the center-surround model and its predictions have been tested more formally in a series of experiments (e.g., Carr & Dagenbach, 1990; Stolz & Besner, 1997). These studies have generally supported the model, which seems to do "an adequate job of explaining data from masked priming experiments when semantic retrieval from the prime is encouraged" (Kahan, 2000, p.1394).

When this model is applied to the present experiments, the reversed priming effects can stem from the fact that (a) the prime codes were only weakly activated due to the masked priming procedure, combined with the fact that (b) the nature of our reaction time task (i.e., evaluative categorisation) specifically induced participants to extract (evaluative) semantic meaning. In as far as this processing goal was also present during prime presentation, this might have induced an inhibition of concepts that shared the same affective meaning as the subliminally presented primes. This inhibition might then have been the basis of the reversed priming effects.

Assuming that such processes of inhibition have played a role in the present experiments, it still has to be explained why similar contrast effects have not been reported in other, highly similar subliminal affective priming studies. One possible explanation would be that whereas our studies started with an individual stimulus selection phase during which participants were explicitly asked to evaluatively categorize a series of 100 colour pictures, other subliminal studies had no such prior phase that involved semantic (evaluative) responses. Most other studies employed a fixed stimulus set and either used a nonsemantic threshold setting procedure (presence-absence or position judgments; e.g., Greenwald et al., 1989, 1995) or included an evaluative test of prime visibility only after the priming phase (e.g., Klauer, Mierke, & Musch, 2002). Similar to what was observed in the between-group design of Dagenbach et al. (1989), the semantic stimulus selection phase might have been crucial to initiate these inhibition effects. Possibly these effects also need some time to build up, which would explain why the reversed priming effects mainly showed in the second block of our priming phase.

Future studies could be aimed at further testing this center-surround account of subliminal affective priming effects. Possible studies could manipulate the presence of a (non) semantic task prior to the priming phase, or could manipulate the type of task during the priming procedure (semantic versus nonsemantic). Another way of testing this model would be to include identity-matching trials in the design, that is, trials on which the prime and target are identical. A direct prediction of the center-surround theory would be that reversed effects can be observed when the target is only semantically (i.e., affectively) related to the prime, but that standard priming effects would be observed when the target is identical (and hence also affectively related) to the prime. This is because inhibition would only affect related concepts and not the concept of the prime itself. Recently, Maier et al. (2003) proposed an inhibition-based account of reversed affective priming effects that is similar to the inhibition model that is proposed here. Future studies could contrast the predictions that can be made on the basis of their "Activation Dependent Inhibition Model" with the ones that follow from the center-surround inhibition model proposed here.

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References

Abrams, R. L., & Greenwald, A. G. (2000). Parts outweigh the whole (word) in unconscious analysis of meaning. *Psychological Science*, *11*, 118-124.

Abrams, R. L., Klinger, M. R., & Greenwald, A. G. (2002). Subliminal words activate semantic categories (not automated motor responses). *Psychonomic Bulletin and Review, 9,* 100-106.

Banse, R. (2001). Affective priming with liked and disliked persons: Prime visibility determines congruency and incongruency effects. *Cognition and Emotion, 15,* 501-520.

Bellezza, F. S., Greenwald, A. G., & Banaji, M. R. (1986). Words high and low in pleasantness as rated by male and female college students. *Behavior Research Methods, Instruments, & Computers*, *18*, 299-303.

Bovens, N., & Brysbaert, M. (1990). IBM PC/XT/AT and PS/2 Turbo Pascal timing with extended resolution. *Behavior Research Methods, Instruments, & Computers, 22,* 332-334.

Bowers, K. S. (1984). On being unconsciously influenced and informed. In K. S. Bowers & D. Meichelbaum (Eds.) *The unconscious reconsidered* (pp. 227-272). New York: Wiley.

Brown, W. P., & Ure, D. M. J. (1969). Five rated characteristics of 650 word association stimuli. *British Journal of Psychology*, *60*, 233-249.

Carr, T. H., & Dagenbach, D. (1990). Semantic priming and repetition priming from masked words: Evidence for a center-surround attentional mechanism in perceptual recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 341-350.

Cheesman, J., & Merikle, P.M. (1985). Word recognition and consciousness. In D. Besner, T. G., Waller, & G. E. MacKinnon (Eds.), *Reading research: Advances in theory and practice, Volume 5* (pp 311-352). New York: Academic Press.

Cheesman, J., & Merikle, P. M. (1986). Distinguishing conscious from unconscious perceptual processes. *Canadian Journal of Psychology, 40,* 343-367.

Croizet, J. C. (1998). Unconscious perception of affective information and its impact on personality trait judgement. *Cahiers de Psychologie Cognitive – Current Psychology of Cognition, 17,* 53-70.

Dagenbach, D., & Carr, T. H. (1994). Inhibitory processes in perceptual recognition. Evidence for a center-surround attentional mechanism. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 327-357). San Diego, CA: Academic Press.

Dagenbach, D., Carr, T. H., & Wilhelmson, A. (1989). Task-induced strategies and near-threshold priming: Conscious influences on unconscious perception. *Journal of Memory and Language, 28,* 412-443.

Dawkins, K., & Furnham, A. (1989). The color naming of emotional words. *British Journal of Psychology, 80,* 383-389.

De Houwer, J. (2003). A structural analysis of indirect measures of attitudes. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation: Affective processes in cognition and emotion*. Mahwah, NJ: Lawrence Erlbaum.

De Houwer, J., Hermans, D., & Eelen, P. (1998). Affective and identity priming with episodically associated stimuli. *Cognition and Emotion, 12,* 145-169.

De Houwer, J., Hermans, D., Rothermund, K., & Wentura,

D. (2002). Affective priming of semantic categorization responses. *Cognition and Emotion, 16,* 643-666.

Draine, S. C., & Greenwald, A. G. (1998). Replicable unconscious semantic priming. *Journal of Experimental Psychology: General*, *127*, 286-303.

Eysenck, M. W. (1992). *Anxiety. The cognitive perspective.* Hove, UK: Lawrence Erlbaum Associates.

Fazio, R. H., Jackson, J. R., Dunton, B. C., & Williams, C. J. (1995). Variability in automatic activation as an unobtrusive measure of racial attitudes: A bona fide pipeline? *Journal of Personality and Social Psychology, 69,* 1013-1027.

Fazio, R. H., Sanbonmatsu, D. M., Powell, M. C., & Kardes, F. R. (1986). On the automatic activation of attitudes. *Journal of Personality and Social Psychology, 50,* 229-238.

Giner-Sorolla, R., Garcia, M., & Bargh, J. A. (1999). The automatic evaluation of pictures. *Social Cognition*, *17*, 76-96.

Glaser, J., & Banaji, M. R. (1999). When fair is foul and foul is fair: Reverse priming in automatic evaluation. *Journal of Personality and Social Psychology, 77,* 669-687.

Greenwald, A. G., Draine, S. C., & Abrams, R. L. (1996). Three cognitive markers of unconscious semantic activation. *Science*, *273*, 1699-1702.

Greenwald, A. G., Klinger, M. R., & Liu, T. J. (1989). Unconscious processing of dichoptically masked words. *Memory & Cognition*, *17*, 35-47.

Greenwald, A. G., Klinger, M. R., & Schuh, E. S. (1995). Activation by marginally perceptible (“subliminal”) stimuli: Dissociation of unconscious from conscious cognition. *Journal of Experimental Psychology: General*, *124*, 22-42.

Hermans, D. (1994). De Zelf-Beoordelings-Vragenlijst (ZBV) [The State-Trait Anxiety Inventory; Dutch adaptation], *Gedragstherapie, 27,* 145-148.

Hermans, D., Baeyens, F., & Eelen, P. (1998). Odours as affective processing context for word evaluation: A case of cross-modal affective priming. *Cognition and Emotion*, 12, 601-613.

Hermans, D., Baeyens, F., & Eelen, P. (2003). On the acquisition and activation of evaluative information in memory: Evaluative learning and affective priming combined. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation: Affective processes in cognition and emotion* (pp. 139-168). Mahwah, NJ: Lawrence Erlbaum.

Hermans, D., Crombez, G., & Eelen, P. (2000). Automatic attitude activation and efficiency: The fourth horseman of automaticity. *Psychologica Belgica, 40,* 3-22.

Hermans, D., De Houwer, J., & Eelen, P. (1994). The affective priming effect: Automatic activation of evaluative information in memory. *Cognition and Emotion, 8,* 515-533.

Hermans, D., De Houwer, J., & Eelen, P. (1996). Evaluative decision latencies mediated by induced affective states. *Behaviour Research and Therapy*, *34*, 483-488.

Hermans, D., De Houwer, J., & Eelen, P. (2001). A time course analysis of the affective priming effect. *Cognition and Emotion, 15,* 143-165.

Hermans, D., & Eelen, P. (1997). Automatische stimulusevaluatie: experimentele evidentie voor een oude hypothese. [Automatic stimulus evaluation: experimental evidence for an old hypothesis]. *Nederlands Tijdschrift voor de Psychologie en haar Grensgebieden, 52,* 57-66.

Hermans, D., Spruyt, A., & Eelen, P. (2003). Automatic affective priming of recently acquired stimulus valence: Priming at SOA 300 but not at SOA 1000. *Cognition and Emotion, 17,* 83-99.

Hermans, D., Vansteenwegen, D., Crombez, G., Baeyens, F., & Eelen, P. (2002). Expectancy-learning and evaluative learning in human classical conditioning: Affective priming as an indirect and unobtrusive measure of conditioned stimulus valence. *Behaviour Research and Therapy, 40,* 217-234.

Hermans, D., Vansteenwegen, D., & Eelen, P. (1999). Eye movement registration as a continuous index of attention deployment: Data from a group of spider anxious students. *Cognition and Emotion, 13,* 419-434.

Holender, D. (1986). Semantic activation without conscious identification. *Behavioural and Brain Sciences, 9,* 1-66.

Kahan, T. A. (2000). Negative priming from masked words: Retrospective prime clarification or center-surround inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1392-1410.

Klauer, K. C. (1998). Affective priming. In W. Stroebe & M. Hewstone (Eds.), *European review of social psychology* (pp. 67-103). New York: John Wiley and Sons.

Klauer, K. C., Greenwald, A. G., & Draine, S. C. (1998). Correcting for measurement error in detecting unconscious cognition: Comment on Draine and Greenwald (1998). *Journal of Experimental Psychology: General, 127,* 318-319.

Klauer, K. C., Mierke, J., & Musch, J. (2002). *The positivity proportion effect: A list-context effect in masked affective priming*. Unpublished research report, Rheinische-Friederich-Wilhelms Universität, Bonn, Germany.

Klauer, K. C., & Musch, J. (2003). Affective priming: Findings and theories. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation: Affective processes in cognition and emotion* (pp. 7-49). Mahwah, NJ: Lawrence Erlbaum.

Klauer, K. C., Roßnagel, C., & Musch, J. (1997). List context effects in evaluative priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 246-255.

Klinger, M. R., Burton, P., & Pitts, S. (2000). Mechanisms of unconscious priming: I: Response competition, not spreading activation. *Journal of Experimental*

Psychology: Learning, Memory, and Cognition, 26, 441-455.

MacLeod, C., & Hagan, R. (1992). Anxiety and the selective processing of emotional information: Mediating roles of awareness, trait and state variables, and personal relevance of stimulus materials. *Behaviour Research and Therapy, 30,* 151-161.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 38,* 653-670.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95,* 15-20.

MacLeod, C., & Rutherford, E. M. (1992). Anxiety and the selective processing of emotional information: Mediating roles of awareness, trait and state variables, and personal relevance of stimulus materials. *Behaviour Research and Therapy*, *30*, 479-491.

Maier, M. A., Berner, M. P., Pekrun, R. (2003). Directionality of affective priming: Effects of trait anxiety and activation level. *Experimental Psychology, 50,* 116-123.

Masson, M. E. J., & Loftus, G. R. (in press). Using confidence intervals for graphically based data interpretation. *Canadian Journal of Experimental Psychology.*

Mathews, A., & MacLeod, C. (1985). Selective processing of threat cues in anxiety states. *Behaviour Research and Therapy, 23,* 563-569.

Milliken, B., Joordens, S., Merikle, P., & Seiffert, A. (1998). Selective attention: A re-evaluation of the implications of negative priming. *Psychological Review*, *105*, 203-229.

Mogg, K., Bradley, B. P., Williams, R., & Matthews, A. M. (1993). Subliminal processing of emotional information in anxiety and depression. *Journal of Abnormal Psychology, 102,* 304-311.

Mogg, K., Kentisch, J., & Bradley, B. P. (1993). Effects of anxiety and awareness on color identification latencies for emotional words. *Behaviour Research and Therapy, 31,* 559-567.

Musch, J. (2000). *Affektives priming: Kongruenzeffekte bei der evaluativen Bewertung* [Affective priming: Congruency effects in evaluative decisions]. Unpublished doctoral dissertation, Universität Heidelberg, Germany.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Erlbaum.

Öhman, A. (1999). Distinguishing unconscious from conscious emotional processes: Methodological considerations and theoretical implications. In T. Dalgleish & M. Power (Eds.), *Handbook of cognition and emotion* (pp. 321-352). Chichester: Wiley.

Olson, M. A., & Fazio, R. H. (2001). Implicit attitude formation through classical conditioning. *Psychological Science, 12,* 413-417.

Otten, S., & Wentura, D. (1999). About the impact of automaticity in the Minimal Group Paradigm: Evidence from affective priming tasks. *European Journal of Social Psychology, 29*, 1049-1071.

Peeters, G., & Czapinski, J. (1990). Positive-negative asymmetry in evaluations: The distinction between affective and informational negativity effects. In W. Stroebe & M. Hewstone (Eds.), *European review of social psychology* (Vol.1, pp. 33-60). Chichester: Wiley.

Reber, R., Haerter, A., & Sollberger, B. (1999, June). *Unbewusstes affektives Priming: Zwei neue experimentelle paradigmen.* Paper presented at the 7. Tagung der Fachgruppe Sozialpsychologie, Universität Kassel, Kassel, Germany.

Rozin, P., & Royzman, E. B. (2001). Negativity bias, negativity dominance, and contagion. *Personality and Social Psychology Review, 5,* 296-320.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Spruyt, A., Hermans, D., De Houwer, J., & Eelen, P. (2002). On the nature of the affective priming effect: Affective priming of naming responses. *Social Cognition, 20,* 227-256.

Stolz, J.A., & Besner, D. (1997). Visual word recognition: Effort after meaning but not (necessarily) meaning after effort. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 1314-1322.

Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin, 110,* 67-85.

Toglia, M. P., & Battig, W. F. (1978). *Handbook of semantic word norms.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Van der Ploeg, H. M., Defares, P. B., & Spielberger C. D. (1980). *Handleiding bij de Zelf-Beoordelings Vragenlijst, ZBV.* [Manual of the State-Trait Anxiety Inventory; Dutch adaptation]. Lisse: Swets en Zeitlinger.

Wentura (2001). *Masked priming in the evaluation task: Size and sign of affective priming effects depend on strategies.* Unpublished manuscript. University of Jena, Germany.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120,* 3-24.

Williams, J. M. G., Watts, F., MacLeod, C., & Mathews, A. (1997). *Cognitive psychology and emotional disorders* (2nd ed.). Chichester: Wiley.

Wolfe, J. M. (1986). Stereopsis and binocular rivalry. *Psychological Review, 93,* 269-282.

Sommaire

Le postulat selon lequel les organismes humains évaluent constamment et inconsciemment leur environnement, en lui donnant des attributs « positifs/agréables » et « négatifs/désagréables », constitue le fondement d'une hypothèse qui s'inscrit depuis fort longtemps dans l'histoire de la psychologie. Cependant, ce n'est qu'au cours des deux dernières décennies qu'on a commencé à amasser des évidences expérimentales qui soutiennent cette hypothèse. L'élément le plus convaincant et qui appuie le plus directement l'hypothèse de l'évaluation automatique nous vient de la documentation traitant de l'amorçage affectif (pour une vue d'ensemble récente, voir Klauer, 1998; Klauer et Musch, 2003). En empruntant une procédure d'amorçage affectif – qui est une version modifiée du paradigme d'amorçage séquentiel standard dans laquelle la relation affective/évaluative des paires cible-sonde est manipulée – les études antérieures ont démontré que les mots-sondes présentés brièvement peuvent exercer une influence sur les réponses en faveur de stimuli-cibles positifs ou négatifs (p. ex., Hermans, De Houwer et Eelen, 1994, 2001).

Le caractère automatique de cet effet d'amorçage est invoqué dans plusieurs champs de recherche, parmi lesquels les études de la présentation subliminale, qui expliquent avec le plus de clarté cet aspect. Un grand nombre d'études ont fait ressortir que l'effet d'amorçage affectif se produit lui aussi lorsque les mots-sondes sont présentés subliminalement (p. ex., Greenwald, Klinger et Schuh, 1995).

Dans la série d'expériences présentées ici, nous avons cherché à savoir si ces conclusions pouvaient s'appliquer aux stimuli picturaux. Nous avons présenté aux participants des images-sondes présentées sous forme d'idéogrammes, positives, neutres et négatives; ces images-sondes, immédiatement superposées par un masque, étaient suivies par la présentation d'images-cibles positives ou négatives (expérience 1) ou de mots (expériences 2 et 3). Les réponses de catégorisation de nature évaluative aux stimuli-cibles étaient considérablement influencées par la valence de la sonde, et ce, de deux façons distinctes. Premièrement, nous avons observé que les participants très anxieux faisaient moins rapidement la sélection de l'image-cible lorsque la sonde présentée subliminalement était négative (expériences 1 et 2). Cette observation s'inscrit parfaitement dans la nouvelle tradition de recherche empirique portant sur les effets de l'attention dans les troubles anxieux (pour un aperçu, voir Williams, Watts, MacLeod et Mathews, 1997). En recourant à des paradigmes de recherche, tels que la tâche de Stroop émotionnelle (p. ex., Mathews et MacLeod, 1985), la tâche visuelle pendant laquelle apparaît un « point de sondage » (p. ex., MacLeod, Mathews et Tata, 1986) et l'enregistrement des mouvements oculaires (p. ex., Hermans, Vansteenwegen et Eelen, 1999), nous avons pu établir qu'un niveau élevé d'anxiété concordait avec une tendance à être distrait par des stimuli apparentés à une menace. Ces phénomènes sont également connus sous les termes de distractibilité sélective et de biais de l'attention (Eysenck, 1992) et se fondent sur les premières phases du traitement automatique de l'information.

C'est au cours des expériences 2 et 3 que nous avons observé une deuxième manifestation de l'influence des sondes présentées subliminalement sur les réponses de catégorisation, qui a pris la forme d'effets d'amorçage inverses. Les mêmes effets d'amorçage inverses se retrouvent dans d'autres résultats de recherche récents et les répercussions de ces conclusions sur les théories de l'amorçage affectif sont abordées.