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Processing of Unattended Emotional Visual Scenes

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Prime pictures of emotional scenes appeared in parafoveal vision, followed by probe pictures either congruent or incongruent in affective valence. Participants responded whether the probe was pleasant or unpleasant (or whether it portrayed people or animals). Shorter latencies for congruent than for incongruent prime–probe pairs revealed affective priming. This occurred even when visual attention was focused on a concurrent verbal task and when foveal gaze-contingent masking prevented overt attention to the primes but only if these had been preexposed and appeared in the left visual field. The preexposure and laterality patterns were different for affective priming and semantic category priming. Affective priming was independent of the nature of the task (i.e., affective or category judgment), whereas semantic priming was not. The authors conclude that affective processing occurs without overt attention—although it is dependent on resources available for covert attention—and that prior experience of the stimulus is required and right-hemisphere dominance is involved.

Keywords: parafoveal pictures, eye movements, laterality, awareness, affective priming

Can the emotional meaning of visual scenes be assessed outside the focus of spatial attention? Emotional stimuli are related to important adaptive events linked with benefit and pleasure or with danger and pain. When facing such stimuli, individuals must initiate appetitive or aversive responses readily to maximize approach or defense. This requires the cognitive system to be able to efficiently identify stimuli as good or bad, for which this system needs perceptual mechanisms that can promptly detect the features associated with emotional meaning. One such mechanism is assumed to involve lowered perceptual thresholds, so that emotionality of low-intensity or briefly presented stimuli can be perceived; another is assumed to involve broadened perceptual span, so that emotionality can be perceived from eccentric stimuli in the visual field. Accordingly, we predicted that emotional stimuli should be detected not only at low thresholds but also in the visual periphery.[1] There has been considerable research on the temporal threshold mechanism (see below). The aim of the current study was to examine the attentional span mechanism.

Attention can be described as an information-processing function that selects and keeps accessible stimulus and mental input for analysis by the cognitive system (e.g., Pashler, 1998). Overt and covert orienting are two mechanisms of visual attention (Findlay & Gilchrist, 2003; Posner & Petersen, 1990). Overt attention involves spatially focusing on a target stimulus by means of eye movements and fixations on it. Covert attention involves mentally focusing on the stimulus through internal neural adjustments, without eye movements or fixations. Covert attentional processes operate to assist in preprocessing information in the visual periphery at the location where the eyes are to be directed (Hoffman, 1998). Our approach is mainly concerned with the role of overt attention in the processing of emotional visual scenes. More specifically, the purpose was to determine whether the affective valence of pictorial stimuli can be discriminated (i.e., whether they are good or bad) when they appear in parafoveal vision (2.5° away from foveal fixation of the eyes; see Wandell, 1995). Accordingly, by *unattended scenes,* we refer (unless otherwise indicated) to visual stimuli that are not overtly attended, that is, not foveally fixated by the eyes. This was operationalized by presenting the stimuli at eccentric locations of the visual field and under gaze-contingent foveal masking, which prevented eye fixations on the stimuli. In these conditions, covert attention would, nevertheless, still be possible. Accordingly, a secondary purpose involved investigating the role of covert attention (under conditions of overt inattention). This was operationalized by presenting the parafoveal visual scenes at the same time as a concurrent foveal load at fixation. In these conditions, covert attention (in addition to overt attention) was focused away from the emotional stimuli.

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[1] One assumption in our approach is that the perceptual span is broadened to facilitate detection of emotional stimuli. This would be functional from an adaptive perspective and is consistent with hypervigilance-to-threat theory (e.g., Eysenck, 1992). This might, however, seem at odds with classic views in which emotional arousal produces a narrowing of attention (Easterbrook, 1959) and with research indicating that negative emotional states narrow the scope of attention, whereas positive states expand it (Derryberry & Tucker, 1994), and that attention is constrained around negative face stimuli (Fenske & Eastwood, 2003). These two views can probably be integrated, though. The perceptual span is initially widened to detect emotional stimuli, which then attract attention, which is zoomed into them and, hence, narrowed for surrounding stimuli. We propose that this applies not only when the stimuli appear at fixation but also when they appear at eccentric locations of the visual field.

The processing of overtly unattended emotional visual scenes does not imply absence of awareness. Awareness involves the recognition of the presence of a stimulus or identification of its content accompanied by the conscious experience of noticing it (see Merikle, Smilek, & Eastwood, 2001). Awareness cannot be equated with overt attention and can probably be reached through covert attention. In the inattentional blindness and the attentional blink paradigms, stimuli presented in the fovea (hence, under overt attention) become unnoticed, or fail to be identified, if covert attention is diverted to another task (see Dehaene, Changeux, Naccache, Sakur, & Sergent, 2006). Nevertheless, although stimuli can be perceived when observers are unaware of them (Merikle et al., 2001), awareness seems to depend on the allocation of some form of attention to the stimuli (e.g., Mack & Rock, 1998). Accordingly, an interesting question to be addressed was whether emotional stimuli could be encoded when attention was reduced (either by preventing foveal fixations or by allocating resources elsewhere) in a way that limited entry into awareness (see Anderson, 2005).

Automatic, Preattentive Processing of Emotional Content

Our approach fits within the research and literature about automatic assessment of emotional stimuli. Models of emotional processing have proposed that the affective valence of stimuli is evaluated automatically, that is, quickly, effortlessly, unintentionally, and/or unconsciously (Bargh, 1997; see Robinson, 1998). Two major lines of research have been developed on the issue of the extent to which attentional processes are involved in the analysis of emotional pictorial stimuli or whether this analysis can be performed without attention. One line of research is relevant to the temporal threshold mechanism referred to above and has focused on some aspects of the automaticity of emotional processing. The other is relevant to the spatial span mechanism and has examined how allocation of overt attention modulates affective processing. Evidence related to each of these mechanisms is reported in turn.

Research has shown that emotional content is detected very early in the processing of emotional pictures. First, event-related potentials (ERPs) recorded from the visual cortices demonstrate differences between schematic emotional and neutral faces as early as 80–90 ms from stimulus onset (Eger, Jedynak, Iwaki, & Skrandies, 2003) and at around 250 ms from stimulus onset for complex emotional scenes (Junghöfer, Bradley, Elbert, & Lang, 2001). Second, subliminally presented and masked emotional pictures produce consistent peripheral physiological changes in the viewers (facial electromyographic responses: Dimberg, Thunberg, & Elmehed, 2000; electrodermal responses: Öhman & Soares, 1998). Third, identification thresholds are lower for schematic emotional faces (25- and 50-ms displays) than for neutral faces (75-ms displays; Calvo & Esteves, 2005). A fourth type of data goes farther in suggesting not only that the presence or absence of emotional content is detected very early but also that positive and negative emotional valence are discriminated, as reflected by affective priming. Affective evaluation of a probe picture following a prime picture is faster when both have the same emotional valence (i.e., both pleasant or both unpleasant) than when they differ in valence (see reviews in Klauer & Musch, 2003). This affective priming effect has been reported when the prime is presented very briefly (200 ms or less; e.g., Carroll & Young, 2005) and even with subliminal presentation (Hermans, Spruyt, De Houwer, & Eelen, 2003; see also S. T. Murphy & Zajonc, 1993, with a related paradigm).

In the studies reviewed above, the pictorial stimuli were typically presented in the center of the visual field and were therefore available to direct foveal vision. Attention to the stimuli was generally restricted by means of short display duration. An alternative approach to examining whether emotional content is processed outside the focus of attention involves presenting the emotional stimuli at unattended locations of the visual field. With this approach, both neurophysiological and eye-movement measures have been collected. First, the brain activation studies have not provided conclusive findings. For fearful versus neutral faces presented between approximately 1.1° and 1.4° away from a central fixation point, no differential cortical activation, as measured by ERPs, has been observed (Holmes, Vuilleumier, & Eimer, 2003). However, activation of the amygdala and right fusiform gyrus has been reported, as assessed by functional magnetic resonance imaging (fMRI; Vuilleumier, Armony, Driver, & Dolan, 2001). When visual scenes were presented 1.3° away from the center of fixation, Keil, Moratti, Sabatinelli, Bradley, and Lang (2005) found enhanced cortical activation for unpleasant versus neutral scenes. Second, eye-tracking studies have revealed an initial orienting bias toward emotional stimuli. Thus, when one emotional and one neutral scene were presented simultaneously 2.5° (or more) away from a central fixation point, the first fixation of the eyes was more likely to be placed on the emotional scene (Calvo & Lang, 2004, 2005; Nummenmaa, Hyönä, & Calvo, 2006). Presumably, the emotional content of the scenes was responsible for such an early orienting effect. That is, the emotional meaning of the scene would have been processed by allocating covert attention to the parafoveal/peripheral retinal inputs, which would then result in a shift of overt attention to the emotional rather than the neutral picture. The reason is that a covert shift of visual attention is normally almost immediately followed by an overt gaze shift to the covertly attended location (see Findlay & Gilchrist, 2003).

The Role of Prior Identification of the Emotional Stimulus

As reviewed above, prior research using the perceptual threshold and the perceptual span approaches has suggested that emotional content of visual stimuli can be detected with minimal or reduced attentional processing, which is consistent with theoretical models about automatic emotional processing (Bargh, 1997; Zajonc, 2000). One assumption of these models is that the processing of affect does not require detailed perceptual or semantic identification of the stimulus and that affect can precede cognition. However, this hypothesis has been challenged (Cave & Batty, 2006; Storbeck, Robinson, & McCourt, 2006). Storbeck et al. (2006) have argued that the features of objects must first be integrated and the objects themselves identified prior to affective analysis. This implies that perceptual and semantic distinctions are required before affective associations can be retrieved and before decisions are taken about whether an object is good or bad. Cave and Batty (2006) have further argued that only low-level perceptual features of visual stimuli can be encoded preattentively across a broad region of the visual field and then guide attentional search. According to Cave and Batty, these features can, however, be selectively activated if earlier practice has produced strong connections with high-level semantic or affective representations and then can facilitate preattentive processing of the associated affective content. The Storbeck et al. and Cave and Batty views cast doubts about whether the so-called preattentive emotional processing found in prior research is genuine or, rather, involves attentional processes as a prerequisite for object identification. One way to solve this issue is to examine the effects of preexposure to the affective stimuli. This is particularly relevant for paradigms in which stimuli are presented outside awareness (i.e., subliminally) or at unattended locations of the visual field.

Regarding the prior studies in which emotional pictures were presented subliminally in the center of the visual field, repetition and preexposure of the stimuli might account for the effects. In the subliminal affective priming studies (Banse, 2001; Hermans et al., 2003), the prime stimuli were presented several times. In fact, Hermans et al. (2003) reported finding affective priming in the second block, but not in the first block, of presentation of the prime pictures. Also, in the studies assessing emotional processing by means of physiological measures (Dimberg et al., 2000; Öhman & Soares, 1998), either the participants had the opportunity to preview the stimuli unmasked or the masked stimuli were repeated across trials. Similarly, in the perceptual threshold study of Calvo and Esteves (2005), the stimuli were presented several times at each of various threshold levels. According to Fox (1996), the prior presentation raises activation of the stimulus content, which then gives way to postconscious, rather than truly preconscious, identification of the subliminal stimuli. In fact, Fox found masked processing of threatening subliminal stimuli only when these had been previously presented unmasked or when masked and unmasked trials were mixed, but not when the masked trials were presented before the unmasked trials. This suggests that so-called unconscious emotional processing requires prior conscious identification of the stimuli.

Regarding the studies in which emotional stimuli were presented at unattended locations of the visual field, attentional factors probably had an effect on the preattentive analysis of the pictures, too. First, both foveal vision and preexposure might have been involved in two studies that found enhanced brain activation for unattended emotional pictures (Keil et al., 2005; Vuilleumier et al., 2001). In the Keil et al. (2005) study, in addition to the pictures being repeated several times, the inner edge of the pictures was located only 1.3° away from the central fixation point. This probably allowed for some foveal processing of the pictures, given that the foveal area extends to between 2° and 2.5° (see Wandell, 1995). Similarly, in the Vuilleumier et al. (2001) study, although the authors did not report the exact eccentricity of the pictures, these seem to have been located 1.4° or less from the central fixation point, and so, they could have been seen partly foveally. In addition, in neither of these studies were eye movements controlled. Second, preexposure effects might also have been involved in two studies that found initial orienting to and facilitated recognition of parafoveal (2.5°) pictures (Calvo & Lang, 2004, 2005), as the same stimuli were presented several times across different experimental conditions.

The Current Study

Some previous research is consistent with the hypothesis that detection and discrimination of emotional content can be performed with reduced attentional resources or without overt attention. Nevertheless, in most of the studies reviewed above, the alternative account that prior attentional identification of the stimuli was involved cannot be totally ruled out. The current study aimed to address this issue by examining whether emotional significance could be processed from truly unattended (outside the focus of spatial attention) and novel visual scenes or whether emotional processing requires prior attention to the stimuli.

We used three major methodological developments. First, in Experiments 1–4 and Experiment 6, an affective priming paradigm was used to determine whether emotional valence is analyzed and whether positive and negative affective significance of stimuli are discriminated. In this paradigm (e.g., Hermans, De Houwer, & Eelen, 1994; see Klauer & Musch, 2003), a prime picture is followed by a probe picture, and participants are asked to decide whether the probe is positive or negative in emotional valence (i.e., pleasant or unpleasant). The prime and the probe can be congruent or incongruent (i.e., of the same or opposite valence). The priming effects are thought to result from spreading activation between process units of prime-related knowledge, which speeds up the subsequent decisions. Hence, if the affective significance of the prime is assessed, facilitation (e.g., shorter response latencies) on the evaluation of the probe will occur when it is congruent with the prime.

Second, the prime stimuli were presented in such a way that they could not be overtly attended, that is, not fixated foveally. To this end, the primes were presented briefly (150 ms) and parafoveally (2.5° away from the fixation point), and two further manipulations were performed. In Experiments 1, 2, 5, and 6, we used a concurrent foveal load task: The central fixation point was replaced with one letter (A or O), which was presented at the same time as a prime picture appeared to the right or the left, and the participant had to name the letter. This foveal load task was assumed to engage attention and prevent any saccades to the prime. In a complementary approach, in Experiments 3, 4, and 5, we used a gaze-contingent masking technique: A round foveal moving mask 2.5° in diameter was contingent on the viewer's gaze direction; wherever the participants directed their gaze, a black circle blocked their foveal vision (i.e., the central 2.5° of their visual field). Accordingly, only parafoveal and peripheral vision of the picture was possible. If overt attention is not necessary for assessing emotional valence, priming will occur in the absence of any foveal fixations on the prime stimuli. However, if covert attention is involved and parafoveal emotional processing is resource limited, such processing will be impaired by a concurrent foveal load.

Third, preexposure of the prime pictures was manipulated to determine the role of prior stimulus identification in valence encoding of unattended stimuli. This was performed at three levels: foveal, parafoveal, or foveal and parafoveal combined. In Experiment 1, the primes were either preexposed foveally or not in a preview phase prior to their parafoveal presentation. In Experiments 2 and 3, the primes were presented once both as a prime and as a probe in each of three repeated blocks of trials. This implies that both foveal (as a probe) and parafoveal (as a prime) identification could be summed across trials. In Experiments 4, 5, and 6, each picture was presented only once, either as a prime or as a probe, in each of three or four blocks. This implies that there was only parafoveal preexposure. If there is genuine processing of unattended emotional scenes, then priming effects will occur the first time a prime is presented. In contrast, if prior identification of the stimulus is required, affective priming will emerge only after preexposure.

Experiment 1

Prime pictures that were unpleasant or pleasant in emotional valence were presented for 150 ms to the parafovea (2.5° away from a central fixation letter), followed by a congruent or an incongruent probe at 300-ms stimulus onset asynchrony (SOA). These prime–probe pairs were shown only once to avoid practice effects. However, in a preview phase, the experimental pictures were preexposed foveally once to half of the participants, whereas the other half were presented with unrelated pictures. For this and the other experiments, a 150-ms prime display was used to prevent eye movements to the prime (as minimal saccade latency is about 150 ms; see Rayner, 1998). A 300-ms SOA was chosen because this has been the standard interval in prior research on affective priming to determine automatic processing (see Klauer & Musch, 2003).

Method

Participants. Forty-eight psychology undergraduates (38 female, 10 male) participated for course credit. Half of the participants of each gender group were randomly assigned to each preview condition. There were 22 right-handed and 2 left-handed participants in the relevant preview condition and 23 right-handed and 1 left-handed in the nonrelevant preview condition. The participants were different for all the experiments, although they were drawn from the same pool of first-year undergraduate students at La Laguna University, Tenerife, Spain, in 2 consecutive years. The participants in all the experiments were from 18 to 23 years old ($M = 19.4$ years).

Stimuli and apparatus. Sixty pictures portraying unpleasant (30) or pleasant (30) scenes involving people were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert 2005) as the experimental stimuli. The IAPS numbers are indicated in the Appendix. The mean IAPS valence scores of the selected pictures in undergraduate Spanish samples (Moltó et al., 1999; Vila et al., 2001) were 2.30 (unpleasant) and 7.73 (pleasant) in a 9-point scale, $t(58) = 36.56$, $p < .0001$, $d = .94$.

The mean luminance level of each picture was assessed (and adjusted whenever necessary) with Adobe Photoshop software (see Ochsner, 2000). The mean contrast level of each picture was determined by root-mean-square (RMS) contrast (see Bex & Makous, 2002; Peli, 1990). Independent-samples *t* tests indicated that the pleasant and the unpleasant visual scenes were comparable in luminance (134 vs. 129, respectively) and RMS contrast (2.06 vs. 1.95, respectively; both ts < 1.0, ps $= .39$).

Both as a prime and as a probe, each picture subtended a visual angle of 13.30° (width: 11.7 cm) × 11.10° (height: 9.7 cm) at a constant viewing distance of 50 cm. The distance from the center of the letter that served as the fixation point to the inner edge of the prime picture was 2.52° (2.2 cm), so that the prime stimulus was located in parafoveal vision. Participants had their heads positioned in a chin and forehead rest. All pictures were presented in their original colors against a dark background. The pictures were displayed on a 17-in. SVGA monitor with a 100-Hz refresh rate at a resolution of 800 × 600 pixels, connected to a Pentium IV 2.8-GHz computer. E-Prime experimental software (Schneider, Eschman, & Zuccolotto, 2002) controlled stimulus presentation and response collection. Response accuracy and latency in the probe evaluation task were collected through keypresses on specified keys. For half of the participants in each SOA condition, the *pleasant* response key was *D* and the *unpleasant* key was *L* in a standard computer keyboard, whereas the reverse applied to the other half of the participants.

Procedure and design. A preview phase took place immediately before the practice trials for the experimental phase. In the preview phase, either the 60 pictures that were presented later in the experimental phase or a set of 60 unrelated pictures were presented in random order. Each picture was displayed once for 1 s in the center of the screen, with no interval between consecutive pictures. Before this phase, the participants were told that photographs would be displayed one at a time on the screen and were asked to pay attention to them, as they might be presented later in the affective evaluation task.

Following the preview phase, the experimental phase began. The participants were informed that they would be presented with a sequence of two photographs on each trial: The first photograph (the prime) could appear either to the left or to the right of a central fixation point (a letter), and the second (the probe) would always appear in the center of the screen. They were also told that the letter (A or O) serving as the fixation point would appear simultaneously with the prime. The participant's task was twofold: First, the letter should be named aloud as soon as it appeared, with accuracy being recorded through a microphone, and second, when the probe appeared, the participant should respond with a keypress as soon as possible to indicate whether the scene was pleasant or unpleasant. Participants were asked to ignore the prime and pay attention to the concurrent letter and the probe.

Figure 1 shows the sequence of events in each trial. A trial started with a central cross for 500 ms, followed by the prime stimulus (on left or right) and the to-be-named letter (A or O) for 150 ms, a blank 150-ms interval, and, finally, the probe stimulus, which remained on the screen until the participant responded or for 2 s. The intertrial interval was 3 s. There were 16 practice trials.

The experimental conditions were combined in a mixed factorial design, with preview (yes vs. no) of the experimental pictures as a between-subjects factor (24 participants at each level) and probe emotional valence (unpleasant vs. pleasant), prime–probe congruence (congruent vs. incongruent), and prime visual field (left vs. right) as within-subject factors. Each picture was presented once as a prime and once as a probe, with random preassignment of prime–probe pairs and random trial order.

Results

There was almost total performance accuracy in the letter identification task, with less than 1.0% of errors across all experiments. Reaction times on this task were not recorded. The high-accuracy performance ensured that the participants were attending to the central letter rather than to the parafoveal picture. Regarding

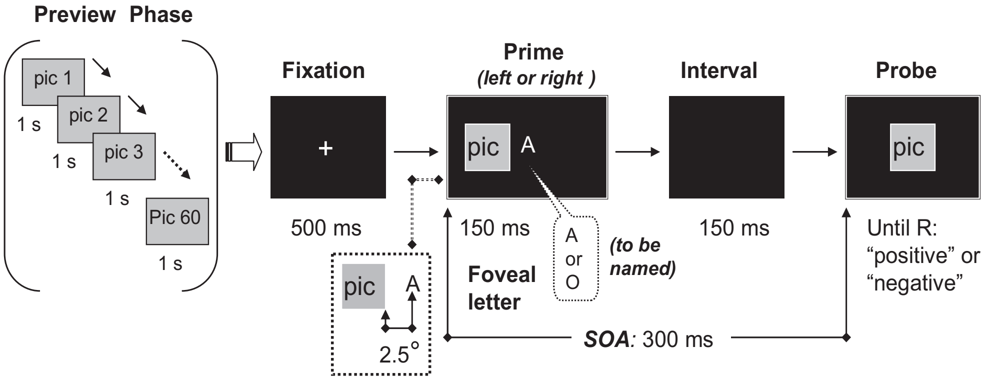

Figure 1. Sequence of events within a trial in Experiment 1. pic = picture; *SOA* = stimulus onset asynchrony; R = response.

performance on the affective evaluation of the probe, the error rate was 3.4% across experiments and did not differ as a function of experimental conditions. Accordingly, analyses were conducted only on reaction times for correct responses. To deal with outliers, we excluded reaction times above 1,500 ms or below 300 ms (3.7% across experiments) from the analyses. In addition, reaction times 2.5 standard deviations (*SD*s) above or below the mean of each participant were replaced by the ±2.5 *SD* values for that participant in the corresponding experimental condition, which represented 3.0% of trials across experiments.

Mean reaction times can be seen in Figure 2. A 2 (preview) × 2 (valence of probe) × 2 (prime–probe congruence) × 2 (visual field of prime) analysis of variance (ANOVA) yielded a significant Preview × Congruence interaction, $F(1, 46) = 4.08$, $p < .05$, $\eta_p^2 = .08$. Separate ANOVAs indicated that in the nonrelevant preview condition, there were no significant differences between the congruent (M = 866 ms) and the incongruent (M = 858 ms) probes. In contrast, in the relevant preview condition, a main effect of congruence revealed that reaction times were shorter for the congruent (M = 819 ms) than for the incongruent (M = 859 ms) probe, $F(1, 23) = 6.76$, $p < .025$, $\eta_p^2 = .23$. Although the tendency for the effect of congruence was similar in both visual fields (with no significant Congruence × Visual Field interaction, $F < 1$), given that the priming scores (i.e., incongruent − congruent reaction times) were clearly different in magnitude for the left and the right visual fields (i.e., 48 ms vs. 31 ms, respectively) and that priming effects were consistently different for left versus right visual fields across all the other experiments, we analyzed them separately in Experiment 1. Whereas the difference between the congruent and the incongruent conditions was statistically signif-

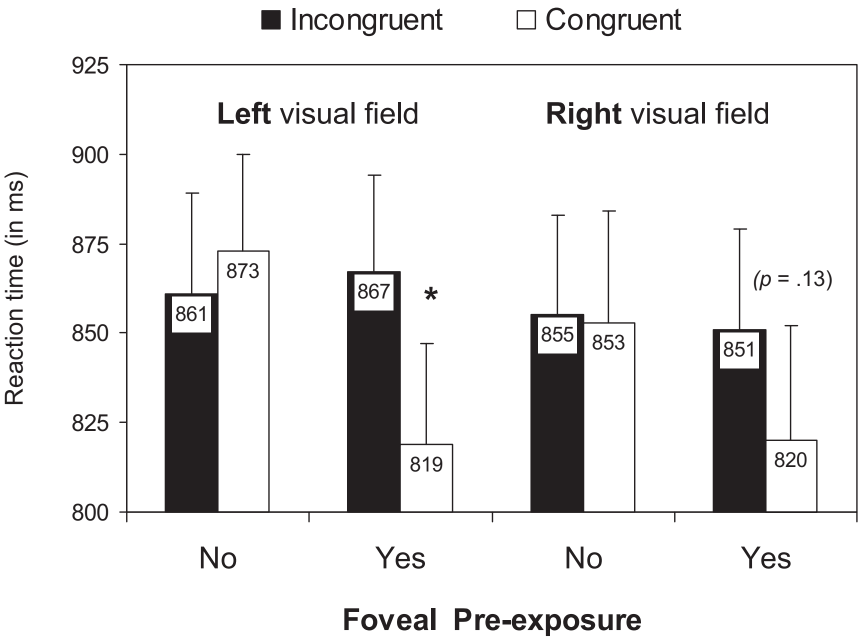

Figure 2. Mean response latencies as a function of prime–probe affective congruence and visual field in Experiment 1. Asterisk indicates a significant difference between the congruent and incongruent conditions.

icant for the left visual field, $t(23) = 2.53$, $p < .025$, $d = .36$, the difference for the right visual field only approached significance, $t(23) = 1.56$, $p = .13$, $d = .20$. There were no other statistically significant effects.

Discussion

The results demonstrated an affective priming effect, that is, faster responses for the probe pictures that were congruent in affective valence with the prime pictures appearing at unattended locations of the visual field. However, this effect occurred only when the same prime pictures had been presented foveally in a preview phase and therefore under the focus of attention. In contrast, when the pictures had not been presented in the preview phase, there was no affective priming. This suggests that parafoveal assessment of emotional significance is possible only after the stimulus objects have been identified by attentional processes under foveal inspection. This is in accordance with Storbeck et al. (2006) and casts doubts on the hypothesis of emotional processing of unattended novel stimuli. In addition, affective priming was particularly evident when the primes appeared in the left visual field. This lateralization effect is consistent with recent findings of Keil et al. (2005) showing cortical activation in the right hemisphere when emotional scenes are presented in the left visual field. A possible explanation involves right-hemisphere dominance in the processing of emotional pictures (see the General Discussion, below).

Experiment 2

Experiment 1 demonstrated that analysis of emotional valence is not performed during a single trial when the stimulus appears parafoveally unless the stimulus has recently been foveally attended. As a complementary approach, Experiment 2 was concerned with the role of practice in the affective priming of unattended emotional stimuli. The role of preexposure was determined by presenting the same prime and probe pictures across three consecutive blocks, once in each block. If parafoveal processing depends on prior attentional processing, the affective priming effects will not emerge in the first block when the stimuli are novel but instead will emerge increasingly in later blocks.

Method

Participants. Twenty-four psychology undergraduates (18 female, 6 male; 22 right-handed, 2 left-handed) participated for course credit.

Stimuli, apparatus, procedure, and design. The same unpleasant (30) and pleasant (30) scenes as in Experiment 1 were used, with the same apparatus. The procedure was the same as in Experiment 1, except that instead of a preview phase with a presentation of the primes, the participants performed three repeated blocks of 60 trials. Each picture was presented once as a prime and once as a probe in each block, and each parafoveal-prime/foveal-probe pair was presented once in each block randomly. The prime display time (150 ms) and the prime–probe SOA were constant (300 ms) across the three blocks. Figure 3 shows the sequence of events in a session. Emotional valence of the probe (unpleasant vs. pleasant), prime–probe affective congruence (congruent vs. incongruent), visual field of prime (left vs. right), and block (first vs. second vs. third) were combined in a within-subjects factorial design.

Results

The 2 (valence of probe) × 2 (prime–probe congruence) × 2 (visual field of prime) × 3 (block) ANOVA yielded a significant main effect of block, $F(2, 46) = 65.73$, $p < .0001$, $\eta_p^2 = .74$, with differences in reaction times between all blocks (first block: $M = 846$ ms; second block: $M = 743$ ms; third block: $M = 679$ ms; all post hoc comparisons, $ps < .0001$). There was only a borderline effect of congruence, $F(1, 23) = 3.00$, $p = .097$, $\eta_p^2 = .11$, which was qualified by Congruence × Block, $F(2, 46) = 3.51$, $p < .05$, $\eta_p^2 = .13$; Congruence × Visual Field, $F(1, 23) = 4.70$, $p < .05$, $\eta_p^2 = .17$; and Block × Visual Field, $F(2, 46) = 3.42$, $p < .05$, $\eta_p^2 = .13$, interactions. These interactions are represented in Figure 4. To decompose the interactions, we conducted separate ANOVAs for each block.

For the first block of trials, no significant effects emerged. For the second block, a main effect of congruence revealed faster reaction times for congruent ($M = 736$ ms) than for incongruent ($M = 751$ ms) prime–probe pairs, $F(1, 23) = 5.25$, $p < .05$, $\eta_p^2 = .19$. There were no significant interactions between congruence and visual field or between congruence, visual field, and valence (both Fs < 1). Nevertheless, the 24-ms priming score in the left visual field approached significance, $F(1, 23) = 3.42$, $p = .077$, $\eta_p^2 = .13$, whereas the 6-ms priming score in the right visual field did not ($F < 1$). This tendency became clearly significant for the third block, where the main effect of congruence, $F(1, 23) = 4.93$, $p < .05$, $\eta_p^2 = .18$, was qualified by a Congruence × Visual Field interaction, $F(1, 23) = 5.70$, $p < .05$, $\eta_p^2 = .20$. Simple effects tests indicated that for primes presented in the left visual field, congruent probes were categorized faster than incongruent probes, $t(23) = 3.22$, $p < .01$, $d = .35$, whereas differences were nonsignificant in the right field ($t < 1$). Accordingly, the Congruence × Visual Field interaction and the Block × Visual Field interaction (see above) resulted from the fact that the parafoveal priming effects occurred only in the left visual field (i.e., congruent: 744 ms vs. incongruent: 766 ms mean scores across blocks), which became especially evident in the third block of trials (see Figure 4).

Discussion

These findings are consistent with those obtained in Experiment 1. Parafoveal affective priming requires preexposure of the parafoveal stimulus, and affective content is preferentially processed in the left visual field. In Experiment 2, priming effects did not emerge the first time the stimuli were presented but only after their repetition in the second and third blocks. This suggests that assessment of the emotional significance of stimuli outside the focus of spatial attention involves recognition rather than genuine initial discrimination of affect. This further implies that affective processing is not simultaneous with and parallel to perceptual processing. Rather, parafoveal perceptual analysis would be performed initially. When the stimulus appears again, the preactivated perceptual representation would be easily accessed and matched with the current stimulus configuration. This preactivated identification of the stimulus would then facilitate analysis of its affective value. This interpretation is consistent with the

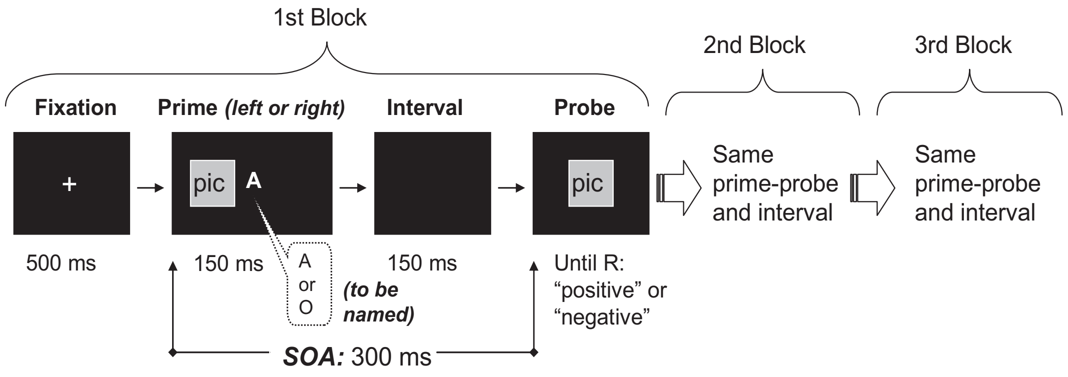

Figure 3. Sequence of events within a trial and across blocks in Experiment 2. pic = picture; *SOA* = stimulus onset asynchrony; R = response.

Calvo and Lang (2005) results. These authors found better immediate recognition of parafoveal emotional scenes, in comparison with paired neutral scenes, when the pictures were presented across several trials.

Experiments 1 and 2 demonstrated that there is processing of the emotional significance of unattended visual scenes but that it takes place only after the stimulus has been preexposed. Nevertheless, this is based on two assumptions: first, that there were no eye fixations on the unattended primes during their 150-ms display. This assumption is reasonable if we take into account that minimal saccade latency is around 150 ms, although express saccades with shorter latencies may occur in certain conditions (see Rayner, 1998). Thus, the 150-ms display duration does not allow us to rule out the possibility of short fixations on the primes. The parafoveal priming effect might actually have involved overt attentional processes during the presentation of the prime. Second, we assumed that the foveal load task (letter discrimination) during the prime display would not interfere with parafoveal processing of the prime picture but would simply prevent looking at it. It is, however, possible that this foveal task depleted the necessary resources for parafoveal processing of the concurrent prime. Lavie and Fox (2000) have shown that parafoveal processing of verbal stimuli is less likely to occur under conditions of perceptual foveal load. Similarly, our foveal load task might have artificially constrained parafoveal processing, which, therefore, would have been underestimated. We conducted Experiments 3 and 4 to test these assumptions.

Experiment 3

If there is processing of truly unattended emotional stimuli, affective priming should occur in the absence of eye movements

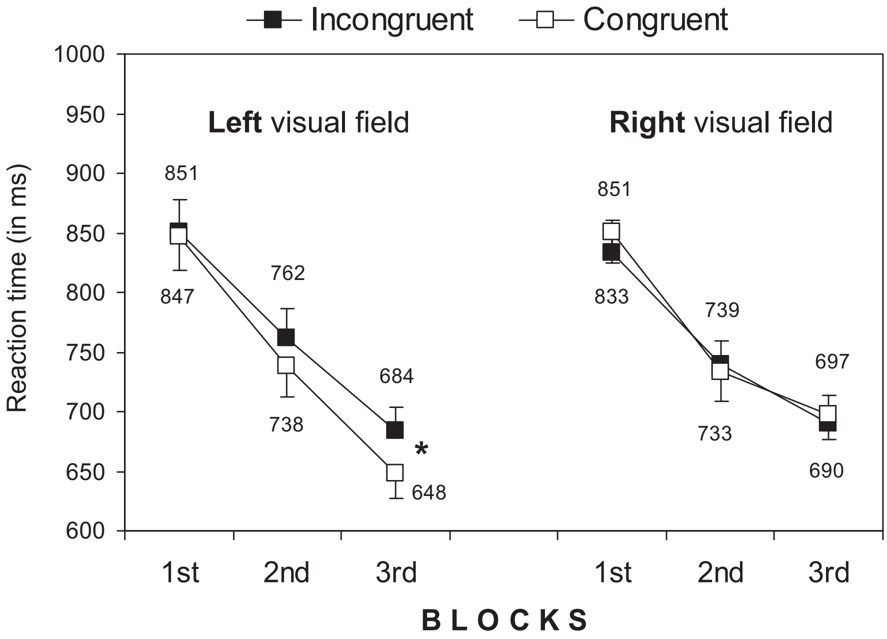

Figure 4. Mean response latencies as a function of prime–probe affective congruence, visual field, and block in Experiment 2. Asterisk indicates a significant difference between the congruent and incongruent conditions.

and fixations on the prime stimuli. Furthermore, the priming effect may appear even the first time the prime is presented (without the need of any preexposure) when no concurrent foveal task interferes with the parafoveal processing of the primes. To address these issues in Experiment 3, we removed the foveal load task. Instead, we recorded participants' eye movements and applied a foveal moving mask that was contingent on the changes in the participant's gaze direction (see Rayner, 1998). These conditions guaranteed that the prime pictures could not be foveally fixated but that resources available for parafoveal processing were not constrained.

Method

Participants. Twenty-four psychology undergraduates (20 female, 4 male; 23 right-handed, 1 left-handed) at La Laguna University participated for course credit.

Stimuli, apparatus, procedure, and design. The same unpleasant (30) and pleasant (30) visual scenes as in the previous experiments were used. The procedure and experimental design were similar to those in Experiment 2, with the following important exceptions. First, eye movements were monitored during the presentation of the primes and the probes. Second, no foveal letter discrimination task was performed during the prime presentation. Third, a round foveal gaze-contingent mask (diameter 2.5°) was used. This implied that participants were free to move their eyes, but wherever the viewer moved his or her gaze, foveal vision was blocked with the black mask. Accordingly, whatever the viewer could see of the prime picture was due to parafoveal or peripheral vision. The mask appeared only when there was a saccade to the prime during the prime display period (i.e., the first 150 ms of a trial). Participants could not notice the mask unless a saccade reached the prime picture. Participants were asked to decide about the emotional valence of the probe scenes and were not told anything about the mask. As in Experiment 2, each picture was presented once as a prime and once as a probe on each block. Figure 5 shows the sequence of events in a trial and a session.

Stimuli were presented on a 21-in. monitor with a 120-Hz refresh rate, connected to a Pentium IV 3.2-GHz display computer. Participants' eye movements were recorded with an EyeLink II tracker (SR Research Ltd., Mississauga, Ontario, Canada), connected to a Pentium IV 2.8-GHz host computer. The sampling rate of the eye tracker was 500 Hz, and the spatial accuracy was better than 0.5°, with a 0.01° resolution in pupil tracking mode. The viewing distance was 60 cm. The size of the pictures was 13.8° × 11.0° (14.0 cm × 11.0 cm), with the center of the fixation point at 2.5° (2.5 cm) of the inner edge of the prime pictures.

Eye-movement measures. The following measures were used to assess whether the prime pictures had been overtly attended: the probability of initiating a saccade toward the prime picture, the end time of these saccades, the percentage of trials in which the participant was able to fixate the prime picture, and the duration of such fixations. The number of fixations on the probe pictures was used as a complementary measure of the priming effects, in addition to reaction times.

Results

Probability and end time of saccades toward the parafoveal prime. The probability that a saccade was made toward the prime picture, as well as the end time of these saccades, was analyzed in 2 (valence of probe) × 2 (visual field of prime) × 3 (block) ANOVAs. The duration of fixations on the prime picture area was also examined, when there was any. There was only a main effect of block on the probability of saccades, $F(2, 46) = 18.88$, $p < .0001$, $\eta_p^2 = .45$, with significant differences between all blocks (first block: $M = .72$; second block: $M = .62$; third block: $M = .56$; all post hoc comparisons, $ps < .001$, except between the second and third blocks, $p = .08$). Neither the time taken to initiate the first saccade from the central fixation point nor the end times of the saccades landing on the prime location were significantly affected by any of the factors ($Fs < 1$). The mean end time of these saccades for the different experimental conditions ranged between 162 and 166 ms (*SD*s = between 9 and 12 ms). As the primes were displayed for 150 ms, this reveals that in most cases, the participants were not able to fixate the pictures. In fact, only a few saccades (5.6%) landed on the prime area before the end of the

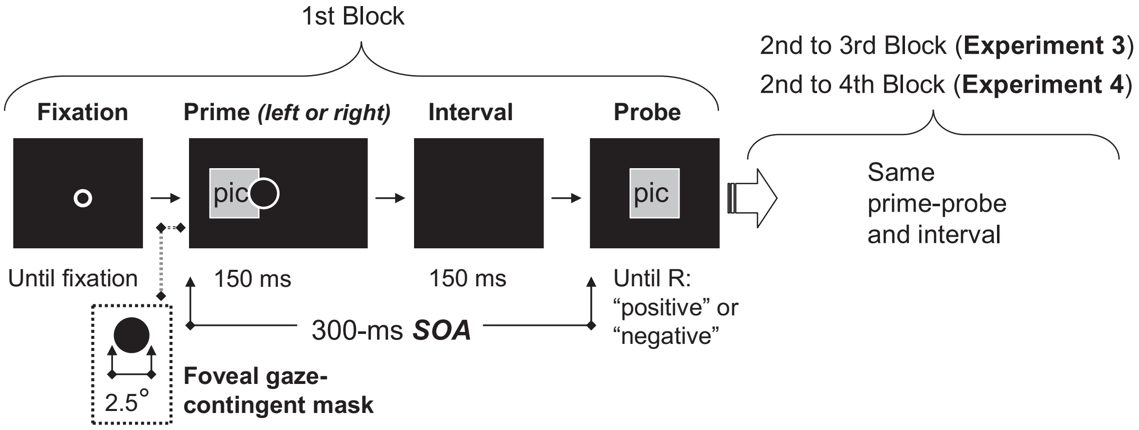

Figure 5. Sequence of events within a trial and across blocks in Experiments 3 and 4. In Experiment 3, there was both foveal and parafoveal preexposure (i.e., repetition of pictures) across blocks. In Experiment 4, there was only parafoveal preexposure. pic = picture; *SOA* = stimulus onset asynchrony; R = response.

prime display period, with mean 5-ms fixation time on the displayed picture.

Correct reaction times and number of fixations on the probe. Reaction times and number of fixations on the probe were analyzed in 2 (valence of probe) × 2 (prime–probe congruence) × 2 (visual field of prime) × 3 (block) ANOVAs. For reaction times, the analysis yielded a significant main effect of block, $F(2, 46) = 42.80$, $p < .0001$, $\eta_p^2 = .65$, with significant differences in reaction times between all blocks (first block: $M = 860$ ms; second block: $M = 739$ ms; third block: $M = 681$ ms; all post hoc comparisons, *p*s $< .0001$). There were also Congruence × Block, $F(2, 46) = 3.51$, $p < .05$, $\eta_p^2 = .13$, and Congruence × Visual Field, $F(1, 23) = 5.32$, $p < .05$, $\eta_p^2 = .19$, interactions. These interactions are shown in Figure 6. To decompose the interactions, we conducted separate ANOVAs for each block. For the first and second blocks of trials, no significant effects emerged. For the third block, the main effect of congruence, $F(1, 23) = 6.50$, $p < .025$, $\eta_p^2 = .22$, was qualified by a Congruence × Visual Field interaction, $F(1, 23) = 4.35$, $p < .05$, $\eta_p^2 = .16$. Simple effects tests indicated that for primes presented in the left visual field, congruent probes were responded to faster than incongruent probes, $t(23) = 3.23$, $p < .01$, $d = .28$, whereas differences were nonsignificant in the right field ($t < 0.5$).

For number of fixations on the probe pictures, the ANOVA also yielded main effects of block, $F(2, 46) = 75.31$, $p < .0001$, $\eta_p^2 = .77$, with significant differences between all blocks (first block: $M = 4.00$; second block: $M = 3.27$; third block: $M = 2.97$; all post hoc contrasts, *p*s $< .0001$). There was also a Congruence × Visual Field interaction, $F(1, 23) = 5.50$, $p < .05$, $\eta_p^2 = .19$, with fewer fixations on the congruent probe when the prime was presented on the left than when it was presented on the right ($M = 3.34$ vs. 3.47, respectively), $t(23) = 2.05$, $p = .052$, $d = .15$, whereas there was a nonsignificant, reversed tendency for incongruent probes ($M = 3.44$ vs. 3.39, respectively) $t(23) = 1.14$, $p = .26$, $d = .07$.

Discussion

With a new methodological approach, the results of Experiment 3 confirmed the major findings of Experiments 1 and 2. There was affective priming of emotional scenes when the primes were presented at unattended locations of the visual field, particularly in the left hemifield, but this required prior exposure to the stimuli. The facilitation of responses (i.e., shorter latencies and also fewer fixations) for probes that followed congruent primes did not emerge until the third time the prime was presented. The two main innovations of Experiment 3 reinforced these conclusions. First, eye-movement monitoring demonstrated that the priming effects occurred even though the prime pictures were truly unattended. There were very few (5.6%) and short (5 ms) fixations on the prime pictures, and these fixations could provide only parafoveal or peripheral perception of the primes because of the gaze-contingent foveal masking. This has implications for the findings of Experiments 1 and 2, in which no foveal mask was used. As most eye movements toward the primes took longer than 150 ms and given that the prime display was always 150 ms, there is support for our first assumption: The priming effects were not due to overt attentional processing of the primes during their parafoveal presentation. Second, the lack of priming during the first presentation of the unattended stimuli in the previous experiments was not simply a result of depletion of resources from the parafoveal analysis of the primes due to the foveal load task. In Experiment 3, with no such task, affective priming emerged as late (i.e., third block) as in Experiment 2, with a foveal load task. This supports our second assumption that the delay of emergence of

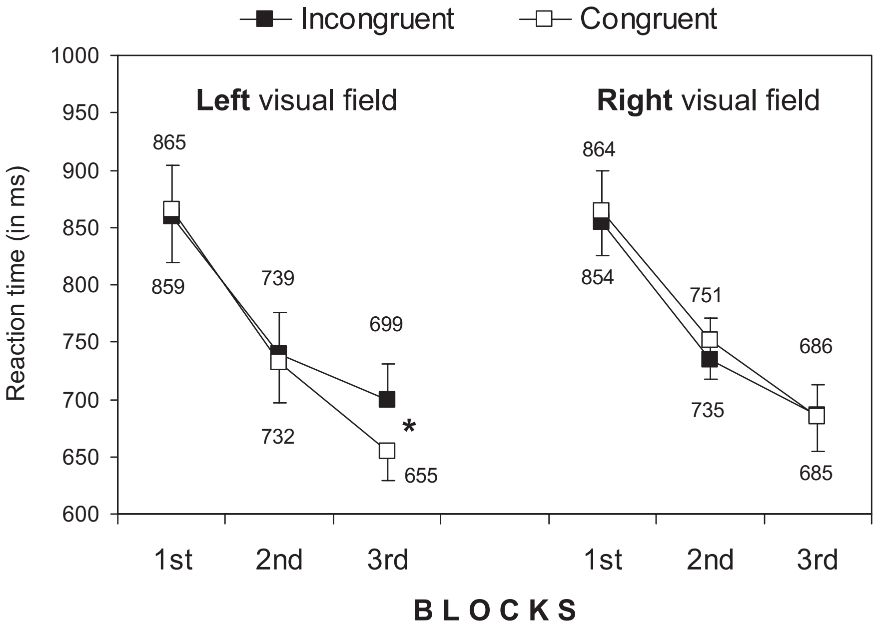

Figure 6. Mean response latencies as a function of prime–probe affective congruence, visual field, and block in Experiment 3. Asterisk indicates a significant difference between the congruent and incongruent conditions.

affective priming is not merely due to foveal interference with parafoveal analysis. The role of attentional load in this delay was further examined in Experiment 5 by manipulating and comparing the effects of single- versus dual-task performance.

Experiment 4

The previous experiments have demonstrated that preexposure to the unattended stimuli is required for affective priming. There remains the question of whether preexposure must necessarily involve attentional processing or whether mere parafoveal preexposure can also be effective. This issue could not be adequately addressed in Experiments 2 and 3, as the prime pictures were presented once in both foveal (as probes) and parafoveal (as primes) vision in each block. Experiment 4 was concerned with the specific contribution of parafoveal preexposure in promoting affective priming of unattended stimuli without the need of any prior attentional processing. To this end, the pictures serving as primes were presented only parafoveally once in each of four blocks. Consequently, each picture appeared either as a prime or as a probe for each participant. This, in addition to a 150-ms display and gaze-contingent foveal masking, guaranteed that the prime pictures could not be viewed foveally. Accordingly, if affective priming develops with cumulative preexposure of the primes, it will be specifically due to information extracted outside the focus of overt attention.

Method

Participants. Twenty-four psychology undergraduates (20 female, 4 male; 23 right-handed, 1 left-handed) participated for course credit.

Stimuli, apparatus, procedure, and design. The same unpleasant (30) and pleasant (30) visual scenes as in Experiments 1–3 were used, plus two new pleasant and two new unpleasant scenes (see the Appendix), with the same apparatus as in Experiment 3. The procedure was the same as in Experiment 3, with two exceptions. First, there were four (instead of three) blocks of trials, with each picture presented once in each block, either as a prime or as a probe. Second, half of the participants were presented with half of the pictures of each valence category only as primes (16, Set A) across blocks and with the other half of the pictures only as probes (16, Set B); the reverse occurred for the remaining participants (i.e., Set B for primes and Set A for probes). This implied that a given picture was always presented only as a prime or as a probe to a given participant, not as both a prime and a probe.

Results

Probability and end time of saccades toward the parafoveal primes. The probability that there was an eye movement toward the prime picture and the time to land a fixation on the prime location were analyzed in 2 (valence of probe) × 2 (visual field of prime) × 3 (block) ANOVAs. There was only a main effect of block on the probability of eye movements, $F(3, 69) = 17.96$, $p < .0001$, $\eta_p^2 = .44$, with significant differences between blocks (first block: $M = .66$; second block: $M = .56$; third block: $M = .51$; fourth block: $M = .43$; all post hoc comparisons, $ps < .025$, except between the second and third blocks, $p = .44$, *ns*). The time taken to land a fixation on the prime picture location was significantly affected by block, $F(3, 69) = 4.97$, $p < .01$, $\eta_p^2 = .18$, with significant differences only between the second and the fourth blocks ($p < .05$; first block: $M = 164$ ms; second block: $M = 164$ ms; third block: $M = 162$ ms; fourth block: $M = 161$ ms). There was also a Block × Visual Field interaction, $F(3, 69) = 6.08$, $p < .001$, $\eta_p^2 = .21$. Simple effect tests indicated that eye movements to the left prime ($M = 157$ ms) were faster than to the right prime ($M = 165$ ms) in the fourth block, $t(23) = 3.66$, $p < .01$, $d = .96$. The mean eye-movement time for the different experimental conditions ranged between 157 and 165 ms (*SD*s = between 6 and 11 ms). Only a few fixations (4.0%) landed on the prime area before the end of the prime display period, with a mean fixation time of only 3 ms.

Correct reaction times and number of fixations on the probe. Reaction times and number of fixations on the probe were analyzed in 2 (valence of probe) × 2 (prime–probe congruence) × 2 (visual field of prime) × 3 (block) ANOVAs. For reaction times, the analysis yielded a main effect of block, $F(3, 69) = 41.91$, $p < .0001$, $\eta_p^2 = .65$, with significant differences in reaction times between all blocks (first block: $M = 902$ ms; second block: $M = 809$ ms; third block: $M = 750$ ms; fourth block: $M = 706$ ms; all post hoc comparisons, $ps < .025$). There was also a Congruence × Visual Field × Block interaction, $F(3, 69) = 4.74$, $p < .01$, $\eta_p^2 = .17$. To decompose this interaction, we conducted separate ANOVAs for each block. For the first and the second blocks, no significant effects emerged. For the third block, there was a Congruence × Visual Field interaction, $F(1, 23) = 4.40$, $p < .05$, $\eta_p^2 = .16$. Nevertheless, this interaction resulted from an opposite tendency in each visual field, with differences between congruent and incongruent probes not reaching statistical significance in either the left ($M = 741$ ms vs. 769 ms, congruent vs. incongruent), $t(23) = 1.59$, $p = .12$, $d = .16$, or the right visual field ($M = 752$ ms vs. 737 ms, congruent vs. incongruent), $t(23) = 1.10$, $p = .28$, $d = .09$, separately. For the fourth block, there was a stronger Congruence × Visual Field interaction, $F(1, 23) = 6.62$, $p < .025$, $\eta_p^2 = .22$. Simple effect tests indicated that when the prime was presented on the left, reaction times were shorter for the congruent ($M = 682$ ms) than for the incongruent ($M = 729$ ms) probe, $t(23) = 3.12$, $p < .01$, $d = .35$, with nonsignificant differences when the prime was presented on the right ($M = 713$ ms vs. 702 ms, respectively; $t < 1$, $d = .07$). These interactions are represented in Figure 7.

For number of fixations on the probe pictures, the ANOVA also yielded main effects of block, $F(3, 69) = 48.78$, $p < .0001$, $\eta_p^2 = .68$, with significant differences between all blocks (first block: $M = 4.12$; second block: $M = 3.55$; third block: $M = 3.15$; fourth block: $M = 2.88$; all post hoc comparisons, $ps < .01$). There was also a Congruence × Visual Field × Block interaction, $F(3, 69) = 4.15$, $p < .01$, $\eta_p^2 = .15$. To decompose this interaction, we conducted separate ANOVAs for each block. For the first, second, and third blocks of trials, no significant effects emerged. For the fourth block, there was a Congruence × Visual Field interaction, $F(1, 23) = 6.89$, $p < .025$, $\eta_p^2 = .23$. Simple effect tests indicated that when the prime was presented on the left, there were fewer fixations on the congruent ($M = 2.78$) than on the incongruent ($M = 3.00$) probe, $t(23) = 2.68$, $p < .025$, $d = .31$, with nonsignificant differences when the prime was presented on the

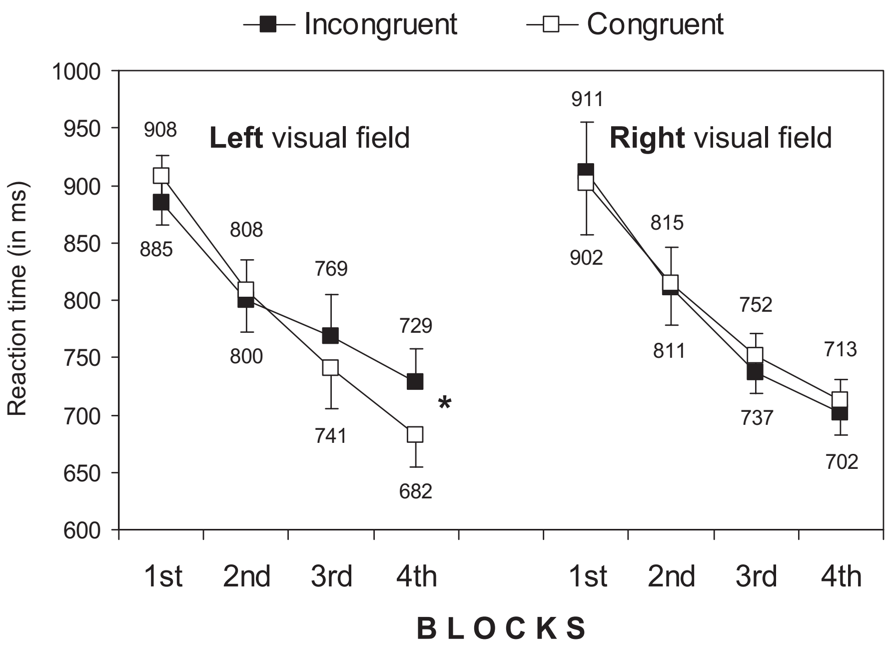

Figure 7. Mean response latencies as a function of prime–probe affective congruence, visual field, and block in Experiment 4. Asterisk indicates a significant difference between the congruent and incongruent conditions.

right (M = 2.92 vs. 2.81, respectively), $t(23) = 1.13$, $p = .27$, $d = .15$.

Discussion

There was affective priming for emotionally congruent prime–probe pairs when the prime was presented in the left hemifield. Nevertheless, this effect did not emerge clearly until the fourth time each prime was presented, as indicated by both shorter reaction times and fewer eye fixations on the congruent probe in the fourth block of trials. This finding reveals that there is processing of the affective valence of emotional stimuli even when these have been preexposed only at unattended locations of the visual field. To determine that there is genuine processing of the emotional significance of truly unattended visual scenes, it is noteworthy that the priming effects occurred in the absence of any foveal inspection of the primes. There were only 4% of very short 3-ms fixations on the primes, which were foveally masked anyway. Therefore, the new important finding of this experiment is that mere parafoveal preexposure (without overt attentional processing) is sufficient on its own for affective assessment.

Experiment 5

The previous experiments have shown that emotional congruence between a parafoveally presented prime scene and a foveal-probe scene facilitates the affective evaluation of the probe. As this occurred when the viewers' focal attention was engaged in a concurrent foveal task and when foveal vision of the prime was masked, the finding has been taken as an indication that the valence of the unattended prime is processed. It should, however, be noted that this is an indirect (although standard) measure, as the affective processing of the prime is inferred from the effects on the probe. In Experiment 5, we used a direct index of the processing of the prime valence and examined the extent to which this would be accessible to consciousness without overt attention. To this aim, participants had to explicitly evaluate the affective valence of the parafoveal primes themselves under foveal masking. This approach is useful in determining if the previously found effects of preexposure and lateralization depend on awareness of the prime valence. If so, identification of the prime valence should become more accurate across blocks, and there should be heightened awareness of the valence of primes presented to the left visual field in a fashion similar to the previously observed enhancement of affective priming across blocks and for the left visual field.

A further aim of Experiment 5 concerned the extent to which such affective analysis of overtly unattended primes involves data-limited versus resource-limited processes in perceptual encoding. Direct affective evaluation of the prime stimuli was performed either in a single-task condition (only the parafoveal-prime scene was presented) or under dual-task conditions (the parafoveal prime appeared at the same time as a concurrent foveal letter to be identified). If parafoveal emotional encoding is resource limited, identification of the prime valence should be lower in the dual-versus the single-task condition; in contrast, if emotional encoding is data limited, performance should be equivalent in both types of conditions. This approach is useful for investigating the role of covert attention—which would be reduced in the dual-task condition—in the absence of overt attention (i.e., foveal masking).

Method

Participants. Forty-eight undergraduates (36 female, 12 male; 41 right-handed, 7 left-handed) participated for course credit.

Stimuli, apparatus, procedure, and design. The same 32 unpleasant and 32 pleasant visual scenes as in Experiment 4 were used. The apparatus and procedure were similar to those used in Experiment 4, with the following exceptions. First, participants were asked to attempt to identify whether the prime scene was positive or negative in valence rather than evaluating the probe valence. The original probes no longer appeared and were replaced with a meaningless combination of colors. In Experiment 5, we adjusted the luminance ($M = 130$) and RMS contrast ($M = 2.19$) of this replacement probe so that they were equivalent, on average, to those of both the pleasant and the unpleasant original probe pictures in the other experiments. Visual scenes were presented only as parafoveal primes once in each of three blocks. After a pilot study, we realized that the new procedure (i.e., focusing only on the prime) produced ceiling effects in the fourth block; accordingly, only three blocks were performed in this experiment.

Second, half of the participants were randomly assigned to a single-task condition, in which only a parafoveal-prime picture appeared following the central fixation point. The other half underwent a dual-task condition in which a foveal letter (A or O) appeared at the same time as the parafoveal prime (as in Experiments 1 and 2), following the fixation point. The participants were to immediately name the letter and then evaluate the prime scene. In both cases, the prime was displayed for 150 ms, foveal gaze-contingent masking was used if the viewers directed their gaze toward the parafoveal picture (as in Experiments 3 and 4), and eye-movement monitoring was employed. Figure 8 shows the sequence of events in a trial and a session.

Third, the experimental conditions were combined in a mixed factorial design, with task condition (single vs. dual) as a between-subjects factor (24 participants at each level) and block (1 vs. 2 vs. 3), prime valence (unpleasant vs. pleasant), and prime visual field (left vs. right) as within-subject factors. Two behavioral measures were collected to assess identification of the prime valence: response accuracy (i.e., probability of hits) and reaction times for correct responses. Three eye-movement measures were collected to determine whether attention was oriented to the prime stimuli: the probability that a saccade was initiated toward the prime, the probability that it landed on the prime before this stimulus disappeared, and the duration of this fixation.

Results

Accuracy above the chance level. One-sample t tests were used to test if the probability of correct responses in the valence evaluation task exceeded the chance level, that is, .50. For the single-task condition, the difference between the empirical hit rates and the chance level was significant for all the combinations of block, valence, and visual field, all $ts(23) \geq 9.98$, $p < .0001$. For the dual-task condition, the differences were also significant in all cases, all $ts(23) \geq 5.33$, $p < .0001$.

Hits and correct reaction times. The probability that the participant correctly identified the valence of the prime, as well as the response latency on this task, was analyzed in 2 (task condition) × 3 (block) × 2 (valence of prime) × 2 (visual field of prime) ANOVAs. For hits, the ANOVA yielded main effects of block, $F(2, 92) = 28.36$, $p < .0001$, $\eta_p^2 = .38$; valence, $F(1, 46) = 26.02$, $p < .0001$, $\eta_p^2 = .36$; and visual field, $F(1, 46) = 12.04$, $p < .001$, $\eta_p^2 = .21$. The hit rate increased across blocks (first block: $M = .813$ vs. second block: $M = .884$ vs. third block: $M = .910$; all differences between blocks, $p < .01$, after Bonferroni corrections). The hit rate was higher for pleasant than for unpleasant scenes ($M = .901$ vs. .837) and higher in the left visual field compared with the right field ($M = .882$ vs. .856). The effect of task condition was not significant, $F(1, 46) = 1.82$, $p = .18$, although there was a Task × Block interaction, $F(1, 92) = 5.46$, $p < .01$, $\eta_p^2 = .11$. This interaction reflected the fact that response accuracy was poorer in the dual- versus the single-task condition for the first block, $t(46) = 2.07$, $p < .05$, $d = .60$, with no significant differences in the other blocks (see the mean scores in Figure 9).

Reaction times for correct responses were affected by task condition, $F(1, 46) = 11.32$, $p < .01$, $\eta_p^2 = .20$; block, $F(2, 92) = 96.29$, $p < .000$, $\eta_p^2 = .68$; and valence, $F(1, 46) = 43.80$, $p < .0001$, $\eta_p^2 = .49$. Response latencies were shorter in the single- than in the dual-task condition ($M = 734$ ms vs. 834 ms) and shorter for pleasant than for unpleasant scenes (760 ms vs. 808 ms). In addition, response times decreased across blocks (first block: $M = 862$ ms vs. second block: $M = 761$ ms vs. third block: $M = 727$ ms; all differences between blocks, $p < .001$). The effect

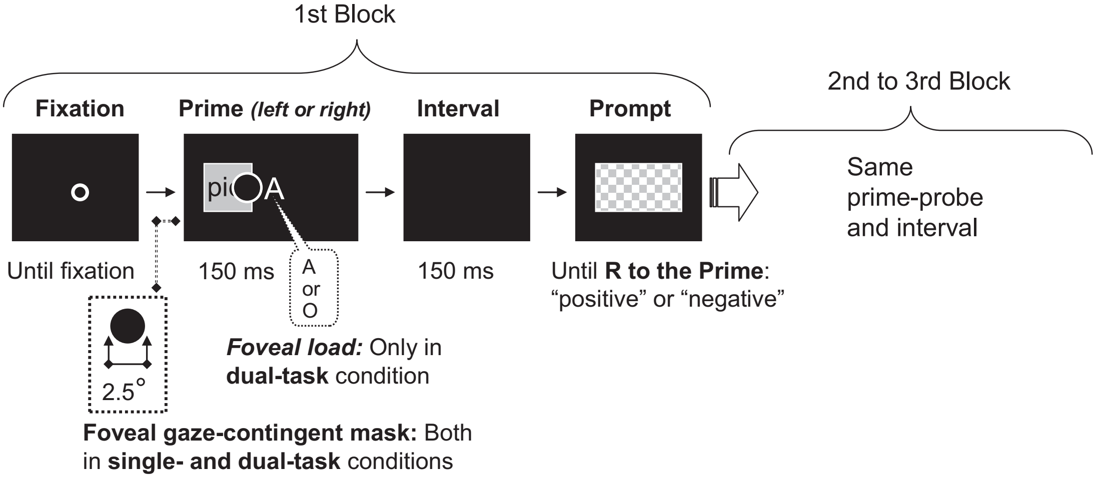

Figure 8. Sequence of events within a trial and across blocks in Experiment 5. pic = picture; R = response.

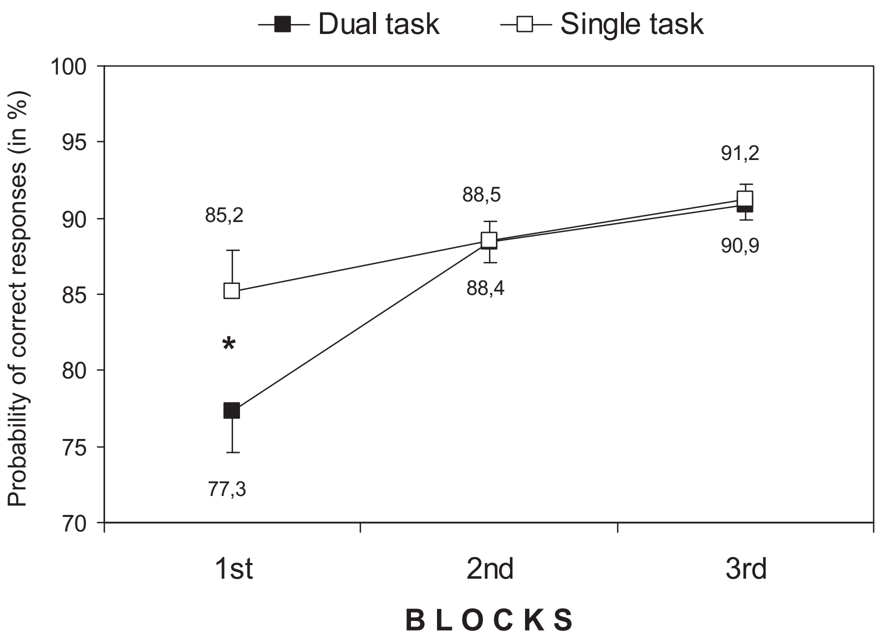

Figure 9. Mean accuracy in the identification of the prime valence across blocks in the single- and dual-task conditions in Experiment 5. Asterisk indicates a significant difference between task conditions.

of visual field was not significant ($F < 1$), although there was a Block × Visual Field interaction, $F(1, 92) = 4.50$, $p < .025$, $\eta_p^2 = .09$. The interaction reflected the fact that response latencies were shorter for primes in the left than in the right visual field in the third block ($M = 721$ ms vs. 736 ms), $t(47) = 2.18$, $p < .05$, $d = .19$, with no significant differences in the other blocks (see the mean scores in Figure 10).

Probability of saccades and fixations on the parafoveal prime. Eye movements toward and on the parafoveal pictures were analyzed in 2 (task condition) × 3 (block) × 2 (valence of prime) × 2 (visual field of prime) ANOVAs. The mean probability of initiating a saccade from the central fixation point toward the prime stimulus was .183 (i.e., on 18.3% of trials). Significant effects emerged only for task condition, $F(1, 46) = 4.09$, $p < .05$,

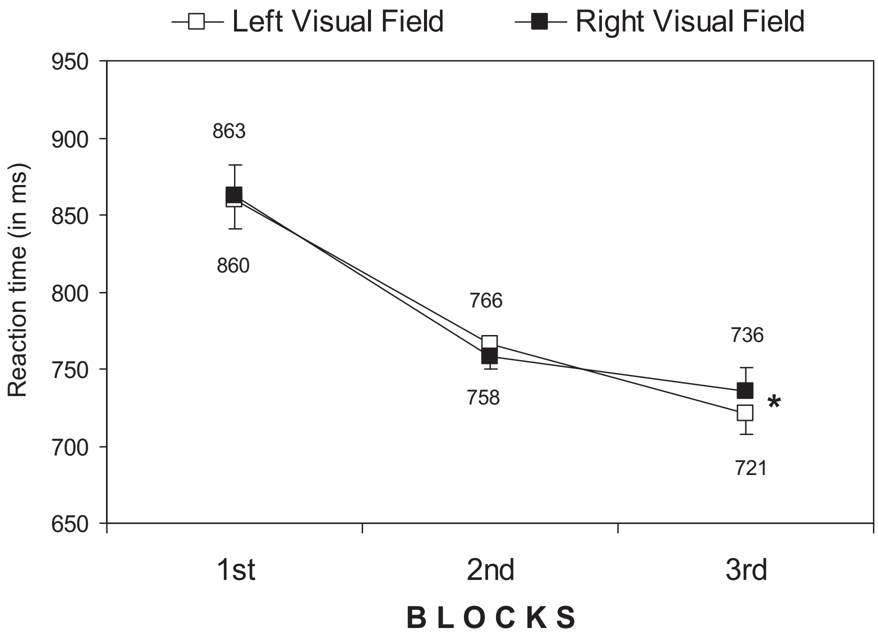

Figure 10. Mean response latencies in the identification of the prime valence across blocks as a function of visual field in Experiment 5. Asterisk indicates a significant difference between the left and right visual fields.

$\eta_p^2 = .08$, with more saccades toward the prime in the single- than in the dual-task condition ($M = .258$ vs. $.108$). There were borderline effects of block, $F(2, 92) = 2.67$, $p = .075$, $\eta_p^2 = .05$ (first block: $M = .203$ vs. second block: $M = .184$ vs. third block: $M = .161$), and no effects of valence ($F < 1$; unpleasant: $M = .184$ vs. pleasant: $M = .182$) or visual field ($F < 1$; left: $M = .189$ vs. right: $M = .177$).

The mean probability that a saccade landed on the prime stimulus area was only .0165 (i.e., 1.65% of trials). No effect reached statistical significance. All Fs < 1 for task condition (single: $M = .021$ vs. dual: $M = .012$), block (first: $M = .016$ vs. second: $M = .017$ vs. third: $M = .017$), valence (unpleasant: $M = .015$ vs. pleasant: $M = .018$), and visual field (left: $M = .018$ vs. right: $M = .015$). The mean end time of all saccades initiated from the central fixation point during the 150-ms prime display (i.e., the time taken to land on the prime stimulus area) was 170 ms, ranging between 136 and 203 ms for the different experimental conditions. There were no statistically significant effects. Furthermore, the mean saccade end time for those cases that landed on the prime stimulus while it was still displayed (i.e., 1.65%) was 145.7 ms, which implies that mean effective fixation time on the prime was only 4.3 ms (and only for these few cases).

Discussion

There were two major groups of related findings. One is concerned with the accessibility to awareness of the affective valence of overtly unattended stimuli. First, in spite of a practical absence of fixations on the pictures, their valence was accurately identified above the chance level. Second, accuracy increased across blocks and was higher in the left than in the right visual field. Third, reaction times were shorter across blocks, and there was a speed advantage for left-visual-field primes in the third block. Accordingly, the enhanced priming with exposure and the left-visual-field bias observed in the other experiments parallel the pattern of heightened identification of valence in Experiment 5. This suggests that awareness of the prime valence is involved in the affective priming of unattended stimuli. Nevertheless, accuracy was above chance in all blocks and visual fields and was greater for pleasant than for unpleasant primes in this experiment. In contrast, affective priming did not emerge until the third trial, was significant only in the left visual field, and was similar for pleasant and unpleasant probes in the other experiments. This implies that although affective valence of overtly unattended scenes has access to awareness, it occurs in a graded fashion and must reach a certain level to produce priming.[2]

The second group of results is concerned with the extent to which parafoveal encoding of emotional scenes is resource limited versus data limited. Two types of data favor the resource-limited account by showing that valence encoding is impaired by attentional load. First, accuracy in the identification of the prime valence was affected interactively by block and task, such that performance was impaired in the dual-task condition in the first block. This reveals that when identification is more difficult (i.e., without any prior exposure to the stimuli), resource consumption by attentional load limits the encoding of valence. Second, there was a main effect of task condition on reaction times, such that response latencies were longer in the dual- than in the single-task condition. This indicates that speed of access to awareness of the overtly unattended prime valence relies on the availability of capacity-limited processing resources. If parafoveal emotional encoding were only data limited, identification of prime valence would be comparable in the dual- and the single-task conditions.

The current data further show that the resources on which parafoveal emotional encoding depends involve covert rather than overt attention. Thus far, we can summarize the findings regarding the role of attention in parafoveal affective priming. Experiments 1 and 2 showed that affective processing can be performed with reduced covert attentional resources (and probably—although not empirically demonstrated—in the absence of overt foveal attention). Experiments 3 and 4 revealed that affective priming can occur in the absence of overt foveal attention (but with available covert attentional resources). The results of Experiment 5 are the most informative and complete regarding this issue. They indicate that in the absence of overt attention (due to foveal masking), reduced covert attention (due to foveal loading or dual-tasking vs. single-tasking) made a difference: The dual-task condition impaired accuracy and slowed down identification of affective valence. This suggests that affective processing relies to some extent on the availability of attentional resources but that this involves covert rather than overt attentional mechanisms.

Experiment 6

Experiment 6 aimed at investigating whether there is any specialness of emotional processing of unattended stimuli in comparison with nonemotional processing. From the previous experiments, we have inferred that emotional valence has some privileged status in that it can be analyzed even when the emotional stimuli are outside the focus of spatial attention. Furthermore, the pattern of findings showing an advantage in the processing of emotional stimuli presented to the left visual field and the dependence on preexposure of the stimuli have led us to argue that laterality is involved and that affective representations are accrued with repeated experience. An important question is, however, the extent to which this is specific or unique to the processing of emotional valence. Do other high-order attributes not related to emotional significance also show a similar processing advantage for the encoding of unattended stimuli, as well as a similar pattern regarding laterality and preexposure?

In Experiment 6, we compared affective and semantic processing by means of varying the task relevance of the affective or semantic attributes of the same stimuli. Essentially, pleasant or unpleasant scenes portraying people or animals were presented as primes and probes, and participants had to make either an affective evaluation (pleasant or unpleasant) or a semantic categorization (people or animal) of the probe. For both these tasks, valence and

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[2] We are grateful to a reviewer for suggesting the following alternative interpretation. Awareness of the prime valence might have appeared earlier (i.e., first block in Experiment 5) than affective priming (i.e., third or fourth block in the other experiments) because of the primes being easier to discriminate in the presence of the meaningless replacement probes (Experiment 5) than in the presence of the meaningful original probes (the other experiments). It is thus possible that awareness and affective priming may, in fact, emerge simultaneously. In any case, from the results of Experiment 5, we can infer that affective priming does not occur without or before awareness when stimuli are presented parafoveally.

category were combined in such a way that a prime–probe pair could be either congruent in both features (e.g., both pleasant people), incongruent in both (e.g., pleasant people/unpleasant animal), or congruent in one and incongruent in the other. This design allowed us to determine whether the processing of unattended affective content is different from the processing of unattended semantic content in terms of three main issues: the dependence on preexposure, the modulation by laterality, and the generality or task-specificity, that is, the extent to which affective and semantic processing occur regardless of whether or not they are relevant to task performance.

Method

Participants. Eighty psychology undergraduates (64 female, 16 male; 67 right-handed, 13 left-handed) participated for course credit.

Stimuli. Sixty-four pictures were presented, of which 32 portrayed scenes involving people (16 pleasant, 16 unpleasant), and 32 portrayed animal scenes (16 pleasant, 16 unpleasant). All the people scenes (a subsample of those used in the previous experiments) and most of the animal scenes (except a few that had to be added to complete the sample) were selected from the IAPS (Lang et al., 2005; see the Appendix).

Apparatus, procedure, and design. The apparatus was the same as in Experiments 1 and 2. The procedure was similar to that in Experiment 2 (i.e., no preview of stimuli, three blocks of trials, concurrent foveal letter identification during the left- or right-visual-field presentation of a parafoveal-prime picture for 150 ms, and response to a probe picture at 300-ms SOA), with the following important differences. First, 40 participants were randomly assigned to a valence evaluation task (as in all the previous experiments), in which they had to make an affective assessment of each probe scene, whereas the other 40 subjects were assigned to a semantic categorization task, where they had to decide whether each probe scene contained people or animals. The picture stimuli were the same for both tasks. Second, on each block, each picture was presented only once either as a prime or as a probe (as in Experiments 4–5). Thus, half of the participants were presented with half of the pictures of each type (e.g., pleasant people) as primes and the other half of the pictures of the same type as probes; the reverse applied to the other half of the participants.

This yielded a complex design involving relevant task (semantic vs. affective judgment) as a between-subjects factor and emotional valence of the prime (unpleasant vs. pleasant), emotional valence of the probe (unpleasant vs. pleasant), semantic category of the prime (people vs. animals), semantic category of the probe (people vs. animals), visual field of the prime (left or right), and block (first vs. second vs. third) as within-subject factors, all of which were orthogonally combined. Each participant received one of four different counterbalancing conditions, with trials within each block being presented in random order. To make this complex design manageable for statistical analysis, we converted the semantic category of the prime and the probe and the affective valence of the prime and the probe into semantic congruence (congruent vs. incongruent) and affective congruence (congruent vs. incongruent), respectively.

Results

The 2 (relevant task) × 2 (affective prime–probe congruence) × 2 (semantic prime–probe congruence) × 2 (visual field of prime) × 3 (block) ANOVA yielded significant main effects of affective congruence, $F(1, 78) = 16.42$, $p < .0001$, $\eta_p^2 = .17$; semantic congruence, $F(1, 78) = 12.53$, $p < .001$, $\eta_p^2 = .14$; and block, $F(2, 156) = 69.64$, $p < .0001$, $\eta_p^2 = .47$, on the latencies of correct responses. Reaction times were faster for valence-congruent than for valence-incongruent probes ($M = 835$ ms vs. 857 ms) and for category-congruent than for category-incongruent probes ($M = 836$ ms vs. 856 ms), with differences in reaction times between all blocks (first block: $M = 921$ ms; second block: $M = 837$ ms; third block: $M = 779$ ms; all post hoc comparisons, $ps < .0001$). The effects of task (affective evaluation: $M = 863$ ms vs. semantic categorization: 829 ms) and visual field (left: $M = 845$ ms vs. right: 847 ms) were not significant (both $Fs < 1$).

The effects of affective congruence were qualified by an interaction with block, $F(2, 156) = 4.89$, $p < .025$, $\eta_p^2 = .054$, whereas those of semantic congruence were not ($F < 1$). To decompose this interaction, we conducted separate 2 (relevant task) × 2 (affective congruence) × 2 (semantic congruence) × 2 (visual field) ANOVAs for each block across tasks. As shown in Figure 11, the priming effect of affective congruence approached significance in the second block, $F(1, 78) = 3.77$, $p = .056$, $\eta_p^2 = .046$, and it became highly significant in the third block, $F(1, 78) = 25.86$, $p < .0001$, $\eta_p^2 = .25$.

In contrast, the effects of semantic congruence were qualified by interactions with task, $F(1, 78) = 6.15$, $p < .025$, $\eta_p^2 = .073$, and with visual field, $F(1, 78) = 9.68$, $p < .01$, $\eta_p^2 = .11$, but the effect of affective congruence was not, $F(1, 78) = 1.21$, $p = .27$, and $F < 1$, respectively. Separate 3 (block) × 2 (affective congruence) × 2 (semantic congruence) × 2 (visual field) ANOVAs were conducted for each task condition. The Semantic Congruence × Task interaction reflects the fact that there was priming of category-congruent probes when semantic categorization was task relevant, $F(1, 39) = 15.38$, $p < .0001$, $\eta_p^2 = .28$, but not when affective evaluation was task relevant ($F < 1$). In contrast, it is important to note that there was affective priming of valence-congruent probes not only when affective evaluation was task relevant, $F(1, 39) = 11.41$, $p < .01$, $\eta_p^2 = .23$, but also when semantic categorization was task relevant, $F(1, 39) = 5.20$, $p < .05$, $\eta_p^2 = .12$, thus corroborating the main effect of affective congruence across tasks. This contrast is shown in Figure 12.

The Semantic Congruence × Visual Field interaction revealed that category-congruent probes were responded to faster than category-incongruent probes when the prime appeared in the right visual field, $F(1, 78) = 24.18$, $p < .0001$, $\eta_p^2 = .24$, but not when the prime appeared in the left visual field ($F < 1$; see Figure 13). In contrast, it must be noted that there was affective priming of valence-congruent probes in both the right and the left visual fields, $F(1, 78) = 9.54$, $p < .01$, $\eta_p^2 = .11$, and $F(1, 78) = 7.55$, $p < .01$, $\eta_p^2 = .088$, respectively. This contrast is shown in Figure 13.

Discussion

The priming patterns for high-order affective attributes (pleasant–unpleasant valence) and high-order semantic attributes

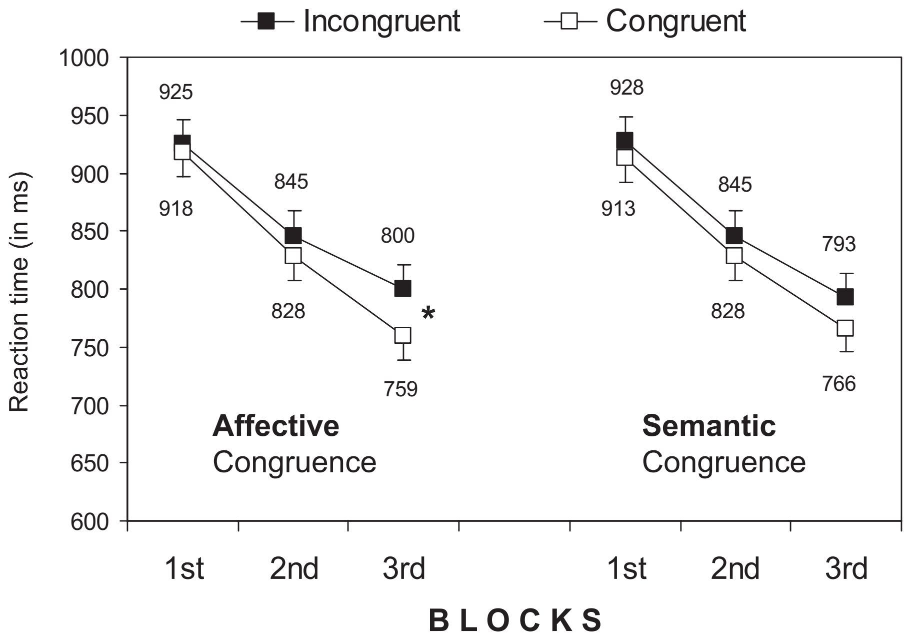

Figure 11. Mean response latencies as a function of prime–probe affective congruence, semantic congruence, and block across tasks in Experiment 6. Asterisk indicates a significant difference between the congruent and incongruent conditions.

(animal–person category) of the same object stimuli were relatively different. The results showed three major differences between emotional (valence) processing and semantic (category) processing of visually unattended scenes. First, there was both affective and semantic priming. However, valence encoding was clearly modulated by preexposure, as shown by the Affective Congruence × Block interaction, whereas category encoding seemed less dependent on preexposure, as revealed by the main

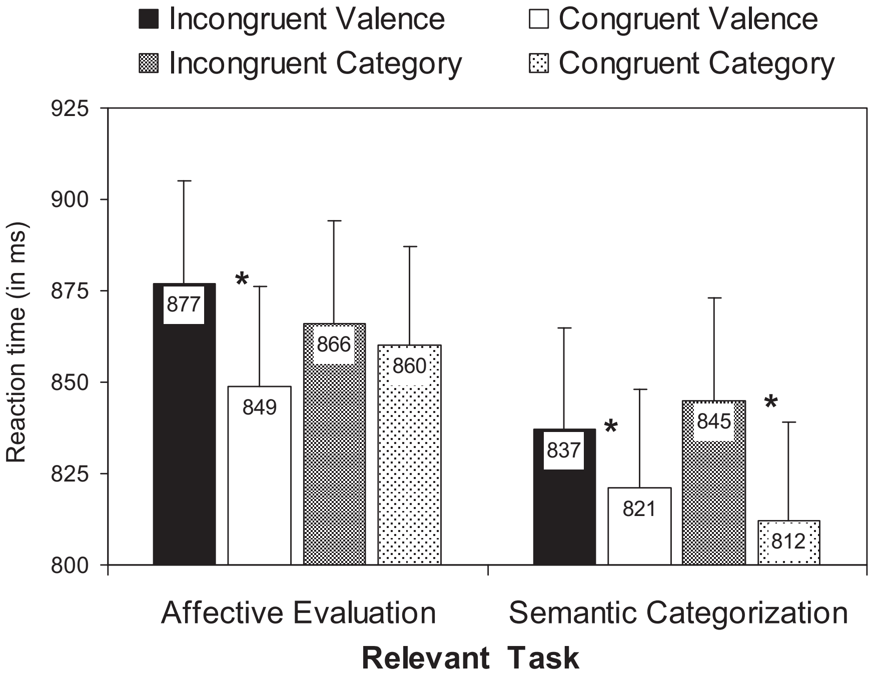

Figure 12. Mean response latencies as a function of prime–probe affective congruence and prime–probe semantic congruence in the affective evaluation task and in the semantic categorization task in Experiment 6. Asterisks indicate significant differences between the congruent and incongruent conditions.

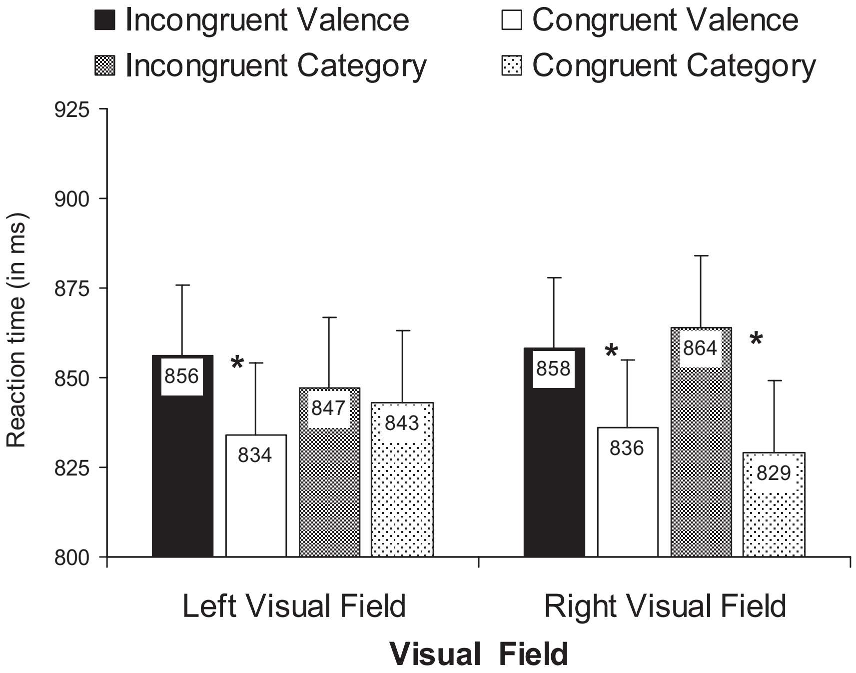

Figure 13. Mean response latencies as a function of prime–probe affective congruence, prime–probe semantic congruence, and visual field of prime in Experiment 6. Asterisks indicate significant differences between the congruent and the incongruent conditions.

effect of semantic congruence. Second, valence encoding and category encoding were affected by visual field in a different fashion. There was semantic priming only when primes were presented in the right visual field, whereas affective priming appeared also in the left field (in this experiment) and systematically in the left field in the previous experiments. Third and possibly most important, affective priming held even under semantic-task-relevant (affective-task-irrelevant) conditions—and also under affective-task-relevant conditions. In contrast, semantic priming was limited to semantic-task-relevant conditions and did not emerge under affective-task-relevant conditions. This suggests that valence encoding generally occurs with emotional stimuli regardless of whether affective processing is relevant for task performance, whereas category encoding is more task oriented. A possible explanation is that category encoding is short-circuited, filtered out, or suppressed when priority is given to emotional processing.

These findings can be related to prior research on the primacy of affective versus semantic processing of pictorial stimuli. S. T. Murphy and Zajonc (1993) demonstrated that subliminally presented faces expressing happiness or anger primed the affective evaluation of probes more than they primed the judgments of the size or gender of probes. This suggests that affective information is more likely to be processed than perceptual and semantic information that is not affective in nature. In contrast, Storbeck and Robinson (2004) found semantic category priming, but not affective priming, using pictures of pleasant and unpleasant animals that had to be either affectively evaluated as good or bad or assigned to one of two semantic categories. This suggests that perceptual and semantic processing of valenced stimuli has priority over affective processing. Our results are partly consistent with both these otherwise discrepant studies. The fact that affective priming, but not semantic priming, occurred in our study even when affective processing was task irrelevant would be consistent with Murphy and Zajonc's view by indicating that emotional valence has some relatively privileged status or access to the cognitive system. In contrast, the fact that affective priming, but not semantic priming, was dependent on preexposure would be consistent with Storbeck and Robinson's view by showing that semantic priming occurs earlier. The different laterality pattern for affective and cognitive priming was not addressed in the Murphy and Zajonc and the Storbeck and Robinson studies, as the primes were presented foveally.

General Discussion

This study investigated whether emotional significance can be extracted from overtly unattended visual scenes (in conditions of reduced or nonreduced covert attention). The processing of emotional significance was examined by means of an affective priming paradigm that assessed facilitated evaluation of probe pictures preceded by emotionally congruent versus incongruent prime pictures. Unattended stimuli were operationally defined as pictures presented in parafoveal locations of the visual field and under gaze-contingent foveal masking (overt inattention) or under concurrent foveal load (reduced covert attention). The current experimental conditions prevented eye fixations on the prime stimuli. Consequently, the stimuli were unattended in the sense that they were not directly looked at or overtly attended to. If information is obtained in such conditions, this implies that the stimuli must have been seen somehow, but this would occur outside the focus of visual spatial attention or by means of covert rather than overt attention.

Results revealed facilitation of affective evaluation responses for probes when emotionally congruent primes were presented at unattended locations of the visual field. Nevertheless, such an affective priming depended on preexposure to the stimuli, as it did not emerge the first time the pictures were presented, but only after a foveal preview phase (Experiment 1), after repeated presentation in either foveal and parafoveal vision (Experiments 2 and 3), or only in parafoveal vision (Experiments 4 and 6). Furthermore, affective priming was associated with a left-visual-field bias, as it generally occurred when the primes were presented to the left hemifield (Experiments 1–4). These patterns regarding preexposure and lateralization for affective priming on the probe were replicated when participants directly assessed the valence of the parafoveally presented, foveally masked primes (Experiment 5). Finally, affective priming showed some special characteristics in comparison with semantic priming in terms of the roles of preexposure, lateralization, and task relevance (Experiment 6).

We have attributed these priming effects to the emotional significance or valence of the stimuli. However, in addition to valence, arousal has been identified as another basic affective dimension of stimuli (see Lang, Bradley, & Cuthbert, 1998). Valence refers to the quality or direction of affect along a continuum of unpleasantness–pleasantness; arousal is a dimension of activation reflecting variations from calm to tension in both unpleasantness and pleasantness. In several studies, the arousal value of words and pictures was a more potent factor than valence in determining how emotion interacts with attention (Anderson, 2005; Keil & Ihssen, 2004; Schimmack, 2005). In our study, however, it is unlikely that arousal accounted for the priming effects associated with valence. The reason is that arousal ratings were significantly higher for unpleasant than for pleasant scenes,[3] whereas the priming effects were similar for both valence categories. Moreover, the effects of valence in Experiment 5 showing a more accurate and faster identification of the pleasant versus unpleasant primes go in the opposite direction to that of the presumed effect of arousal, that is, the less arousing scenes were actually perceived more accurately and faster than the more arousing scenes. This suggests that although high arousal is related to enhanced sensory and attentional processing (e.g., Anderson, 2005; Keil & Ihssen, 2004; Schimmack, 2005; in all cases, foveal fixation on the stimuli was allowed), valence also has genuine access to parafoveal processing.

Automaticity Versus Resource Dependence in the Affective Processing of Unattended Emotional Visual Scenes

The affective priming paradigm has been used in prior research to assess whether the emotional valence of visual scenes is automatically extracted from pictorial stimuli (see Klauer & Musch, 2003). Affective priming is revealed by faster responses to the probe when it is preceded by primes of the same emotional valence than by primes of different valence. This effect has been observed when the prime is presented very briefly (200 ms or less; e.g., Carroll & Young, 2005) and even with subliminal exposure (Banse, 2001), in the presence of a secondary resource-demanding task (Hermans, Crombez, & Eelen, 2000), when the participants are asked to ignore the prime and attend only to the probe (Hermans et al., 1994), and when the participants have to name (rather than evaluate) the probe stimulus (Spruyt, Hermans, De Houwer, & Eelen, 2004). This suggests that affective processing is fast and efficient and can occur outside awareness and involuntarily, thus satisfying major criteria of automaticity (Moors & De Houwer, 2006).

In these studies, stimuli were always presented in the center of the visual field and, hence, within the focus of spatial attention. The current study has extended these conclusions for stimuli that are not overtly attended. Some criteria of automaticity, but not others, have been fulfilled similarly for foveally attended and unattended stimulus processing. On the one hand, our data corroborate the speed criterion, with the prime stimuli being presented for 150 ms and a 300-ms SOA. They also confirm the unintentionality criterion, with affective priming occurring not only when affective processing was task relevant but also when processing of the semantic category of stimulus content was task relevant (and affective processing was task irrelevant). Furthermore, there was parallel processing of the parafoveal prime, thus complying with one important aspect of the efficiency criterion. This is inferred from the fact that priming occurred when the prime was presented at the same time as attentional resources had to be engaged in identifying a foveal letter (in Experiments 1, 2, 5, and 6).

However, on the other hand, two types of data argue against a totally automatic conceptualization of parafoveal affective priming. First, the affective processing of parafoveal stimuli was impaired by foveal load (Experiment 5), which indicates that affective analysis consumes covert attentional resources. Anderson (2005) found that it is the arousal value of words, rather than their valence, that is associated with reduced need of attentional resources. Consistent with this, our findings reveal that although emotional valence can be assessed without overt attention, the valence evaluation process is capacity limited in the sense of being dependent on the available covert attentional resources for encoding. Second, and related to the previous issue, the heightened awareness across blocks and for the primes presented in the left visual field (Experiment 5) clearly mirrors the patterns of enhancement of affective priming by preexposure and a left-visual-field advantage. This implies that parafoveal affective priming depends on the degree of awareness of the unattended stimulus valence. This is in contrast with findings of affect processing under subliminal, albeit foveal, presentation of stimuli (Banse, 2001; Hermans et al., 2003; S. T. Murphy & Zajonc, 1993). Accordingly, emotional processing of parafoveally presented, foveally unattended stimuli can be automatic in the sense of being fast, involuntary, and performed in parallel to unrelated foveal tasks, but it is sensitive to other regulatory influences of attention (see Lavie, 2005; Vuilleumier, 2005), such as the availability of resources and awareness. This is consistent with a flexible view of automaticity (see Moors & De Houwer, 2006).

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[3] We compared the arousal rating scores of the pleasant and unpleasant stimuli that were used in these experiments. Mean arousal was higher for the unpleasant than for the pleasant scenes: 5.95 vs. 4.94 in American samples of participants (Lang et al., 2005), $t(62) = 4.77$, $p < .0001$, and 6.67 vs. 4.99 in Spanish samples of participants (Moltó et al., 1999; Vila et al., 2001), $t(62) = 6.71$, $p < .0001$.

Brain Hemispheric Dominance in Affective Priming

The conclusion that information about the affective significance of emotional scenes is obtained even when these are presented at unattended locations of the visual field must be qualified by two constraints. First, although, during the presentation of the prime pictures, something was perceived that facilitated processing of the congruent probe, this effect depended on stimulus preexposure (see next section). Second, affective priming was consistently found when the prime appeared in the left visual field; for primes in the right hemifield, there was generally no affective priming (except in Experiment 6).

An interpretation of this second finding is that there is right-hemisphere dominance in the processing of visual emotional content, both pleasant and unpleasant, which manifests itself in a wider attentional span to the left visual field. This is consistent with early right-hemisphere models of emotion perception (e.g., Schwartz, Davidson, & Maer, 1975) and more recent variants of this hypothesis (e.g., Adolphs, Damasio, Tranel, & Damasio, 1996; Borod et al., 1998; Heller, Nitschke, & Miller, 1998). However, a valuable meta-analysis combining results from 106 brain imaging studies on emotion (F. C. Murphy, Nimmo-Smith, & Lawrence, 2003) failed to support a special role for the right hemisphere in emotion perception. It should, nevertheless, be noted that F. C. Murphy et al. (2003) included a wide range of stimulus modalities in the analysis (visual, auditory, olfactory, tactile, and taste) and that within the visual modality, there was also considerable variety in the stimulus format and content (scenes, faces, films, ideograms, sentences, words, and imagery), in addition to a wide array of experimental paradigms used to obtain brain activation measures. Although this meta-analysis showed that there is no firm evidence in support of an overall lateralization in the processing of emotional content, it is possible that right-hemisphere dominance is particularly involved in some conditions or for some types of stimuli.

In the present study, we used emotional visual scenes, for which prior research has provided some specific support regarding right-hemisphere dominance. Such support comes, first, from studies using fMRI and positron emission tomography (PET) to assess brain activity during the presentation of pictures in central vision. With fMRI, Lang, Bradley, Fitzsimmons, et al. (1998) found more activation for both pleasant and unpleasant scenes than for neutral scenes in the right posterior region of the occipital cortex. Also with fMRI, Bradley et al. (2003) reported more activation for emotional than for neutral scenes at both right and left sides of the posterior visual cortex, although the difference tended to be greatest on the right side, particularly for highly arousing unpleasant scenes. With PET, Lane, Chua, and Dolan (1999) noted more activation in extrastriate visual cortex and right anterior temporal cortex for emotional scenes, particularly for highly arousing unpleasant scenes. The second source of evidence comes from studies in which the visual hemifield of stimulus presentation is manipulated. Keil et al. (2005) recorded ERPs while flickering unpleasant and neutral pictures were presented simultaneously to left and right visual fields. Participants had to attend to the picture at one of the locations while the other picture served as a distractor. These authors found right occipito-temporal and parietal activation when unpleasant scenes (in comparison with neutral scenes) were presented in the left visual field. They concluded that arousing information does not depend on spatial attentional resources when presented in the left visual field and that emotional information has facilitated access to the right-hemispheric sites in the brain. Nevertheless, as indicated in the introductory section above, the inner edges of the pictures in the Keil et al. study were located only 1.3° away from the central fixation point, and eye movements were allowed (see also Vuilleumier et al., 2001). The current study has extended these findings to parafoveal processing (2.5°) and to both types of emotional stimuli, pleasant and unpleasant.

Preattentive Versus Postattentive Processing: The Role of Prior Exposure

According to models of preattentive processing of emotional content (e.g., Bargh, 1997; Zajonc, 2000), assessment of the affective valence of visual scenes can be performed automatically, and such evaluations precede categorization and identification of objects. More specifically, Bargh (1997; see also Chartrand, van Baaren, & Bargh, 2006) argued that an evaluation module exists that first evaluates every stimulus people encounter on a positive–negative dimension, both within and outside their conscious awareness. According to Zajonc (2000; S. T. Murphy & Zajonc, 1993), this crude valence distinction of objects as good or bad precedes more discriminative processing of other perceptual or semantic characteristics, such as the size or gender of emotional face expressions, for example.

The findings of the current study are relevant to this conceptualization. We have already examined the distinction between overt and covert attention. The preattentive view would imply that emotional stimuli can be encoded without attention of any kind. The fact that valence is extracted and priming occurs in the absence of overt spatial attention to the prime stimuli is consistent with the preattentive assumptions. However, the fact that valence processing of unattended stimuli is affected by foveal load implies that it is capacity limited and therefore dependent on covert attentional resources. This, nevertheless, does not rule out that emotional processing can be less resource limited than the processing of nonemotional stimuli (see Anderson, 2005). Furthermore, a related finding supporting the preattentive conceptualization is that in our study, there was affective priming even under the category-task-relevant (valence-task-irrelevant) conditions, whereas semantic priming was limited to the category-relevant condition. This implies a form of priority given to affective over semantic (at least, category) processing.

There is, however, a systematic finding across our experiments that argues against the preattentive view, which is the fact that affective priming depended on preexposure. This especially applies to the results from our first three experiments showing no affective priming if the unattended prime pictures had not been foveally preexposed earlier. Only after the pictures could be attended to in a foveal preview phase (Experiment 1) or as probes in previous trials (Experiments 2 and 3) was their affective valence perceived parafoveally. These findings seem, then, more consistent with models of postattentional processing of affective significance (Cave & Batty, 2006; Storbeck et al., 2006). Storbeck et al. (2006) have argued that the features of objects must first be integrated and the objects themselves identified prior to affective analysis. Cave and Batty (2006) have argued that only low-level perceptual features of visual stimuli can be encoded preattentively, which can, through practice, be associated with affective meaning. In our experiments, the foveal preexposure and repetition across trials provided an opportunity for perceptual identification and also for association of perceptual features with affective value. Preexposure would thus produce a representation that would remain accessible and then facilitate recognition of the stimuli when presented in unattended locations on subsequent trials, leading to affective priming. This is compatible with the idea that the visual system does not detect affect but rather serves to identify objects to retrieve affective associations (see Storbeck et al., 2006). This would imply that preattentive priming is, actually, postattentive, as it does not occur unless the scenes have been attended to earlier (see Fox, 1996).

Nevertheless, the fact that affective priming did not emerge the first time the unattended stimuli were presented, but only after preexposure, should not lead us to definitely reject the preattentive conceptualization. Affective priming emerged even when stimulus preexposure involved only parafoveal displays of stimuli, as evidenced in Experiments 4 and 6 (and 5, for prime valence detection). This shows that affective significance is processed even in the absence of any prior overt attention to the stimuli. This is also relevant to the Storbeck et al. (2006) and Cave and Batty (2006) views. Our results suggest either that the prior perceptual and semantic identification of the stimulus objects is obtained preattentively or that such identification is not necessary for affective evaluation. The solution to this dilemma may depend on how object identification is defined. If it involves the integration of multiple features of the object into a single object code (Storbeck et al., 2006), then we are faced with the hypothesis that cumulative feature perception, through repeated practice without overt attention, can lead to integration and object recognition (Cave & Batty, 2006) and then facilitate the retrieval of affective associations.

From the previous analysis, a major conclusion is that affective priming of overtly unattended visual scenes depends on preexposure to the primes, be it foveal or parafoveal. This conclusion is, nonetheless, in contrast to some findings obtained for foveally presented emotional words (Anderson, 2005; Harris & Pashler, 2004) and faces (S. T. Murphy & Zajonc, 1993). These authors found attentional effects of emotional stimuli upon their first presentation. Moreover, Harris and Pashler (2004) found that the effect faded, rather than increased, with repetition. There is some relationship between our study and the others in that they all investigated how attention modulates the processing advantage of emotional stimuli. However, a major difference is that we investigated spatial attentional mechanisms (i.e., the processing of overtly unattended emotional stimuli), whereas the other studies were mainly concerned with the temporal dynamics of attention (e.g., by means of presenting stimuli with short exposures, ranging from 4 ms—S. T. Murphy & Zajonc, 1993—to 100 ms—Anderson, 2005—and 150 ms—Harris & Pashler, 2004). We manipulated the spatial location of stimuli (in addition to presenting them briefly for 150 ms) so that they could not be foveally fixated. In contrast, in all the other studies, the stimuli appeared at fixation, and so, they could be directly fixated. Thus, preexposure seems more necessary for stimuli outside the focus of attention than when they can be fixated. Presumably, stimulus identification would be easier (i.e., require less preexposure) with foveal, parvocellular-cone-based visual mechanisms, which provide fine-grained high-spatial-frequency information, than with parafoveal, magnocellular mechanisms, which provide coarse low-spatial-frequency information (see Holmes, Green, & Vuilleumier, 2005).

Parafoveal Processing of Emotional Scenes Versus Words Versus Facial Expressions

In this series of experiments, we have used emotional visual scenes as stimuli and found that their affective valence can be extracted when they are not overtly attended, although this happens or is increased after some preexposure to the stimuli and generally when these appear in the left visual field. An important issue is whether these patterns of findings also hold for other sorts of affectively charged visual stimuli.

Research on the parafoveal processing of emotional words has been scarce (see Calvo & Castillo, 2005; Calvo, Castillo, & Fuentes, 2006; Hyönä & Häikiö, 2005). This is probably due to the fact that research using neutral words has frequently failed to find semantic parafoveal priming (see Rayner, 1998). With emotional words, there are discrepant findings. Hyönä and Häikiö (2005) found no evidence of priming for any kind of emotional words (including sex- and threat-related words and curse words). Calvo and Castillo (2005) noted parafoveal priming of threat-related words, but not of neutral and positive words, when the prime was presented in the right visual field. Calvo et al. (2006) also observed selective right-hemifield priming of threat-related words, although the effect depended on prior exposure to visual scenes that were emotionally congruent with the words. Accordingly, parafoveal emotional word priming is weak, may need a supporting affective context, and tends to occur particularly for threat words in the right visual field. Nevertheless, this lateralization effect might not be specific to emotional verbal stimuli, as a right-visual-field advantage has been found also for parafoveal neutral words in lexical decision tasks (e.g., Voyer, 2003).

Perception of schematic emotional faces has been investigated with the visual search paradigm (e.g., Öhman, Lundqvist, & Esteves, 2001). The fact that search rates are faster for angry than for neutral expressions suggests that affective content may be analyzed in parafoveal or peripheral vision. The reason is that most of the stimuli in the visual array are located away from the central fixation point, and so, emotional content might be processed before a face is overtly attended. Nevertheless, this paradigm does not separate attentional from preattentive effects because the stimuli can be foveally fixated. Fenske and Eastwood (2003) found that a schematic target face at fixation was identified faster when it was flanked by faces that were identical in valence to the target face than when flanked by different faces. Nevertheless, this finding might not reflect truly parafoveal processing of unattended stimuli because the flanker faces were located only 0.76° apart from the central target face and eye movements were not controlled. Calvo and Esteves (2005) presented a schematic prime face for 25 to 125 ms either foveally or parafoveally (2.1° away from a fixation point), followed by an identical or different probe face. Participants decided whether the probe was the same as the prime. There was a lower perceptual recognition threshold for angry, sad, and happy faces than for neutral and scheming faces following both foveal and parafoveal primes. This suggests that there is parafoveal processing of emotional faces, although no clear hemifield advantage has been reported, and preexposure effects were probably involved, given that the schematic faces were usually repeated across trials.

Regarding real emotional faces, discrepant neurophysiological data have been collected. Some findings support the hypothesis of perception of unattended emotional content. Thus, in an fMRI study, amygdala responses to fearful expressions were unaffected by spatial attention, with enhanced activity in left amygdala and right fusiform gyrus for parafoveal emotional versus neutral faces even when overt attention was allocated elsewhere (Vuilleumier et al., 2001). Also, findings obtained with patients with brain damage reveal that the processing of emotional faces may be less dependent on spatial attention than that of neutral faces. Patients with visual spatial neglect and cortical blindness are more likely to detect emotional than neutral faces presented in the damaged hemifield (Fox, 2002; Vuilleumier & Schwartz, 2001). In contrast, other findings indicate that spatial attention is necessary for the processing of emotional faces. Thus, elevated activation in the amygdala and other brain regions in response to attended fearful versus neutral faces disappeared when spatial attention was diverted away from the faces (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Also, ERP studies have shown enhanced brain activation only when emotional faces were presented at fixation but not when they were presented parafoveally (Eimer, Holmes, & McGlone, 2003; Holmes et al., 2003). A review by Borod, Zgaljardic, Tabert, and Koff (2001) is relevant to the laterality issue. Of 20 reviewed studies, 17 showed right-hemisphere dominance in the processing of unattended emotional faces. This is consistent with our findings for scenes and makes sense if we take into account that our scenes included people (with emotional faces). As for potential preexposure effects, it must be noted that a small sample of face stimuli (generally, the Ekman pictures of facial affect) was repeatedly presented in many of the previous studies.

Conclusions

The emotional valence of scenes as pleasant or unpleasant can be evaluated by the cognitive system when these are not overtly attended to, that is, when presented in parafoveal location, in the absence of eye fixations on the stimuli, and under foveal masking. Nevertheless, although overt attention is not necessary for affective processing, covert attention is involved, as the analysis of affective content is impaired by a concurrent foveal load, thus revealing attentional resource dependence. Furthermore, affective processing of overtly unattended stimuli depends on prior exposure to the stimuli, be it foveal or parafoveal. In addition, there is a left-visual-field advantage in the extraction of the affective significance of such stimuli. Finally, in comparison with the processing of stimulus semantic category, there is some specialness in the assessment of affective valence, such as more dependence on preexposure, different hemifield advantage, and less task specificity.

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Appendix

International Affective Picture System Number of the Experimental Pictures Used as Pleasant and Unpleasant Primes and Probes

Experiments 1–5

Asterisk (*) indicates a picture added in Experiments 4 and 5.

Pleasant: 2000, 2040, 2057, 2070, 2092, 2160, 2165, 2311, 2332, 2340, 2341, 2352, 2360, 2395, 2540, 2550, 4574, 4599, 4624, 4641, 4653, 4660, 4680, 4687, 4694, 4695*, 4700, 7325, 8205*, 8461, 8490, 8499.

Unpleasant: 2120, 2683, 2691, 2703, 2799, 2800, 2900, 3022, 3030, 3180, 3181, 3350, 3530, 3550, 6243*, 6250, 6313, 6315*, 6510, 6550, 6560, 8231, 9040, 9230, 9250, 9254, 9410, 9421, 9429, 9440, 9594, 9921.

Experiment 6

Pleasant people: 2040, 2057, 2070, 2165, 2311, 2341, 2360, 2550, 4574, 4599, 4624, 4641, 4643, 4653, 4660, 4700.

Unpleasant people: 2120, 2800, 2811, 2900, 3181, 3225, 3350, 3530, 3550, 6312, 6315, 6510, 6550, 6560, 9410, 9429.

Pleasant animals: 1440, 1441, 1460, 1463, 1510, 1540, 1604, 1610, 1620, 1710, 1750, 1811, 1920, pa1-added, pa2-added, pa3-added.

Unpleasant animals: 1050, 1052, 1200, 1205, 1270, 1280, 1300, 1321, 1525, 1930, 1931, 9561, ua1-added, ua2-added, ua3-added, ua4-added.

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