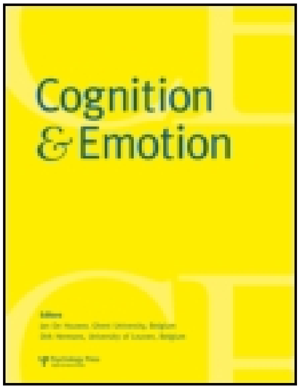

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Primacy of emotional vs. semantic scene recognition in peripheral vision

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Emotional scenes were presented peripherally (5.2° away from fixation) or foveally (at fixation) for 150 ms. In affective evaluation tasks viewers judged whether a scene was unpleasant or not, or whether it was pleasant or not. In semantic categorisation tasks viewers judged whether a scene involved animals or humans (superordinate-level task), or whether it portrayed females or males (subordinate-level task). The same stimuli were used for the affective and the semantic task. Results indicated that in peripheral vision affective evaluation was less accurate and slower than animal/human discrimination, and did not show any advantage over gender discrimination. In addition, performance impairment in the peripheral relative to the foveal condition was greater or equivalent for affective than for semantic categorisation. These findings cast doubts on the specialness and the primacy of affective over semantic recognition. The findings are also relevant when considering the role of the subcortical "low route" in emotional processing.

Keywords: Emotion; Recognition; Scene perception; Peripheral vision; Subcortical; Primacy.

Emotional stimuli are detected readily and quickly, as indicated by neurophysiological and behavioural research using pictures of scenes and faces. Neuroimaging studies have reported enhanced responses to emotional relative to neutral stimuli, particularly in the amygdala and the occipito-parietal cortex (see Vuilleumier, 2009). Electrophysiological studies assessing the time course of affective processing have shown amplified responses to emotional stimuli, as reflected by enhanced early sensory components (e.g., P1 and N1 at 120–150 ms), as well as later components (after 300–400 ms; see Olofsson, Nordin, Sequeira, & Polich, 2008, for a review). Similarly, a wide range of behavioural measures (Hermans, Spruyt, De Houwer, & Eelen, 2003, with affective priming paradigms; Calvo & Esteves, 2005, with recognition sensitivity measures) and peripheral physiological responses (Öhman & Soares, 1998, with electrodermal assessment; Dimberg, Thunberg, & Elmehed, 2000, with electromyographic assessment) have revealed processing of emotional stimuli even when presented very briefly, subliminally, or masked.

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Prior research has thus provided evidence for a fast encoding of emotional stimuli. An important yet unresolved issue is whether affective processing holds a special status in comparison with semantic processing (see Eder, Hommel, & De Houwer, 2007), particularly regarding their neural timing (Storbeck, Robinson, & McCourt, 2006). In other words, can the brain determine whether an object is good or bad (affective evaluation) before knowing what the object is (semantic analysis)? In the current study, this issue was examined for both foveally and peripherally presented scenes for the following reasons. First, in prior studies the stimuli were generally presented only at fixation. Given the limited size of foveal vision (see Wandell, 1995) and the fact that most objects in a natural environment normally fall beyond the foveal boundaries, adaptive behaviour requires that significant events for well-being (i.e., those related to threat and benefit) are detected also in the visual periphery. Emotional stimuli are thus expected to have facilitated access to the cognitive system even when they appear in peripheral vision. Second, affective processing has been proposed to be accomplished via a subcortical route through the amygdala (see Zald, 2003), even prior to cortical analysis (LeDoux, 1996). This subcortical route receives projections from the magnocellular layers of lateral geniculate nucleus, which in turn receives its sensory inputs particularly from the peripheral retina (see below). Accordingly, a primacy of affective analysis over semantic analysis should be particularly likely to occur for emotional stimuli that appear in peripheral vision.

Processing of affective vs. neutral stimuli in peripheral vision

Many studies have established that extrafoveally presented emotional pictures are more likely to be processed than neutral, non-emotional pictures. First, in exogenous cueing paradigms, emotional or neutral cues are presented at locations where a subsequent target appears (valid trials) or does not appear (invalid trials). When emotional cues appear at invalid locations, the identification of the target is delayed in comparison with when the invalid cue is neutral (Fox, Russo, Bowles, & Dutton, 2001). Similarly, with an anti-saccade paradigm using emotional and neutral scenes as peripheral saccade cues, Kissler and Keil (2008) found more anti-saccade errors towards emotional than towards neutral pictures. These findings suggest that viewers make task-irrelevant attentional shifts, or erroneous saccades, to emotional pictures because the emotional content is perceived and attracts attention reflexively (see Nummenmaa, Hyönä, & Calvo, 2009).

Second, neurophysiological research has revealed that emotional information can be extracted from extrafoveally presented scenes. Keil, Moratti, Sabatinelli, Bradley, and Lang (2005) recorded steady-state visual evoked potentials (ssVEPs) while flickering unpleasant and neutral scenes were shown simultaneously to left and right visual fields. Participants had to attend to the picture at one of the locations while the picture in the opposite location was a distracter. Occipito-temporal and parietal activation appeared when unpleasant distracters were presented. In a functional magnetic resonance imaging (fMRI) study, Vuilleumier, Armony, Driver, and Dolan (2001) reported enhanced activation in the amygdala and the right fusiform gyrus to extrafoveally seen fearful versus neutral faces (although see Eimer, Holmes, & McGlone, 2003, using ERP measures).

In a third approach involving eye-movement monitoring, selective overt orienting to emotional relative to paired neutral pictures has been found. When emotional and neutral scenes appeared between 4° and 9° away from a central fixation point, the first fixations were more likely to land on emotional rather than neutral scenes (Alpers, 2008; Calvo & Lang, 2004; Nummenmaa, Hyönä, & Calvo, 2006). As selective orienting was initiated *before* the pictures were fixated, this finding suggests that the viewers had recognised something of the emotional scene while it was still in peripheral vision, which then attracted the gaze. As emotional and neutral scenes were matched in low-level image properties known to attract fixations (e.g., luminance, contrast, etc.), attentional orienting was probably due to perception of emotional significance rather than physical image features.

Affective vs. semantic processing in peripheral vision

The emotional processing advantage in peripheral vision is consistent with the view (see Holmes, Winston, & Eimer, 2005; Vuilleumier, 2009) that the emotional content of pictorial stimuli is primarily conveyed by low spatial frequencies (LSF) that are accessible to magnocellular neurons receiving inputs from large ganglion cells in the peripheral retina. A close functional relationship has been found between the extraction of LSF and emotional processing of both faces (see Eimer & Holmes, 2007) and more complex scenes (Carretié, Hinojosa, López-Martín, & Tapia, 2007), which further suggests that emotional information can be extracted in peripheral vision from LSF input. In addition, the magnocellular pathway projects from the lateral geniculate nucleus (LGN) to subcortical structures such as superior colliculus, pulvinar thalamus, and amygdala (and also to primary sensory cortices). Given the role of the amygdala in rapid global emotional processing (see Zald, 2003) and that it more strongly responds to low- rather than high-pass filtered fearful faces (Vuilleumier, Armony, Driver, & Dolan, 2003), it has been assumed that the magnocellular LGN-to-amygdala pathway may be crucially involved in initial emotional processing. Within this framework, emotional scenes appearing in peripheral vision can be processed more accurately or rapidly than neutral scenes: It is assumed that emotional valence might be assessed by the amygdala before visual information is transmitted to the striate cortex, and the projections from the amygdala to V1 and higher order visual areas could then amplify the processing of emotional scenes by these areas, which would subsequently lead to an attention shift.

The previous review and explanation suggest that emotional valence may have privileged access to the cognitive system, as it can be analysed even when the emotional stimuli are presented outside the focus of overt attention in peripheral vision. Nevertheless, it remains elusive whether this is unique to emotional valence. Specifically, it is unknown whether some *semantic* stimulus attributes are also processed in peripheral vision. And, if so, would such attributes be analysed before or after emotional significance? Although affect-sensitive electrophysiological responses occur remarkably early ($\sim$150 ms post stimulus; see Olofsson et al., 2008), intracranial field potentials recorded from the visual cortices show that object-selective responses to object transformations occur already at 100 ms from stimulus onset (Liu, Agam, Madsen, & Kreiman, 2009). Also, semantic categorisation of scenes may begin between 120 ms (as assessed by minimum saccade latencies; Kirchner & Thorpe, 2006) and 150 ms (as assessed by ERPs; Rousselet, Fabre-Thorpe, & Thorpe, 2002) post stimulus. Accordingly, although the visual system can be biased towards the processing of emotional relative to neutral stimuli, the affective analysis might not *precede* semantic object recognition. Consequently, studies directly comparing the speed of affective and semantic recognition of the same stimuli are needed to provide a definite answer to this issue.

The present study

In the current study, the participants categorised the same emotional visual scenes with respect to both affective and semantic features. In the semantic task, participants decided whether a scene involved animals or humans (Experiment 1; a superordinate-level task), or whether it portrayed female or male people (Experiment 2; a subordinate-level task). In the affective task, participants judged whether a scene was unpleasant or not or whether it was pleasant or not (both Experiments 1 and 2). If emotional processing is prioritised over semantic processing, affective evaluation should be faster than semantic categorisation.

This approach represents a contribution to prior research in two respects. First, as exactly the same pictures were presented for both the affective and the semantic task, these were comparable in other respects, including potential differences in low-level image factors. Second, it has been proposed that different levels of semantic categorisation operate hierarchically and that one of these levels (e.g., superordinate level, basic level or subordinate level) is always accessed first in object recognition (see Macè, Joubert, Nespoulous, & Fabre-Thorpe, 2009). Accordingly, it is important to establish at which stage affective processing occurs in relation the various stages of semantic processing. In other words, can affective evaluation bypass all the object recognition stages or only some stages, or none? To investigate this issue, we compared recognition of affective valence with semantic processing at a superordinate level (animal vs. human categorisation) and a subordinate level (male vs. female categorisation).

The comparison of semantic and affective tasks was combined with two additional approaches. One was concerned with the contrast between foveal and peripheral vision. To this end, the stimulus scenes were presented both centrally and 5.2° away from fixation. A critical prediction is that, if there is a special advantage for emotional evaluation in peripheral vision, the impairment (i.e., a reduction in performance accuracy or an increase in reaction times) in the peripheral relative to the foveal condition will be smaller for the affective evaluation task than for the semantic categorisation task. The other approach involved the comparison of negatively versus positively valenced scenes. The neural mechanisms that we have proposed for the processing of emotional stimuli in peripheral vision are better established for threat stimuli than for reward-related stimuli (see Vuilleumier, 2005). If, however, the mechanisms that underlie unpleasant and pleasant stimulus processing operate on similar perceptual constraints, the amount of impairment in the peripheral versus the foveal condition will be equivalent for both types of scenes.

Recently, Nummenmaa, Hyönä, and Calvo (2010) demonstrated that semantic categorisation of visual scenes is faster than their affective evaluation. The present study extends the previous one in an important respect. Namely, in the Nummenmaa et al. study, the stimuli were presented at or very close to fixation. Accordingly, it is likely that their conclusions regarding the primacy of semantic over affective processing might be limited to scenes appearing in central vision. In contrast, as we have argued above, the link between the peripheral retina and the magnocellular LGN-to-amygdala pathway might enhance the early emotional versus semantic processing of stimuli appearing in peripheral vision. In fact, ERP studies have suggested that the magnocellular pathway projecting from the peripheral retina might be more strongly involved in the affective evaluation of facial expressions (Pourtois, Dan, Grandjean, Sander, & Vuilleumier, 2005) and complex emotional scenes (Carretié et al., 2007) than the parvocellular pathway projecting from the fovea. In the current study, the comparison between a foveal and a peripheral presentation condition was critical to determine whether the primacy of semantic processing remains also for stimuli in peripheral vision or, rather, the affective content of such stimuli is processed faster than their semantic content.

EXPERIMENT 1

Visual scenes were presented for 150 ms either foveally or peripherally. The scenes depicted animals or people, of which half were unpleasant in affective valence and half were pleasant. Each scene could thus be categorised as a function of affective and semantic properties. Participants decided whether each scene was unpleasant or not (or pleasant or not), or whether it was an animal or a people scene. An advantage in affective over semantic processing in peripheral vision would involve more accurate and/or faster affective evaluation than semantic categorisation, with less impairment of affective than semantic processing in the peripheral relative to the foveal condition.

Method

Participants. Eighty psychology undergraduates (60 female) at La Laguna University participated for course credit.

Stimuli. In addition to 16 practice stimuli, a set of 128 experimental pictures were used, of which 64 portrayed people (32 unpleasant, 32 pleasant) and another 64 portrayed animals (32 unpleasant, 32 pleasant). All the people pictures and some of the animal pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert 2008; see appendix). To complete the series of animal pictures, some were obtained from other sources. Valence ratings (ranging from 1 to 9; *unpleasantness* vs. *pleasantness*) for the IAPS pictures have been obtained in norming studies (Lang et al., 2008). Given that some non-IAPS pictures had to be added, we collected valence ratings for the new pictures as well as for the IAPS pictures. Twenty-four psychology undergraduates (different from those participating in the experiments) were presented with all the 128 stimulus pictures, using the same procedure for rating as in the Lang et al. (2008) studies. Pleasant pictures had higher scores than unpleasant pictures ($M = 7.54$ vs. 2.70, respectively), $t(126) = 44.23$, $p < .0001$, both for the animal ($M = 7.52$ vs. 3.12) and the people ($M = 7.56$ vs. 2.29) scenes (both ps $< .0001$). Mean valence scores were equivalent for the animal and the people pictures ($M = 5.32$ vs. 4.92; $t < 1$, $p = .37$, *ns*).

Apparatus and procedure. Each picture subtended a visual angle of 13.3° (width 11.7 cm) by 11.1° (height 9.7 cm) at a constant viewing distance of 50 cm. Participants had their heads positioned on a chin and forehead rest. All pictures were presented in their original colours against a black background on a 17″ SVGA monitor with a 100 Hz refresh rate. The E-Prime software controlled stimulus presentation and response collection.

Figure 1 shows the sequence of events on a trial, which started with a central fixation cross for 500 ms, followed by one target picture for 150 ms. In the peripheral location condition, the target picture appeared either to the left or right of the fixation cross, and a meaningless picture (a random combination of colours) on the opposite side, simultaneously. The meaningless picture was the same in content and size for all of the target scenes, although the mean luminance of the meaningless picture was adjusted (by means of Photoshop™ 6.0) to make it comparable to that of the particular target scene with which it was paired on each trial. With this we aimed to balance the raw visual saliency of the stimulus display such that the target scene onset would not serve as an exogenous attentional cue. In the foveal location condition the target scene appeared at the centre of the screen and the meaningless picture was not displayed. Following the target (and meaningless) picture, a 150 ms backward mask appeared. The mask was the same as the meaningless picture, but it encompassed the whole screen. After the

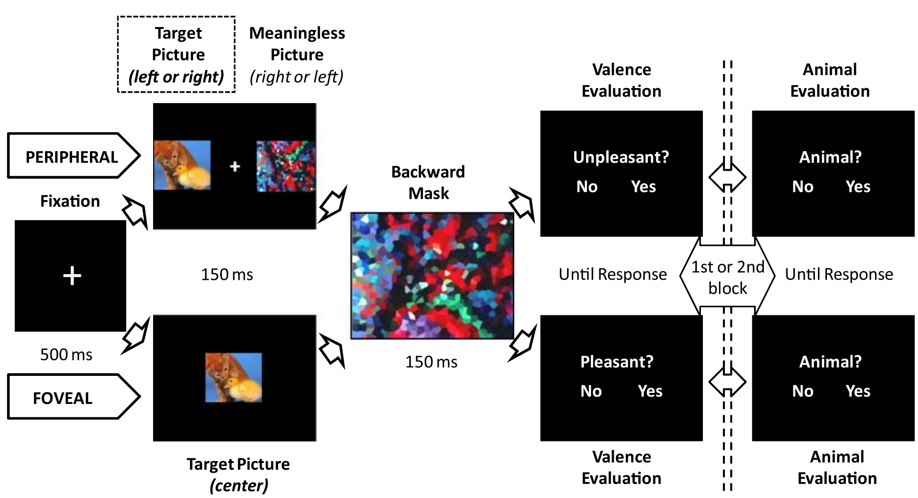

Figure 1. *Sequence of events within a trial in Experiment 1. [To view this figure in colour, please visit the online version of this Journal.]*

mask, there was a prompt to respond whether the target scene was unpleasant or not (or pleasant or not; see design), or whether it portrayed animals or not, by pressing pre-specified keys (labelled as YES or NO) with the right or the left index finger as soon as possible. The inter-trial interval was 1,500 ms. In each of two blocks, there were 16 practice trials followed by 128 experimental trials.

Design. A mixed factorial design was used, with Task (affective evaluation or semantic categorisation of the pictures) as a within-subjects factor, and Type of Affective Evaluation (unpleasantness or pleasantness) and Target Picture Location (foveal vs. peripheral) as between-subjects factors. There were 20 participants in each combination of the four resulting between-subject conditions. The affective and the semantic tasks were assigned to one or other of two blocks of trials. The order of blocks was counterbalanced, such that 40 participants performed affective evaluation in the first block and semantic categorisation in the second block, and the other 40 participants underwent the reverse order. Within each block, each of the 128 target pictures was presented once to each participant in random trial order. In the unpleasantness evaluation task the participants responded whether each picture was unpleasant or not; in the pleasantness evaluation task, whether each picture was pleasant or not. In the peripheral condition, the distance from the central fixation cross and the inner edge of the lateralised target scene was 5.2° of visual angle (4.3 cm).[1] In the foveal condition, the target scene appeared at fixation.

Results

One-sample *t*-tests were computed to examine whether the probability of correct responses in the affective and the semantic tasks exceeded the chance level (i.e., .50). For all combinations of Valence, Task and Location, in both experiments, the difference between the observed hit rate and the chance level was significant, all $ts(19) > 8$, $p < .0001$. This implies that both affective valence and animal/people were reliably recognised, i.e., that unpleasant scenes were perceived as unpleasant (and pleasant scenes, as pleasant), and animal scenes, as animals, whereas pleasant scenes were correctly perceived as *not* being unpleasant (and unpleasant, as *not* being pleasant), and people, as *not* being animals.

To deal with outliers, reaction times that were above or below 3 *SD*s from the mean of each participant in each experimental condition were removed ($M = 2.58\%$ of data). A 2 (Task) × 2 (Affective Valence) × 2 (Location) analysis of variance (ANOVA) was conducted on the mean response accuracy and latency scores for correct responses. The mean scores are shown in Figures 2 and 3. Initially, we included block order as another factor in the ANOVA. Given the lack of task-order effects or interactions with the other factors and the fact that block order had been controlled by means of counterbalancing, we collapsed data across blocks, for this and the following experiment.

For response accuracy, strong effects of Task, $F(1, 76) = 118.51$, $p < .0001$, $\eta_p^2 = .609$, and Location, $F(1, 76) = 89.09$, $p < .0001$, $\eta_p^2 = .540$, emerged, as well as a Task by Location interaction, $F(1, 76) = 27.91$, $p < .0001$, $\eta_p^2 = .269$. Semantic categorisation was performed more accurately than valence evaluation ($M = .953$ vs. .859), and the hit rate was higher for foveal than for peripheral scenes ($M = .950$ vs. .862). The Task by Location interaction revealed that the impairment in the peripheral versus the foveal condition was greater for the valence evaluation task, $t(78) = 8.38$, $p < .0001$, than for the semantic categorisation task, $t(78) = 5.19$, $p < .0001$, and that the advantage for semantic over affective processing was greater in the peripheral,

[1] A 150 ms display at a 5.2° distance from the fixation point has been found to prevent fixations on peripheral pictures (Calvo, Nummenmaa, & Hyönä, 2008). In that study, the mean latency of the first saccade towards the picture was 175 ms (hence above the 150 ms display duration used here); the probability of fixating the picture during the 150 ms display was less than 1%; and whenever fixations on the scenes occurred, their mean duration was only 4 ms.

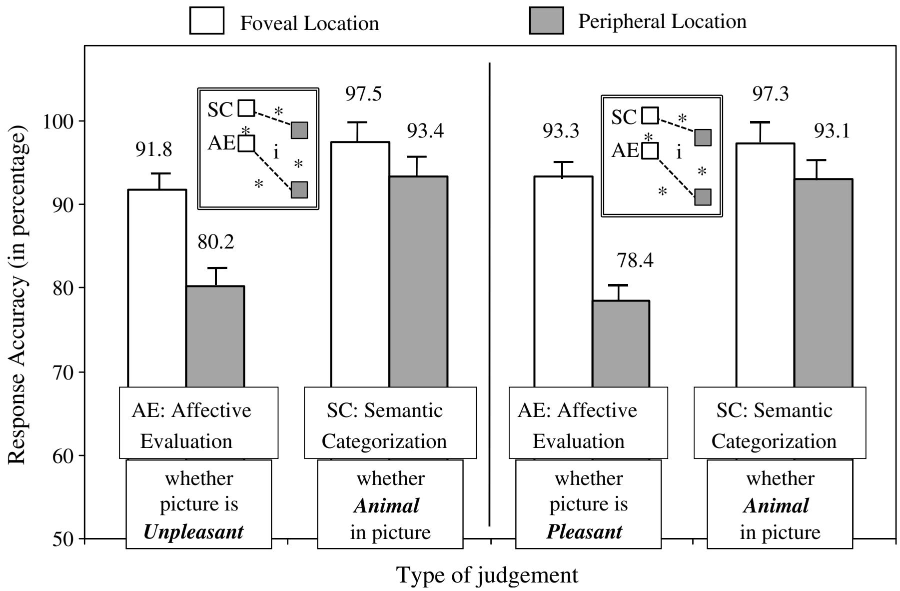

Figure 2. *Means and standard errors of response accuracy scores for the identification of affective valence and semantic category, as a function of picture location and type of task. Small squares with two dotted lines inside: i = interactive effects; * = significant differences. Left/right side of the figure: performance in the unpleasantness/pleasantness between-subjects conditions.*

$t(39) = 8.74$, $p < .0001$, than in the foveal condition, $t(39) = 5.74$, $p < .0001$, although all these differences were significant (see Figure 2). Importantly, there was no main effect of Type of affective valence or an interaction of this factor with others (all Fs < 1), thus showing that the aforementioned effects held similarly for the evaluation of both pleasantness and unpleasantness.

For reaction times, the effects of Task, $F(1, 76) = 89.11$, $p < .0001$, $\eta_p^2 = .540$, and Location, $F(1, 76) = 146.35$, $p < .0001$, $\eta_p^2 = .658$, were qualified by a Task by Location interaction, $F(1, 76) = 11.24$, $p < .001$, $\eta_p^2 = .129$. Response latencies were shorter in the semantic than in the affective task ($M = 449$ vs. 559 ms), and they were shorter in the foveal than in the peripheral condition ($M = 395$ vs. 613 ms). The interaction revealed that the impairment in the peripheral versus the foveal condition was greater for the affective task, $t(78) = 12.71$, $p < .0001$, than for the semantic task, $t(38) = 8.04$, $p < .0001$, and that the advantage for semantic categorisation over affective evaluation was greater in the peripheral, $t(39) = 8.25$, $p < .0001$, than the foveal condition, $t(19) = 4.97$, $p < .0001$, although all these differences were significant (see Figure 3). There was no main effect of Type of affective valence or an interaction of this factor with others (all Fs < 1), thus showing that positive and negative evaluation were similarly affected by location, and were at a similar disadvantage with respect to semantic categorisation.

Discussion

Both affective evaluation and semantic categorisation were performed reliably, with accuracy well above the chance level when the scenes appeared in peripheral vision. However, not only was semantic categorisation more accurate and faster than affective evaluation, but the former was also *less* impaired than the latter in peripheral relative to foveal vision. This finding supports an advantage in semantic over affective processing not only in foveal, but also in peripheral vision. Furthermore, the task by location interactions are crucial in showing that affective processing is not simply less accurate or slower than semantic

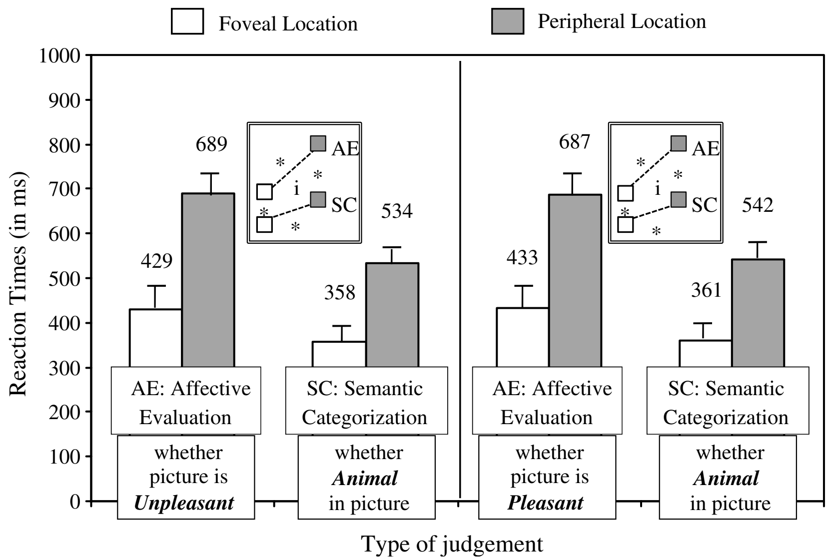

Figure 3. *Means and standard errors of response latencies for the identification of affective valence and semantic category, as a function of picture location and type of task. Small squares with two dotted lines inside: i = interactive effects; * = significant differences. Left/right side of the figure: performance in the unpleasantness/pleasantness between-subjects conditions.*

processing, but that this disadvantage becomes *greater* for peripheral vision. This is contrary to the view that affective stimulus content might have privileged access through peripheral vision and magnocellular pathways (see general discussion).

The present data are consistent with prior research supporting semantic primacy, using foveally or parafoveally (rather than peripherally, as in the current study) presented pictures and an affective priming paradigm (rather than direct evaluation of the target pictures, as in the current study). Storbeck and Robinson (2004) used a comparative approach in which words and pictures could be categorised based on affect (good or bad) or a non-affective dimension (e.g., type of animal category), and found stronger semantic than affective priming effects. In a similar setup with pictures, Calvo and Nummenmaa (2007) found both semantic and affective priming effects. Nevertheless, whereas semantic priming was not dependent on pre-exposure to the stimuli on previous trials, affective encoding was: For affective priming to occur, it was necessary that the prime scenes had been seen previously. These pre-exposure effects further suggest that object recognition is required for affective evaluation.

In Experiment 1, we showed that recognition of a superordinate semantic category (animal vs. people) precedes recognition of the affective valence of the same stimulus. In Experiment 2, we extended the semantic versus affective processing comparison to subordinate-level categorisation. This approach is important in the context of recent studies that have provided support for the Parallel Distributed Processing model of object recognition (e.g., Macè et al., 2009). This model assumes that semantic representations are activated from broad to narrow categories, such that superordinate-level categorisation is accomplished faster and precedes basic-level object categorisations. After having established that affective evaluations cannot bypass the elementary superordinate-level semantic processing stage, we now aimed at determining whether affective evaluation can bypass some later stages in the hierarchy of object-recognition operations.

EXPERIMENT 2

In Experiment 2, the unpleasant and pleasant scenes depicted only people, either females or males. Participants evaluated each scene as unpleasant or pleasant, and categorised it as involving females or males. An advantage in emotional over semantic processing in peripheral vision would involve more accurate and/or faster affective evaluation than gender categorisation, with less impairment for affective than for semantic task performance in the peripheral relative to the foveal condition.

Method

Participants. Eighty psychology undergraduates (60 female) at La Laguna University participated for course credit.

Stimuli. In addition to 16 practice stimuli, a different set of 64 experimental pictures were used. These portrayed either unpleasant (32) or pleasant (32) scenes. All scenes involved people. In half of the pictures in each category, there was one or more females (either woman or girl; with or without male/s), whereas in the other half there was one or more males, but no female. All the stimuli were selected from the IAPS (Lang et al., 2008). The IAPS numbers are indicated in the appendix. On a 1- to 9-point scale, pleasant pictures had higher valence ratings than unpleasant pictures ($M = 7.64$ vs. 2.26, respectively), $t(126) = 40.80$, $p < .0001$, both for the female ($M = 7.51$ vs. 2.37) and the male ($M = 7.77$ vs. 2.13) scenes (both $ps < .0001$). Mean valence scores were practically identical for the female and the male pictures ($M = 4.94$ vs. 4.96, respectively; $t < 1$).

Procedure. The size of the stimuli and the viewing distance were the same as in Experiment 1, as well as the apparatus, procedure, and measures. The only significant difference was concerned with the use of a subordinate-level categorisation task involving people gender (instead of the superordinate-level task involving animal/human) identification. Following the target picture and a 150 ms backward mask, there was a prompt to respond whether the scene was unpleasant or not (or pleasant or not, depending on the type of affective evaluation factor in the design; block 1 or 2) or whether it portrayed a female or not (block 2 or 1). See Figure 4.

Design. The experimental conditions were combined in a mixed factorial design, with Task

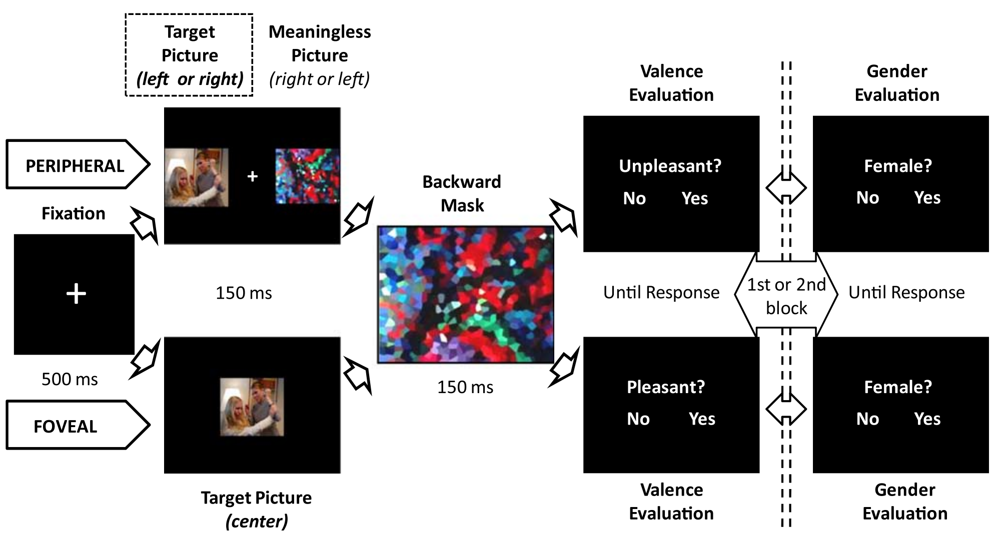

Figure 4. *Sequence of events within a trial in Experiment 2. [To view this figure in colour, please visit the online version of this Journal.]*

(valence or gender, in two different blocks) as a within-subjects factor, and Type of Affective Evaluation (unpleasantness or pleasantness) and Target Picture Location (foveal vs. peripheral) as between-subjects factors, with 20 participants in each between-subjects condition. The order of blocks for valence and gender judgement was counterbalanced.

Results

One-sample *t*-tests were used to examine whether the probability of correct responses in the valence evaluation task and the gender categorisation task exceeded the chance level (i.e., .50). For all combinations of valence, task and location, in both experiments, the difference between the observed hit rate and the chance level was significant, all ts$(19) > 13, p < .0001$. Both tasks were thus reliably performed, including the peripheral presentation condition.

A 2 (Task) × 2 (Affective Valence) × 2 (Location) ANOVA was conducted on the response accuracy scores and the mean latencies for correct responses. Reaction times above or below 3 *SD*s from participant-wise means were removed as outliers ($M = 2.51\%$ of data). The mean scores are shown in Figures 5 and 6.

For response accuracy, main effects of Task, $F(1, 76) = 15.86, p < .0001, \eta_p^2 = .173$, and Location $F(1, 76) = 80.52, p < .0001, \eta_p^2 = .514$, emerged. Emotional valence was identified more accurately than gender ($M = .860$ vs. .802), and the hit rate was higher for foveal than for peripheral scenes ($M = .880$ vs. .783). These effects were significant both for unpleasant scenes, $F(1, 38) = 9.03, p < .01, \eta_p^2 = .192$ (Task), $F(1, 38) = 25.98, p < .0001, \eta_p^2 = .406$ (Location), and pleasant scenes, $F(1, 38) = 7.71, p < .01, \eta_p^2 = .169$ (Task), $F(1, 46) = 69.85, p < .0001, \eta_p^2 = .648$ (Location), and there was no interaction between Type of affective valence evaluation and the other factors (Fs < 1). The Task by Location interaction was not significant ($F = 0.32, p = .57$).

For reaction times, only the effects of Location were significant, $F(1, 76) = 204.25, p < .0001, \eta_p^2 = .729$. Response latencies were shorter in the foveal than in the peripheral condition ($M = 425$ vs. 785 ms), and this effect was similar for unpleasant, $F(1, 38) = 91.38, p < .0001, \eta_p^2 = .706$, and pleasant scenes, $F(1, 38) = 115.35, p < .0001, \eta_p^2 = .752$, with no interaction between Type of affective valence evaluation and the other factors (Fs < 1). The effects of task were not significant ($F < 1$; $M = 609$ vs. 601 ms, affective vs. gender categorisation). The Task by Location interaction was not significant either ($F = 0.04, p = .83$). This confirms that both positive and negative affective evaluation were similarly influenced by location, and that both were performed more accurately, yet—importantly—not faster, than semantic categorisation.

Discussion

The novel finding in Experiment 2 was that gender recognition was *equally fast* as affective evaluation in both the foveal and the peripheral presentation condition, even though the gender task was performed less accurately (and therefore was probably more difficult). This confirms that there is no primacy of affective over semantic processing. Our findings are thus in apparent contrast with those of some previous studies in which valence evaluation was also compared with gender categorisation. Murphy and Zajonc (1993) showed that subliminally and centrally presented female and male faces expressing happiness or anger primed the affective evaluation of probes more than they primed gender judgements, and that the affective polarity of faces was discriminated earlier than gender differences between the faces. In the same vein, using drawings of parafoveally presented happy and sad faces, Stapel, Koomen, and Ruys (2002) found that affective evaluations (e.g., *positive*) were triggered earlier, i.e., at shorter stimulus exposures (30 ms), than gender identification (e.g., *female*), which became available at longer exposures (100 ms). These findings would support the affective primacy hypothesis in that affective evaluations would occur prior to descriptive classifications of semantic attributes.

The empirical discrepancies between the current findings and those obtained by Murphy and

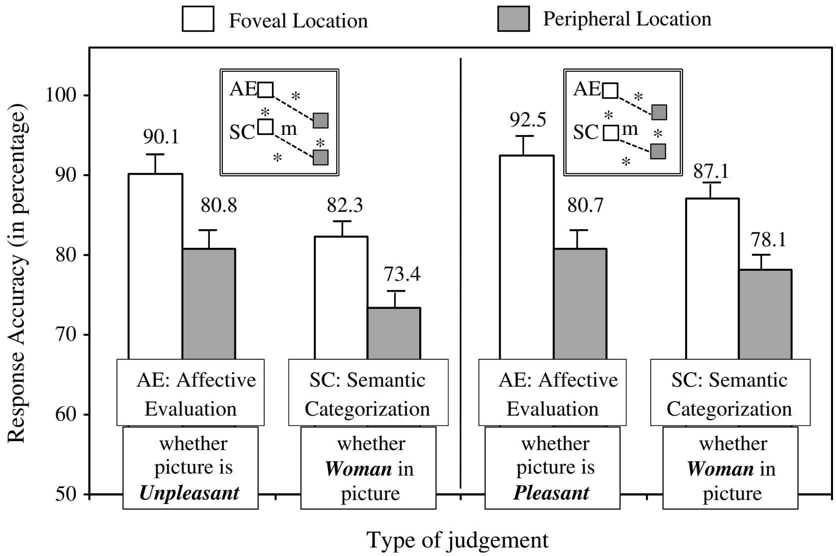

Figure 5. *Means and standard errors of response accuracy scores for the identification of affective valence and semantic category, as a function of picture location and type of task. Small squares with two dotted lines inside: m: main effects; * = significant differences. Left/right side of the figure: performance in the unpleasantness/pleasantness between-subjects conditions.*

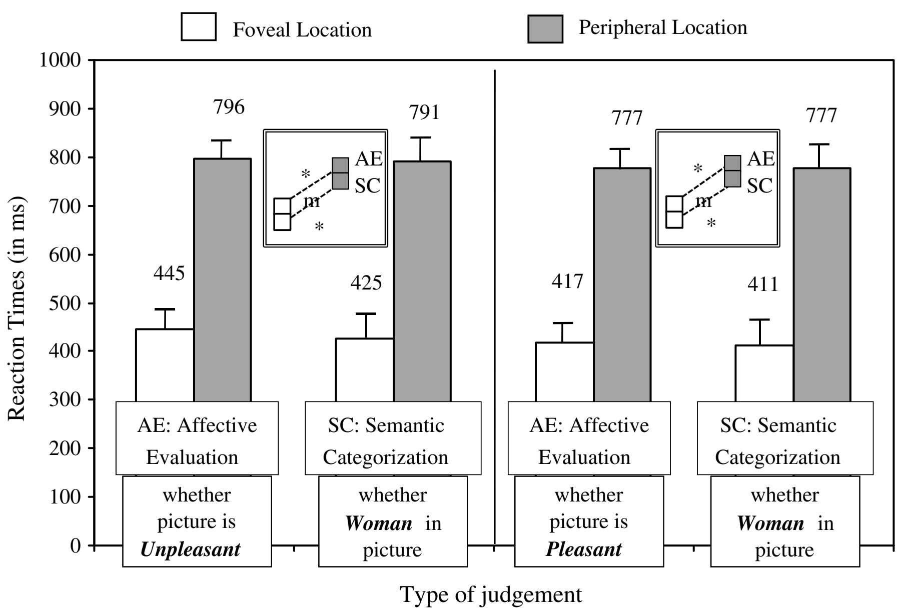

Figure 6. *Means and standard errors of response latencies for the identification of affective valence and semantic category, as a function of picture location and type of task. Small squares with two dotted lines inside: m = main effects; * = significant differences. Left/right side of the figure: performance in the unpleasantness/pleasantness between-subjects conditions.*

Zajonc (1993) and Stapel et al. (2002) may, nevertheless, be accounted for in terms of levels of unconscious versus conscious processing. First, these authors inferred affective and semantic processing indirectly by means of a priming task, in which participants are typically instructed to ignore the prime and attend to the probe. In contrast, we measured affective and semantic processing by means of direct, explicit judgements, which required conscious processing. Second, affective primacy was found by Murphy and Zajonc and by Stapel et al. when the stimuli were flashed very briefly (from 10 to 30 ms; see Winkielman, Zajonc, & Schwarz, 1997). Interestingly, gender information became accessible similarly to affective information at longer, 100 ms exposures (Stapel et al., 2002), which are closer to our own display conditions (150 ms). Accordingly, our results are more related to the latency of consciously accessed visual representations, whereas those by Murphy and Zajonc (1993) and Stapel et al. (2002) may reflect unconscious processing. This distinction may thus be important to decide about the primacy of affect or cognition (see general discussion, potential limitations and issues for further research).

GENERAL DISCUSSION

We investigated whether emotional processing is faster than semantic processing for pictorial stimuli appearing in peripheral vision. To this end we compared affective evaluation and semantic categorisation of scenes in a peripheral relative to a central display condition. Two major findings emerged. First, when pictures were presented peripherally, response latencies for affective evaluation (i.e., detecting un/pleasantness) were slower than those for superordinate-level semantic categorisation (i.e., animal vs. people), and equal to those involving subordinate-level categorisation (i.e., female vs. male). Second, a key finding involved a task by location interaction: Relative to performance under foveal presentation, affective evaluation was more impaired under peripheral viewing conditions than superordinate semantic categorisation was, and subordinate semantic categorisation was no more impaired than affective evaluation.

This indicates that affective processing has no temporal advantage over semantic processing. Rather, affective categorisation seems to be at a disadvantage with respect to semantic processing for pictorial stimuli in peripheral vision. This interpretation is consistent with findings obtained by Nummenmaa et al. (2010) using saccade latencies rather than manual reaction times, and a two-alternative forced-choice paradigm with two scenes appearing simultaneously. In that study, saccadic responses were also faster in the semantic than the affective task. Nevertheless, in that study the scenes were presented at or very close to fixation. In the current study, we presented the scenes in a truly peripheral (5.2° away from fixation) location, and made a direct comparison of recognition performance for foveal and peripheral stimulus presentations. The new experimental conditions thus allow us to examine whether peripheral vision is particularly sensitive to emotional information, as has been suggested (see the introduction).

Is affective processing special relative to semantic processing in peripheral vision?

Evidence from prior scene-recognition studies suggests that a coarse impression of emotional valence can be extracted in peripheral vision (Calvo, 2006; Calvo et al., 2008; Gutiérrez, Nummenmaa, & Calvo, 2009). Emotional prime scenes are especially prone to trigger incorrect "yes" responses when followed by probe scenes that are related in affective valence (e.g., both scenes are pleasant) but are different in various details (e.g., different people and actions depicted). This false-recognition effect is restricted to peripheral vision and does not occur when the scenes are presented foveally. False alarms to conceptually similar but visually different prime-probe pictures have been interpreted as an indication of coarse processing of picture *gist* or category

(Castelhano & Henderson, 2008; Greene & Oliva, 2009). Accordingly, we argue that the emotional scene gist (i.e., whether something good or bad is portrayed)—rather than specific contents about the identity of the depicted people, actions, or objects—is likely to be processed in peripheral vision. Such gist would involve a general impression about the scene's affective valence, which would then cause an erroneous recognition (hence the false alarms) of probes that share the same valence as the primes. It seems as if the affective valence the viewers can encode is used to replace the semantic details they cannot encode.

However, the advantage for coarse over detailed processing of objects in peripherally presented scenes is not specific to emotional scenes. A similar gist processing advantage has been found for *non-emotional* scenes. Eye-movement research has shown that a great deal of semantic content is analysed outside of foveal vision. Most importantly, studies have shown that gist or category information of the whole scene can be grasped with only a very short fixation on a central scene area before details are fixated (Underwood, 2005), and this gist then guides object search as a function of semantic relatedness (De Graef, 2005). In addition, scene categorisation (e.g., landscape, traffic, etc.) occurs when the scene is presented peripherally even though viewers are unable to report precisely what they have seen (Thorpe, Gegenfurtner, Fabre-Thorpe, & Bülthoff, 2001). Furthermore, semantic incongruity of a peripheral object in a scene attracts attention to its location before there is time to fixate the target object and when viewers are not aware of its identity (Gordon, 2004). These findings suggest that some type of global processing of scenes occurs in peripheral vision prior to identifying individual objects.

Accordingly, the fact that emotional valence *can* be assessed in peripheral vision does not demonstrate any specialness or advantage of affective relative to semantic processing, as semantic gist-level recognition occurs outside the fovea as well. Rather, the global gist-processing superiority is probably related to the level and amount of detail required to obtain a representation of what the scene is about (see Grill-Spector & Kanwisher, 2005). As global-scene configurations can be inferred from low spatial frequency ranges accessible by peripheral vision, it is understandable that gist processing must precede detailed object recognition. Broad categories (such as animal vs. human, or pleasant vs. unpleasant) can be recognised by relying on low spatial frequency information. In contrast, the recognition of specific objects requires more detailed information that is conveyed by higher spatial frequencies accessible through foveal vision. But, importantly, this would occur similarly for both emotional and non-emotional visual scene content.

A subcortical route for the processing of emotional stimuli in peripheral vision?

The amygdala is thought to be crucial for the rapid emotional evaluation of stimuli (see Vuilleumier, 2009; Zald, 2003). The role of the amygdala may be especially important for detecting affect in the visual periphery because peripheral vision typically provides only low spatial frequency (LSF) information. There is an advantage in the processing of LSF-filtered emotional versus neutral faces (see Eimer & Holmes, 2007) and scenes (Carretié et al., 2007). Furthermore, the LSF information stemming from the large ganglion cells of the peripheral retina is relayed through the magnocellular pathway that projects to the superior colliculus, pulvinar, and amygdala (and also to the visual cortex). In this context, two findings from our study cast doubts on the involvement of the subcortical route in rapid emotional processing without initial cortical object-recognition steps. First, we found affective evaluation to be either slower or equally fast as (but never faster than) semantic categorisation. Second, affective recognition performance improved more than semantic recognition performance in the foveal (where high spatial frequency information are accessed) relative to the peripheral presentation condition.

This implies that affective evaluation was, actually, even *more* dependent on *high* spatial frequency inputs than semantic categorisation.

Our results thus suggest a *sequential* cortical-subcortical model for semantic and affective recognition. In this model, *both* affective and semantic processing would rely initially on the magnocellular (for peripheral input) layers that project to cortical areas involved in object recognition. Subsequently, feedback connections from the temporal cortex to the amygdala could support the extraction of affective information from the scenes (see Nummenmaa et al., 2010). This view would add to doubts about whether the subcortical route is capable of emotional recognition of complex visual stimuli prior to cortical analysis (see Adolphs, 2008; Pessoa, 2005; Storbeck et al., 2006). Nevertheless, it is still possible that some degree of *parallel* affective and semantic processing can be involved if separable neural systems encode affect and semantics. But, even if emotional processing is based on a parallel subcortical and cortical analysis, such processing would be slower, or at least not faster, than the processing on the extrastriate cortical areas that lead to semantic object recognition.

A "fear module" involving the amygdala and related subcortical structures has been put forward as responsible for monitoring the environment for potential threat (Öhman & Mineka, 2001), with superior detection of threat-related relative to neutral pictures (Öhman, Flykt, & Esteves, 2001). There is, nevertheless, increasing evidence that positively valenced scenes also enjoy a similar advantage over neutral stimuli (Calvo & Lang, 2005). In addition, enhanced cortical and amygdala activation has been found for both unpleasant and pleasant relative to neutral scenes (Sabatinelli, Lang, Keil, & Bradley, 2007). Consistently, our results revealed an equivalent accuracy and speed in emotional valence processing for pleasant and unpleasant scenes in peripheral vision, as well as equivalent impairment in peripheral relative to foveal vision. If the amygdala is involved in emotional processing—either in parallel with or in sequence after cortical analysis—our data suggest that this emotion-processing system is tuned to detect both aversive and appetitive stimuli. As indicated by Adolphs (2008) and Vuilleumier (2009), the amygdala is one component of a circuit that is important for processing of biological relevance in a broad sense, be the stimuli threatening, rewarding, or unexpected.

Potential limitations and issues for further research

In general, our results support the hypothesis that affective processing does not occur prior to semantic recognition, but rather that semantic categorisation precedes or parallels affective evaluation, and that this occurs for pictorial stimuli presented in both central and peripheral vision. This may, nevertheless, be a strong claim that needs some critical consideration and refinement.

First, it could be argued that our affective evaluation tasks might be more difficult than the semantic categorisation tasks. For example, the affective tasks were probably more ambiguous due to their involving a subjective judgement for a scene that can be *more or less* un/pleasant, while the semantic tasks would involve objective judgements of the *presence or absence* of objects such as females or males, or humans or animals. However, the task by location interaction in Experiment 1 provides evidence against such an account: The affective judgement was *more* impaired than the superordinate-level categorisation judgement in the peripheral *relative to* the foveal condition. If any difficulty factor had put the affective task at a disadvantage relative to the semantic task, this would have occurred under all conditions, which was not the case. Similarly, the main effect of location in Experiment 2 on reaction times contradicts any difficulty-based explanations of our findings: The affective and the subordinate-level semantic tasks were *similarly* impaired in the peripheral condition in spite of the *higher* performance accuracy in the affective than in the semantic task. Accordingly, even when task difficulty was lower for the affective than for the semantic task, affective evaluation did not hold any primacy over semantic categorisation. Further research should, nevertheless, extend the affective–semantic comparisons to other type tasks and sensory modalities.[2]

Second, it is possible that some kind of affective evaluation actually occurs prior to consciousness, and also prior to semantic categorisation, but that the type of tasks and measures we used are not sensitive to such unconscious processes. In fact, responses required explicit decisions—and therefore conscious recognition—about the affective and semantic scene content. Furthermore, the responses also involved verbal coding or labelling of the scene content, which had to be translated to words (e.g., pleasant, animal, etc.). This additional implicit verbal activity might have overridden an earlier, non-verbal affective impression of the scenes. In line with this, Lieberman et al. (2007) found that affect labelling (e.g., responding whether a face was angry or scared), compared with merely observing an emotional face, diminished the response in the amygdala and other limbic regions. In addition, affect labelling was associated with increased activity in the right ventrolateral prefrontal cortex (RVLPFC; a region associated with the symbolic processing of emotional information), and the magnitude of this activity was inversely correlated with the magnitude of amygdala activity during affect labelling. This suggests that RVLPFC may functionally inhibit the amygdala; or that verbal processing inhibits emotional processing. Accordingly, a safer conclusion from our findings is the fact that affective evaluation was slower than (or as fast as) semantic categorisation reveals that affective content does not have a privileged *access to awareness*, although affect might be processed prior to consciousness and verbal coding.[3]

Conclusions

Semantic processing (animal vs. human categorisation, or gender categorisation) of peripherally presented visual scenes was faster than or as fast as their affective processing (valence evaluation). Consistently, affective processing was either more or equally impaired as semantic processing of scenes in peripheral relative to foveal vision. These findings show primacy of cognition over affect in peripheral visual recognition rather than the opposite. We argue that the emotional information of visual scenes is either relayed to cortical object recognition systems in the brain *prior to* subcortical structures involved in affect evaluation, or that emotional information is processed *in parallel* with (but not earlier than) cortical object recognition. Nevertheless, this applies to information that is accessible to awareness and can be verbally coded. It may still be possible that non-conscious processes lead to extraction of an affective impression prior to it being verbally coded and prior to obtaining a semantic representation of visual stimuli.

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[2] As acknowledged by Nummenmaa et al. (2010), there is obviously no universal answer to the primacy of affect versus cognition in the most general sense. Some cognitive operations may occur earlier (e.g., visual recognition; this study) and some are bound to occur later (e.g., abstract reasoning) than affective processing. In the context of the present study, this primacy issue is applicable to (a) the initial processing of sensory input in the visual domain, and (b) broad categories (pleasantness vs. unpleasantness, animal vs. human, female vs. male), with all involving biologically and socially relevant stimuli.

[3] Nevertheless, Nummenmaa et al. (2010) found that, at very brief display durations (20 ms) where semantic categorisation was already possible from the first presentation of a novel visual scene, affective evaluation was not, even after the third repetition. Only at 40 ms exposure was affective valence accurately recognised above the chance level. So, even if affective processing could be accomplished earlier than semantic processing, a representational product of it cannot be brought to consciousness before the information that is produced by semantic processing.

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APPENDIX

International Affective Picture System number of the scenes used as unpleasant and pleasant stimuli in Experiment 1.

Unpleasant people: 2399, 2399.1, 2683, 2691, 2703, 2716, 2718, 2722, 2799, 2800, 2811, 2900, 3051, 3180, 3181, 3225, 3300, 3350, 6010, 6250, 6313, 6315, 6550, 6560, 8480, 8485, 9250, 9254, 9410, 9415, 9423 and 9435.

Pleasant people: 2040, 2070, 2160, 2165, 2311, 2332, 2352, 2540, 2550, 4599, 4610, 4624, 4647, 4658, 4660, 4669, 4676, 4680, 4687, 4694, 4700, 5621, 5831, 5836, 7325, 8021, 8080, 8161, 8186, 8200, 8490 and 8499.

Unpleasant animal: 1050, 1052, 1200, 1205, 1270, 1280, 1300, 1321, 1525, 1726, 1820, 1930, 1932, 9561 (18 pictures added).

Pleasant animal: 1440, 1441, 1460, 1463, 1500, 1510, 1540, 1600, 1604, 1610, 1620, 1630, 1710, 1721, 1722, 1750, 1811, 1920 (14 pictures added).

International Affective Picture System number of the scenes used as unpleasant and pleasant stimuli in Experiment 2.

Unpleasant female: 2141, 2399, 2799, 3180, 3181, 3225, 6312, 6313, 6315, 6550, 6560, 6838, 9253, 9254, 9249, 9921.

Unpleasant male: 2490, 2703, 2810, 2811, 2900, 3530, 6010, 6242, 6250, 6821, 6840, 8231, 8485, 9400, 9410, 9421.

Pleasant female: 2070, 2332, 2340, 2352, 2360, 2540, 2550, 4599, 4641, 4687, 4695, 4700, 5836, 7325, 8032, 8461.

Pleasant male: 2057, 2154, 2160, 2165, 2260, 2339, 2655, 4572, 4614, 5831, 8021, 8050, 8161, 8185, 8186, 8200.