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Eye Movement Assessment of Selective Attentional Capture by Emotional Pictures

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The eye-tracking method was used to assess attentional orienting to and engagement on emotional visual scenes. In Experiment 1, unpleasant, neutral, or pleasant target pictures were presented simultaneously with neutral control pictures in peripheral vision under instruction to compare pleasantness of the pictures. The probability of first fixating an emotional picture, and the frequency of subsequent fixations, were greater than those for neutral pictures. In Experiment 2, participants were instructed to avoid looking at the emotional pictures, but these were still more likely to be fixated first and gazed longer during the first-pass viewing than neutral pictures. Low-level visual features cannot explain the results. It is concluded that overt visual attention is captured by both unpleasant and pleasant emotional content.

Keywords: emotion, picture, attention, orienting, eye movements

A major function of attention is to ignore irrelevant and select relevant stimuli in the environment for further scrutiny (Lavie, Hirst, Fockert, & Viding, 2004). The affective content of stimuli informs about how stimuli are related to the individual's needs and well-being. Appraisal of the affective content of stimuli reveals their appetitive or aversive properties, and therefore serves an important adaptive function in adequately governing approach–avoidance behavior. Thus, an adaptive cognitive system is likely to be complemented by a perceptual mechanism that is biased to readily detect and process emotional stimuli among other, competing stimuli. If so, it may be assumed that affective stimuli are especially likely to capture attention.

The purpose of this study was to investigate whether emotional visual scenes capture attention when they compete for attentional resources with neutral scenes. Our main goal can be decomposed into four specific research questions: (a) Does emotional content attract initial orienting of attention as well as later attentional engagement? (b) Is attentional capture by emotional content completely automatic, or can it also be voluntarily controlled? (c) Is attention drawn specifically by unpleasant content, or can also emotionally pleasant stimuli capture attention? (d) Can the observed effects be attributed to emotional content per se, rather than to stimulus novelty or low-level visual features?

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A subset of these issues has been addressed by prior research by means of three different paradigms. First, in the dot-probe paradigm (e.g., Mogg & Bradley, 1999) two pictures—one neutral and one emotional—are briefly displayed simultaneously side by side. When they disappear, a dot probe replaces one of them, and the participants' task is to press a button as soon as they detect the dot. A shorter reaction time for an emotional than a neutral picture indicates that the observer was attending to the emotional picture at the time when the dot probe was presented. Anxious individuals have been found to react particularly quickly when the dot replaces an angry face (Bradley, Mogg, Falla, & Hamilton, 1998; Mogg & Bradley, 1999). When aversively conditioned angry faces were presented, Armony and Dolan (2002) found that all participants were faster to respond to the probe that replaced an angry face in comparison with a neutral face. Similarly, when the threat value of the cue stimuli increases (i.e., the stimuli depict highly threatening scenes rather than emotional faces), all individuals tend to show a bias toward them, although this occurs to a greater extent for anxious people (Mogg, MacNamara, et al., 2000).

A second paradigm that has been frequently used with emotional pictorial stimuli is the visual search task (e.g., Öhman, Flykt, & Esteves, 2001). Participants are required to search a prespecified target stimulus (e.g., a spider) embedded in an array of nontarget stimuli (e.g., flowers). A series of studies has consistently demonstrated that discrepant schematic angry faces are detected faster among other faces than are friendly or sad faces (Calvo, Avero, & Lundqvist, in press; Fox et al., 2000; Öhman, Lundqvist, & Esteves, 2001; Tipples, Atkinson, & Young, 2002). When more complex stimuli such as pictures of animals have been used, the results have been less clear cut. Öhman, Flykt, and Esteves (2001) observed faster identification of phobic animals among nonphobic stimuli than vice versa. In contrast, a search detection advantage has also been observed for pictures of both threatening and pleasant animals (Tipples, Young, Quinlan, Brooks, & Ellis, 2002) and for any animal regardless of their fear relevance (Lipp, Derakshan, Waters, & Logies, 2004). Furthermore, in another recent study (Miltner, Krieschel, Hecht, Trippe, & Weis, 2004), facilitation in the search for phobic animals could not be established even for phobic participants. Rather, the presence of a phobic animal served as a distractor that slowed down the search for a neutral target among phobic stimuli.

A third experimental paradigm is the exogenous cueing task (Posner, 1980), in which a picture is presented very briefly as a cue to the right or left of a fixation point and a target (e.g., a square) is presented at the same (valid trials) or opposite (invalid trials) location where the cue had appeared. Faster reaction times for the target in valid trials are assumed to indicate attentional orienting to the cued picture, whereas slower responses in invalid trials reflect attentional engagement on the cued picture. Using this task, Fox, Russo, Bowles and Dutton (2001) found no reaction time benefit for trials validly cued with angry or happy expressions when compared with trials validly cued with neutral expressions. In other words, this study found no bias in attentional orienting to emotional faces. Instead, participants were slower to respond on trials invalidly cued with angry expressions, which suggests that emotional content engaged attention, especially for anxious individuals. This finding has been replicated by other studies using both pictures of angry faces and of threat-related scenes (Fox, Russo, & Dutton, 2002; Yiend & Mathews, 2001). Recently, Koster, Crombez, van Damme, Verschuere and de Houwer (2004) proposed that pictorial stimuli can also exert a direct effect on orienting of attention if the stimuli are endowed with genuine threat value. These authors subjected color slides to aversive conditioning and found faster responses when these slides were presented as cues in the valid trials, thus demonstrating attentional orienting toward threatening stimuli.

From these three groups of studies, the following conclusions can be drawn that are relevant to our aims. First, the dot probe and the visual search task do not allow us to distinguish between the orienting and the engagement components of attention to emotional pictures. Thus, it is not known whether the observed effects are a result of orienting or engagement of attention. Most studies using the cueing task where this distinction can be reliably made support the attentional engagement hypothesis, with the exception of Koster et al. (2004) who were the first to demonstrate facilitation in orienting by conditioned visual signals of threat. Second, no study has directly addressed the issue of whether the effects of emotional pictures on attentional orienting and engagement are automatic (which is often assumed) and whether they can be counteracted by voluntarily attending to concurrent neutral stimuli. Third, although prior research using schematic emotional faces generally supports the attentional capture by threat-related but not by pleasant content (e.g., Fox et al., 2001; Öhman, Lundqvist, & Esteves, 2001), there are few studies in which threat-related and pleasant contents are compared using more complex emotional visual scenes.

In the present study, we attempted to extend these prior findings. First, to address the selective attentional orienting/engagement distinction, observers' eye movements were registered when two pictures (emotional and neutral) were presented simultaneously. The eye-tracking method allows us to assess both orienting and engagement of attention to two stimuli that are competing for attentional resources. The initial orienting of attention was measured with (a) the probability that one picture of the pair received the first fixation after the eyes left a central fixation point located between the pictures, and with (b) the latency of making a fixation to one of the two target pictures. Subsequent attentional engagement was measured with the summed duration of fixations made on the initially preferred picture before fixating away from it, and the number of fixations made during the visual encounter with a picture. Second, to examine the involvement of automatic/strategic control of attentional capture, participants were free to inspect the target pictures in any order they preferred (Experiment 1), or they were instructed to attend first to either the neutral or the emotional picture of each pair (Experiment 2). Third, to determine the specificity/emotionality issue (i.e., whether either unpleasant or pleasant content, or both, selectively attracts attention) negatively valenced, positively valenced, or neutral target pictures were presented simultaneously with neutral control pictures.

The eye-tracking methodology has been successfully applied in prior research to study a wide variety of phenomena related to attention and vision (see Findlay & Gilchrist, 2003, for a review). Its successful application rests on findings demonstrating that, in many visual tasks, attention shifts and gaze shifts are tightly coupled (Findlay & Gilchrist, 2003; Hoffman, 1998). According to an influential view (Henderson, 1992; Reichle, Pollatsek, Fisher, & Rayner, 1998), a covert shift of visual attention is almost immediately followed by an overt gaze shift to the attended spatial location. The eyes follow an attention shift with a short delay, as it takes time to program and execute an eye movement to the attended location. What is crucial in the present context is that eye movements are an overt behavioral manifestation of allocation of attention and can therefore be used to study the functioning of the attentional system in real time (Henderson, 2003). The eye-tracking method is also valuable in that it provides an online record of the time course of the initial orienting and the subsequent engagement of attention.

Eye-fixation monitoring has recently been used to investigate preferential attention to emotional pictures. The study of Calvo and Lang (2004) is particularly relevant to the aims of the present study, as in this study eye movement measures were collected to differentiate between attentional orienting and engagement, and complex visual scenes were presented to healthy individuals. In contrast, other studies using eye tracking to study emotion and attention have been concerned with the role of individual differences in anxiety or specific phobia, have used single stimulus presentation (either a face or an animal), and have made no comparison between the two attentional components (Bradley, Mogg, & Millar, 2000; Hermans, Vansteenwegen, & Eelen, 1999; Miltner et al., 2004; Mogg, Millar, & Bradley, 2000; Rohner, 2002; see General Discussion). Calvo and Lang (2004) presented pairs of emotional scenes depicting people (one neutral, one emotional), and the participants' task was to decide whether both pictures were similar or different in valence. The probability of first fixating each picture and the fixation times during a 3-s exposure period were collected. The results indicated that an emotional picture, either pleasant or unpleasant, was more likely to be fixated than a neutral picture, and that emotional pictures were also fixated longer during the first 500 ms of stimulus exposure. This suggests that emotional pictures capture attention and also engage attention during the early stages of picture processing.

In the present study, we extended the study of Calvo and Lang (2004) in five different ways. First, we used a more sophisticated eye-tracking device with higher temporal (500 Hz) precision (Calvo and Lang recorded gaze shifts with a digital camera that had a temporal accuracy of 50 Hz). Second, when manipulating the emotional valence of the pictorial stimuli, we controlled for the arousal values of the unpleasant and pleasant pictures. Though valence and arousal of pictorial stimuli are often associated (Bradley, 2000), it is possible that both affect the allocation of attention independently. Third, as low-level visual features are involved in generating visual salience in a picture (see Henderson, 2003), and therefore may exert an influence on the initial orienting of attention, we controlled for contrast density of the stimuli, in addition to other physical characteristics. Fourth, to determine the role of novelty or familiarity in the selective attention to emotional pictures, in Experiment 1 we presented each stimulus twice and compared the effects of emotional valence across the two presentations. Finally, to determine the degree to which attentional bias is exogenous or endogenous in nature, we tested in Experiment 2 whether shifts of attention toward and/or away from emotional stimuli may be voluntarily controlled.

Experiment 1

Experiment 1 assessed the spontaneous allocation of attention to emotional and neutral pictures when displayed simultaneously in peripheral vision. In each trial, the participants were presented with two pictures, of which one was a target stimulus (either unpleasant, neutral, or pleasant; always depicting people) and the other was a neutral control picture (depicting inanimate objects). Participants were asked to freely look at the pictures, their eye movements were recorded while they looked at the pictures, and they were instructed to estimate whether the affective valence of the two pictures was similar or dissimilar. The instruction ensured that the participants had to look at both pictures at least once. We wanted to determine whether the initial orienting and the subsequent engagement of attention are biased toward emotional stimuli. An increased probability of first fixating the emotional target was expected if emotional content was found to be more effective in capturing attention than neutral content. In addition, more fixations and longer gaze durations were expected for affective than neutral target pictures if emotional content also affects the engagement of attention.

Method

Participants. A mostly female sample of 23 students (19 women, 4 men) from the University of Turku participated in the experiment as part of a completion of an introductory psychology course. Participants' visual acuity was tested with a standard Snellen chart to ensure normal visual acuity. Depression was measured with the Beck Depression Inventory—II (BDI–II; Beck, Steer, & Garbin, 1988), and trait anxiety was measured with the State–Trait Anxiety Inventory (STAI), Form 2 (Spielberger, Gorsuch, & Lushene, 1970). All participants had visual acuity within the normal limits ($\geq$1.0), and none of them showed symptoms of depression (BDI–II score $<$12) or high amounts of trait anxiety (STAI Form 2 score $<$35).

Apparatus. Stimuli were presented on a 17–in. (43.18-cm) ViewSonic P775 monitor with a 200 MHz Pentium II computer. Participants' eye movements were recorded with an EyeLink II tracker (SR Research, Mississauga, Ontario, Canada) connected to a 2000-MHz Pentium III computer. The sampling rate of the eyetracker was 500Hz, and the spatial resolution was better than 0.5°.

Materials. The stimuli were 128 pictures chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). The IAPS picture codes are presented in the Appendix. There were 16 pleasant, 16 unpleasant, and 16 neutral target pictures and 80 neutral control pictures. The pleasant target pictures represented people showing pleasant affect or enjoying themselves. The unpleasant target pictures depicted threatening people or people suffering from a serious threat or harm. Neutral target pictures depicted people in daily, nonemotional activities. The control pictures represented various inanimate scenes and objects. The overall luminance levels of the pictures were slightly adjusted with the Adobe Photoshop 6.0 program to achieve uniform values for the different picture categories. The means and standard deviations of the luminance level of each picture were computed with Scion Image software. The complexity of the pictures was assessed in terms of the number of bytes of the compressed image file size in JPEG format, with the assumption that the more complex the image is, the larger the file (see Boudo, Sarlo, & Palomba, 2002). The mean contrast level of each picture was measured with root mean square (RMS) contrast (see Bex & Makous, 2002; Peli, 1990). Color saturation for the red, green, and blue channels was assessed with Adobe Photoshop 6.0.

The means and standard errors of affective valence and arousal ratings (from Lang et al., 2005), luminance level, complexity value, RMS contrast, and color saturation for the red, green and blue channels of the target and the control pictures are presented in Table 1, and the correlations between these variables are shown in Table 2. The stimulus characteristics of the four target sets were compared using one-way analyses of variance (ANOVAs). There were significant differences in valence, $F(3, 124) = 325.54$, $p < .01$, $\eta_p^2 = .88$; and arousal, $F(3, 124) = 49.33$, $p < .01$, $\eta_p^2 = .54$. The mean valence rating was higher for the pleasant than for the unpleasant, $t(30) = 30.78$, $p < .01$; neutral, $t(30) = 16.95$, $p < .01$; and control pictures, $t(94) = 18.04$, $p < .01$, whereas the mean rating was higher for neutral pictures, $t(30) = 18.59$, $p < .01$; and control pictures, $t(94) = 20.89$, $p < .01$, than for unpleasant pictures. Mean valence ratings for neutral target and control pictures did not differ from each other, $t = 1.80$. Regarding arousal, planned comparisons showed no significant difference between the pleasant and the unpleasant stimuli, $t = 1.31$, and between the neutral and the control stimuli, $t < 1$. However, arousal rating was higher for the pleasant than for the neutral pictures, $t(30) = 8.79$, $p < .01$, and the control pictures, $t(94) = 7.71$, $p < .01$. Mean arousal rating was also higher for the unpleasant than for the neutral pictures, $t(30) = 10.07$, $p < .01$; and the control pictures, $t(94) = 9.11$, $p < .01$. The mean luminance level, complexity value, RMS contrast, and color saturation for the red, green, and blue color channels did not differ as a function of picture type, $F\text{s} < 2.30$.

Of the associations between the stimulus properties, only the trivial correlations between complexity and luminance, between RMS contrast and luminance, and those between the red, green, and blue channel saturations were statistically significant. It is important to note that none of the low-level stimulus characteristics was associated with either valence or arousal (see Table 2). All in all, the analysis of the stimulus properties demonstrates that we were reasonably successful in selecting stimulus pictures that differed only with respect to valence and arousal but not with respect to low-level visual features.

Stimulus displays. Each stimulus display (see examples in Figure 1) consisted of two pictures: a target picture (involving people) and a control picture (inanimate objects). The target picture was either unpleasant, neutral, or pleasant. The target and control pictures were randomly paired, thus producing three groups of experimental trials: 16 pleasant-control, 16 unpleasant-control, and 16 neutral-control trials. Additionally, there were 16 filler displays (pairs of control pictures), which were included to balance the number of emotional and neutral displays. The size of the target and control pictures was 250 × 188 pixels, which equals to 12.5° × 9° of visual angle at a viewing distance of 60 cm. The pictures in each trial were presented in two opposing corners of the computer screen (top left/top right, bottom left/bottom right, top left/bottom right, or top right/bottom left). The horizontal and vertical locations of the target pictures were

Table 1

Means and Standard Errors for Valence and Arousal Ratings, Stimulus Luminance (0–255), Stimulus Complexity Value (Compressed Image Size in Kbytes), RMS Contrast, and Color Saturation (0–255) for the Red, Green and Blue Channels, Separately for the Unpleasant, Neutral, Pleasant, and Control Pictures

	1. Unpleasant		2. Neutral		3. Pleasant		4. Control	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Valence[a]	$2.15_{2,3,4}$	0.08	$5.22_{1,3}$	0.09	$7.53_{1,2,4}$	0.13	$4.97_{1,3}$	0.06
Arousal[a]	$5.41_{2,4}$	0.13	$3.40_{1,3}$	0.15	$5.11_{2,4}$	0.19	$3.28_{1,3}$	0.10
Luminance	83.40	9.23	90.28	6.58	99.92	11.53	105.05	4.20
Complexity	433.13	52.38	568.25	63.16	329.63	84.65	413.20	31.66
RMS contrast	2.50	0.24	2.22	0.19	1.79	0.13	2.06	0.10
Red channel saturation	87.69	9.50	98.60	10.02	107.94	13.11	117.21	3.96
Green channel saturation	74.38	8.56	81.13	9.23	87.13	9.76	98.41	4.18
Blue channel saturation	62.13	28.05	67.87	22.34	73.75	43.85	77.78	40.76

Note. Subscripts indicate significant differences between categories.
[a] 1 = *most negative,* 9 = *most positive.*

balanced across trials. The distance of the innermost edge of each picture from the initial fixation point was 4°, with a mean distance of 8.5°, between the initial fixation point and the center of the pictures. Each target–control pair was presented twice in separate blocks. In the second presentation, the horizontal and vertical locations of the pictures were reversed. Altogether there were 128 different trials divided into two blocks. Because the location of the target pictures was counterbalanced across trials and their distance from the initial fixation point was constant, the spatial location of the pictures cannot explain possible attentional bias. Moreover, the variation in the picture locations and the randomization of stimulus displays ensured that the participants were not able to successfully use any preset scanning strategy.

Procedure. Participants were tested individually. On arrival, visual acuity was measured with a standard Snellen chart located at a distance of 6 m. Participants were told that the study was concerned with the accuracy of judging the emotional content of pictures. Prior to the experiment, the participants filled the STAI and BDI–II forms. Participants were seated in a comfortable chair 60 cm apart from the screen. A gamepad controller was handed to them for responding to the questions. They were told that they were going to see pairs of pictures, and their task was to estimate whether the emotional valence of the two pictures on each trial was similar or dissimilar. Emotional valence was described as pleasantness or unpleasantness of the pictures. Participants were shown examples of pleasant, unpleasant, neutral, and control pictures. Finally, six practice trials were performed, and the eye-tracker was calibrated. The calibration was accepted if the average error was less than 0.5° of visual angle.

Before each trial (see Figure 1), a fixation point (a black circle with a white center, diameter approximately 1.5°) appeared on the center of the screen, and the participant had to focus his or her gaze at the center of the circle. When the participant's eye was fixated on the circle, the experimenter initiated the trial. Next, two pictures appeared on two different corners of the screen. The fixation circle stayed on the screen so that the appearance of the pictures was the only thing that changed in the participants' field of vision. The pictures remained on the screen for 3,000 ms. Thereafter, the pictures and the fixation circle were replaced with a question ("Were the pictures equally pleasant?"), and the participant was to respond, using the designated response buttons, whether the valence of the pictures was similar or dissimilar. After the response, the question was replaced with the fixation circle, and the next trial was initiated by the experimenter when the participant looked at the center of the fixation circle. The first experimental block consisted of 64 trials in a random order. After the first stimulus block, there was a short break followed by a recalibration of the eye-tracker. Finally, the same pictures were presented again in a random order.

Eye movement measures. Three types of eye movement measures were gathered: (a) the position of fixations, (b) the duration of fixations, and (c) the sequence of fixations. Of these measures, we constructed four variables for the analysis: (a) the latency of the first fixation on a picture, more precisely, the time taken to fixate a target picture (the eyes moved either directly to a target, or there was an intervening fixation on nontarget area on the way); (b) the probability of first fixation; (c) the gaze duration on the picture, that is, the summed duration of fixations made on the picture when

Table 2

Correlations Between Affective and Low-Level Visual Properties of the Stimulus Pictures

	Valence	Arousal	Luminance	Complexity	RMS contrast	Red channel saturation	Green channel saturation
Valence	—						
Arousal	−0.10	—					
Luminance	−0.15	0.07	—				
Complexity	0.01	−0.09	0.18*	—			
RMS contrast	−0.17	−0.02	0.74**	0.16	—		
Red channel saturation	0.08	−0.11	−0.11	−0.04	−0.12	—	
Green channel saturation	0.05	−0.16	−0.05	0.00	−0.05	0.82**	—
Blue channel saturation	0.07	−0.14	0.00	−0.02	0.05	0.56**	< 0.81**

* $p < .05$, two-tailed. ** $p < .01$, two-tailed.

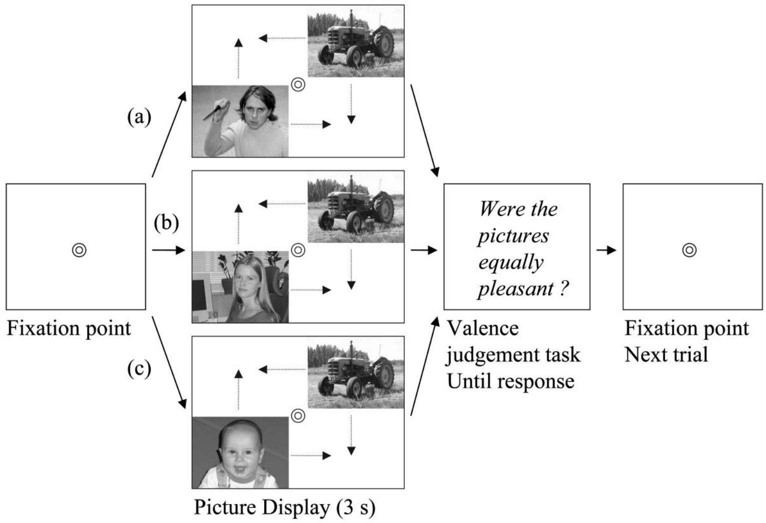

Figure 1. Time sequence of an experimental trial with an unpleasant (a), neutral (b), and pleasant (c) target picture. Note that these example pictures were not among the experimental stimuli.

looking at it for the first time, before fixating away from it; and (d) the number of the first-pass fixations. Initial attentional orienting was assessed by the latency and the probability of first fixation on the target picture; subsequent attentional engagement was assessed by gaze duration and the number of first-pass fixations.

Results

The means and standard errors of the eye movement measures for the different target types are presented in Figure 2 and Table 3. They were subjected to a 3 (target type: unpleasant vs. neutral vs. pleasant) × 2 (block: first vs. second) repeated measures ANOVA.

Attentional orienting. The latency measure was not reliably affected by target type, $F < 1$, or block, $F < 1$, or their interaction, $F < 1$. This was also the case for trials where the eyes moved directly to a picture, Fs < 1 (the overall latency of these trials was 417 ms). However, the target type had a significant influence on the probability of first fixation on target, $F(2, 44) = 10.94$, $p < .01$, $\eta_p^2 = .33$ (see Figure 2A). This effect was similar for both stimulus blocks, $F < 1$, and was not qualified by a Target Type × Block interaction, $F < 1$. Planned comparisons showed that the probability of first fixating a pleasant picture (.62) was greater than that of first fixating a neutral (.53), $F(1, 22) = 20.15$, $p <$ 01; or an unpleasant picture (.57), $F(1, 22) = 7.91$, $p < .01$; and the probability of first fixating a unpleasant picture was higher than that of first fixating a neutral picture, $F(1, 22) = 4.27$, $p = .05$.

Attentional engagement. Gaze duration was also affected by target type, $F(2, 44) = 4.15$, $p = .02$, $\eta_p^2 = .16$. Planned comparisons showed that, across blocks, unpleasant pictures received longer gaze durations than neutral pictures, $F(1, 22) = 7.15$, $p = .01$ (712 and 649 ms, respectively). A main effect of block indicated that average gaze duration was shorter on the second (653 ms) than on the first (701 ms) viewing, $F(1, 22) = 5.19$, $p = .03$, $\eta_p^2 = .21$. Also for the number of first-pass fixations (see Figure 2B), main effects of target type, $F(2, 44) = 6.72$, $p < .01$, $\eta_p^2 = .23$, and block, $F(1, 22) = 14.53$, $p < .01$, $\eta_p^2 = .40$, were observed. The participants made fewer first-pass fixations on the

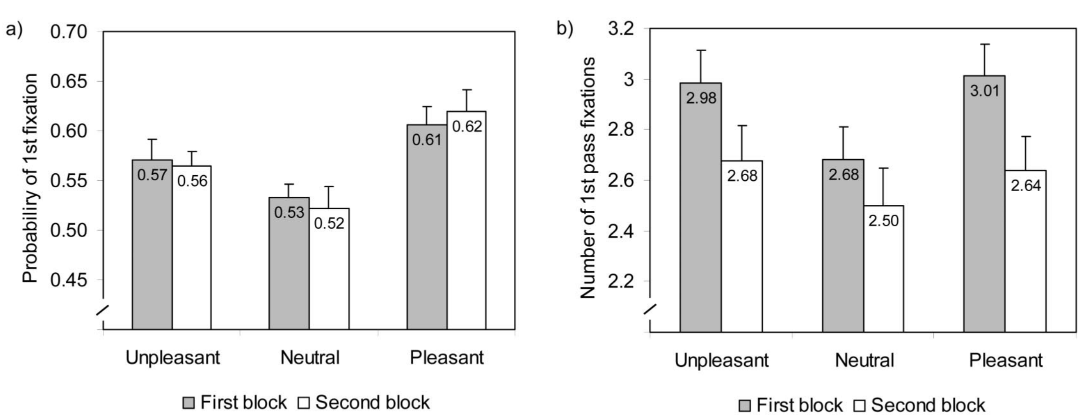

Figure 2. Probability of first fixation (a) and number of first-pass fixations (b) for target pictures by experimental block in Experiment 1.

Table 3
Means and Standard Errors of Latency of First Fixation (ms) and Gaze Duration for the Target Pictures, Separately for the First and Second Stimulus Block in Experiment 1

	First Block						Second Block					
	Unpleasant		Neutral		Pleasant		Unpleasant		Neutral		Pleasant	
Measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Latency of first fixation (ms)	449	7.14	449	6.56	454	7.04	439	6.01	448	6.29	450	4.30
Gaze duration	745	37	672	39	687	39	678	45	627	44	654	44

second (2.61) than on the first (2.89) viewing. Moreover, the unpleasant targets, $F(1, 22) = 9.97$, $p < .01$; and the pleasant targets, $F(1, 22) = 10.29$, $p < .01$, received more first-pass fixations than the neutral targets (the mean was 2.83 for the pleasant and unpleasant pictures and 2.59 for the neutral pictures).

Discussion

The major findings of Experiment 1 were that (a) the first fixation was especially likely to be directed to emotional pictures and that (b) gaze duration and number of first-pass fixations were greater for emotional than for neutral pictures. This supports the hypothesis that both attentional orienting and engagement are biased toward emotional visual stimuli. The participants were not only more likely to attend first to the emotional pictures, but once fixated, these were also attended to for longer time and with more fixations than neutral pictures. Another important finding is that the initial orienting and attentional engagement was similarly biased toward both unpleasant and pleasant target pictures. This supports the emotionality hypothesis, rather than any form of specificity (e.g., a bias to threatening stimuli), although attention was slightly more biased to pleasant than to unpleasant stimuli (see particularly the gaze duration data).

The contention that this bias is due to the affective content of the stimuli, rather than other extraneous factors, is reinforced by the finding that the differences between emotional and neutral targets appeared even though all three target picture categories were matched for luminance, contrast, color saturation, and complexity, which rules out the possibility that the emotional bias effects could be accounted for by low-level features. Moreover, the attentional bias was not due to the possibility that the affective stimuli had been more novel than the neutral ones, as the effects of valence appeared both when the stimuli were presented for the first and for the second time. It should also be noted that, in Experiment 1, emotional stimuli were compared with neutral stimuli involving people in all cases and that the bias was assessed by the relative attention devoted to the target pictures (unpleasant, pleasant, neutral) when presented simultaneously with control pictures.

Experiment 2

Experiment 1 established that initial attentional orienting and subsequent attentional engagement are biased toward both pleasant and unpleasant emotional scenes. The purpose of Experiment 2 was to examine the extent to which this attentional capture by emotional content is automatic and whether it can be counteracted by voluntary control. We cannot conclude from Experiment 1 that the higher probability of first fixation on emotional pictures necessarily results from an automatic, exogenous shift of attention. It is possible that participants may have actively tried to attend to the emotional pictures first (although it is unlikely that such a strategy would be effective, as emotional pictures were presented randomly at four different locations), which would suggest an endogenously determined attention shift. In Experiment 2, we used the same stimuli as in Experiment 1 but changed the experimental task. To determine the degree to which attention can be voluntarily controlled in the presence of emotional stimuli, the participants were asked to either direct their gaze first to an emotional picture or to a neutral picture and to keep fixating on either of them. If emotional pictures capture attention despite endogenous avoidance, that is, when participants are instructed to fixate the neutral picture of a pair, this would support the hypothesis that emotional content captures visual attention exogenously and automatically.

Method

Participants. A mostly female sample of 32 students (28 women, 4 men) from the University of Turku participated in the study as part of an introductory psychology course requirement. None had participated in Experiment 1. Participants' visual acuity, depression, and trait anxiety were measured, similarly to Experiment 1. All participants had visual acuity within the normal limits (>1.0), and none of them showed clinical symptoms of depression (BDI–II score <12) or high levels of trait anxiety (STAI score <35).

Stimuli and apparatus. The stimuli and apparatus were the same as in Experiment 1, with the exception that the neutral pictures of Experiment 2 were those that served as the control pictures in Experiment 1, which were presented simultaneously with the emotional pictures. Moreover, when the target stimuli were presented for the second time, they were paired with different control pictures. Finally, trials containing a neutral and a control picture were not analyzed, as they served only as filler trials to balance the number of the stimulus displays with emotional versus nonemotional content.

Procedure. The procedure was analogous to the one of Experiment 1, with the following exceptions. The 128 experimental trials were divided into four blocks; within each block the order of trials was randomized. Before each block, the participant was instructed to either (a) "direct your gaze to an emotional picture and keep it there as long as the pictures are displayed" (attend-to-emotional condition), or (b) "direct your gaze to a neutral picture and keep it there as long as the pictures are displayed" (attend-to-neutral condition). Unlike in Experiment 1, participants were not asked to compare the valence of the pictures, but just look at one of them. Each participant performed the task with both the attend-to-emotional and attend-to-neutral instructions. Both conditions were split into two separate blocks, and each stimulus pair appeared only once in the attend-to-emotional and once in the attend-to-neutral condition. The order of the stimulus blocks and task instructions were counterbalanced across participants. The eye-tracker was calibrated between blocks.

Results

In addition to the eye movement variables used in Experiment 1, we computed an index of total allocation of attention, as reflected by the total fixation time on the picture (i.e., summing up the gaze duration with possible reinspections during the whole 3-s exposure period). This was used to determine that the instructional manipulation was effective, in the sense that the overall allocation of attention was done as requested (i.e., spending more time looking at an emotional target in the attend-to-emotional task and more time on neutral target in the attend-to-neutral task). Similarly to Experiment 1, initial attentional orienting was assessed by the latency to fixate a target and by first fixation probability, and subsequent attentional engagement was assessed by gaze duration and number of first-pass fixations.

Means and standard errors of the eye movement measures for the different target types in the two task conditions are presented in Figures 3 and 4 and in Table 4. All eye movement measures were subjected to a 3 (target type: unpleasant vs. neutral vs. pleasant) × 2 (task: attend-to-emotional vs. attend-to-neutral) repeated measures ANOVA.

Attentional orienting. The time taken to make an initial fixation on a target was affected both by target type, $F(2, 62) = 10.37$, $p < .01$, $\eta_p^2 = .25$; and task, $F(1, 31) = 7.85$, $p < .01$, $\eta_p^2 = .20$. These main effects were qualified by a Target Type × Task interaction, $F(2, 62) = 4.04$, $p = .02$, $\eta_p^2 = .12$. Planned contrasts indicated that the latency for fixating a neutral target was longer in the attend-to-neutral than in the attend-to-emotional condition (490 ms vs. 460 ms), $F(1, 31) = 6.45$, $p = .02$, whereas the task instructions had no effect on the latencies for unpleasant and pleasant pictures (see Table 4). This increase in latency for the neutral pictures is probably spurious and has no apparent theoretical significance.

The probability of first fixation (see Figure 3) was significantly affected by target type, $F(2, 62) = 40.01$, $p < .01$, $\eta_p^2 = .59$; and task, $F(2, 31) = 9.00$, $p < .01$, $\eta_p^2 = .23$; moreover, the Target Type × Task interaction also proved significant, $F(2, 62) = 7.55$, $p < .01$, $\eta_p^2 = .20$. The interaction reflects the fact that the probability of first fixating a pleasant, $F(1, 31) = 5.22$, $p = .03$, or an unpleasant picture, $F(1, 31) = 9.37$, $p = .01$, was higher in the attend-to-emotional than in the attend-to-neutral condition, whereas the opposite was true for the neutral pictures, $F(1, 31) = 9.49$, $p = .01$. Nevertheless, it is important to note that emotional pictures were more likely to be fixated first than neutral pictures in both task conditions (the means were .65, .59, and .38 for the pleasant, unpleasant, and neutral pictures, respectively), Fs $(1, 31) > 9.37$, ps $< .01$.

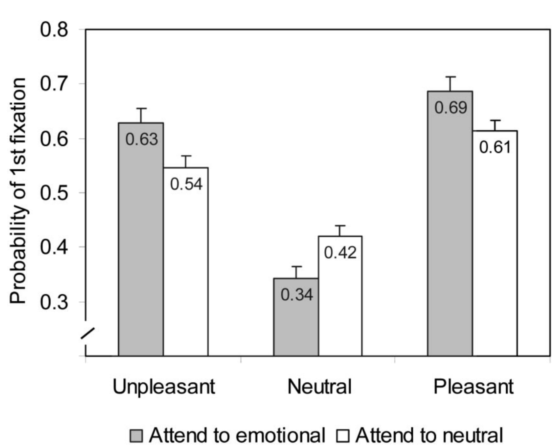

Figure 3. Probability of first fixation on target pictures in attend-to-emotional and attend-to-neutral conditions in Experiment 2.

Early attentional engagement: First-pass fixations. The analysis of gaze duration (see Figure 4A) yielded a reliable Target Type × Task interaction, $F(2, 62) = 44.12$, $p < .01$, $\eta_p^2 = .59$. Both unpleasant pictures, $F(1, 31) = 133.17$, $p < .01$; and pleasant pictures, $F(1, 31) = 98.21$, $p < .01$, received longer gaze durations in the attend-to-emotional than in the attend-to-neutral condition, whereas the opposite was true for the neutral pictures, $F(1, 31) = 123.46$, $p < .01$. Moreover, in the attend-to-emotional condition, both unpleasant pictures, $F(1, 31) = 132.16$, $p < .01$; and pleasant pictures, $F(1, 31) = 99.12$, $p < .01$, received longer gaze durations than neutral pictures. In contrast, in the attend-to-neutral condition exactly the opposite pattern emerged, in that both unpleasant pictures, $F(1, 31) = 20.56$, $p < .01$, and pleasant pictures, $F(1, 31) = 21.63$, $p < .01$, received shorter gaze durations than neutral pictures. However, these interactive effects were asymmetric in that the difference between emotional and neutral pictures was greater in the attend-to-emotional condition (a difference of 1,483 ms in favor of emotional pictures) than in the attend-to-neutral condition (a difference of 598 ms in favor of neutral pictures), $F(1, 31) = 68.28$, $p < .01$. This implies that the instruction for attending to an emotional stimulus was more effective than that for attending to a neutral stimulus.

The analysis of the number of first-pass fixations yielded a similar Target Type × Task interaction, $F(2, 62) = 61.40$, $p < .01$, $\eta_p^2 = .66$. Both unpleasant pictures, $F(1, 31) = 99.60$, $p < .01$; and pleasant pictures, $F(1, 31) = 197.60$, $p < .01$, received more first-pass fixations in the attend-to-emotional than in the attend-to-neutral condition, whereas the opposite was true for neutral pictures, $F(1, 31) = 22.14$, $p < .01$. Moreover, in the attend-to-emotional condition, both unpleasant pictures, $F(1, 31) = 116.97$, $p < .01$, and pleasant pictures, $F(1, 31) = 115.28$, $p < .01$, received more first-pass fixations than the neutral pictures, whereas in the attend-to-neutral condition no reliable differences were found between the picture categories. This indicates again that the difference between emotional and neutral pictures was greater in the attend-to-emotional condition (a difference of 3.09 fixations in favor of emotional pictures) than in the attend-to-neutral condition (a difference of 0.57 fixations in favor of neutral pictures), $F(1, 31) = 70.32$, $p < .01$.

Overall allocation of attention: Total fixation time. As expected, the participants were able to allocate the total viewing time as instructed (see Figure 4B). This is shown by a reliable Target Type × Task interaction, $F(2, 62) = 1{,}100.79$, $p < .01$, $\eta_p^2 = .97$. Both unpleasant pictures, $F(1, 31) = 1076.80$, $p < .01$; and pleasant pictures, $F(1, 31) = 953.96$, $p < .01$, were inspected longer in the attend-to-emotional than in attend-to-neutral condition, whereas the opposite was true for neutral pictures, $F(1, 31) = 1{,}311.85$, $p < .01$. Moreover, in the attend-to-emotional condition, both unpleasant pictures, $F(1, 31) = 926.68$, $p < .01$ and pleasant

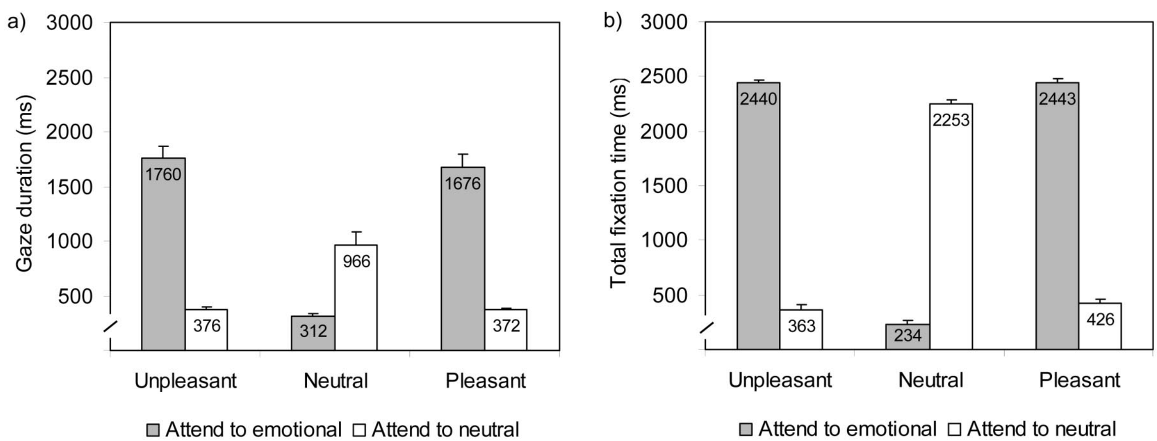

Figure 4. Gaze duration (a) and total fixation time (b) for target pictures in attend-to-emotional and attend-to-neutral conditions in Experiment 2.

pictures, $F(1, 31) = 1{,}265.64$, $p < .01$, received longer total fixation times than the neutral pictures, whereas in the attend-to-neutral condition both unpleasant pictures, $F(1, 31) = 988.00$, $p < .01$, and pleasant pictures, $F(1, 31) = 692.58$, $p < .01$, received shorter total fixation times than neutral pictures.

The task instructions yielded less asymmetric effects for emotional versus neutral pictures in the total fixation time than in gaze duration The proportion of total time spent fixating the emotional picture in the attend-to-emotional condition (a difference of 2,129 ms in favor of emotional pictures) was significantly different from that for neutral pictures in the attend-to-neutral condition (a difference of 1,853 ms in favor of neutral pictures), $F(1, 31) = 30.71$, $p < .01$. As noted in the discussion (see also Figure 5), the proportional asymmetry linearly diminishes as a function time.

Discussion

To summarize the main findings of Experiment 2, bias scores for the three temporally arranged eye movement variables (probability of first fixation, gaze duration, and total fixation time; see Figure 5) in the two task conditions (i.e., attend-to-neutral and attend-to-emotional) were computed as follows. First, the proportional allocation of attention to emotional (collapsed over unpleasant and pleasant pictures) and neutral pictures was computed for each of the three eye movement variables. Second, the score for neutral pictures was subtracted from that for emotional pictures to yield the bias score. Hence, a positive score indexes a bias toward emotional and a negative score a bias toward neutral pictures. To assess the degree of voluntary control over allocation of attention, we summed the bias scores in the attend-to-emotional and attend-to-neutral conditions. The logic underlying this summation is that, if voluntary control over allocation of attention toward the emotional and the neutral stimuli is equivalent, the bias scores for both types of stimuli would be high and, most important, they would sum up to zero in the two task conditions (the degree of bias is shown by black squares). Next, we tested whether the difference in the bias score for each eye movement variable differed significantly from zero (a significant difference was denoted by an asterisk) and finally fitted a linear trend to the bias score differences across the eye movement variables.

As indicated in Figure 5, there were three major findings in Experiment 2. First, there was a strong attentional orienting bias toward the emotional pictures. Both pleasant and unpleasant pictures were more likely to be fixated first than neutral ones, even when participants were instructed to actively avoid them (i.e., to fixate a neutral target first). This suggests that orienting toward emotional stimuli is to a significant degree exogenously controlled. However, voluntary initial avoidance of emotional pictures was possible to some extent, as the probability of first fixation for emotional targets was lower in the attend-to-neutral condition than in the attend-to-emotional condition. Second, there was also a bias toward emotional pictures in early attentional engagement. This was demonstrated by the asymmetric effects of instructions on

Table 4
Means and Standard Errors of Latency of First Fixation (ms) and Number of First Pass Fixations for the Target Pictures in the Attend-to-Emotional and Attend-to-Neutral Conditions in Experiment 2

	Attend to emotional						Attend to neutral					
	Unpleasant		Neutral		Pleasant		Unpleasant		Neutral		Pleasant	
Measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Latency of first fixation (ms)	463	9.92	460	8.43	475	9.80	465	9.57	490	11.30	482	10.05
Number of first pass fixations	4.15	0.21	1.40	0.08	4.07	0.20	1.80	0.08	2.29	0.16	1.80	0.07

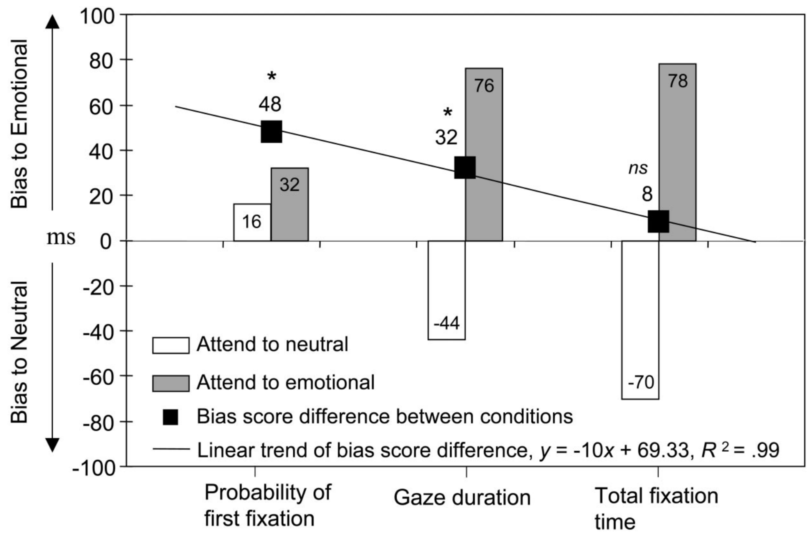

Figure 5. Bias scores (the relative degree of attentional orienting, in percentages), difference in bias scores (attend-to-emotional—attend-to-neutral; shown by black squares), and linear trend of bias score difference, for the emotional and neutral pictures in Experiment 2. Asterisks indicate that the difference in the bias scores differs significantly from zero; *ns* = for nonsignificant differences.

gaze duration during the first-pass viewing of the pictures: The proportion of gaze duration for emotional pictures—relative to neutral pictures—in the attend-to-emotional condition was greater than that for neutral pictures—relative to emotional pictures—in the attend-to-neutral condition (see Figure 5). And, third, in the later stages of attentional engagement there was a symmetric bias (i.e., equally strong) toward emotional pictures in the attend-to-emotional condition and toward neutral pictures in the attend-to-neutral condition, as revealed by a task effect of similar size on total fixation time. This shows that the task manipulation was most effective in later processing stages. In other words, voluntary control was possible when additional time was allotted. In contrast, the effectiveness of instructions to direct attention to neutral stimuli was diminished for early attentional engagement, and was poorest for initial orienting (see Figure 5). This is probably due to early involuntary capture of attention by emotional stimuli, which initially overruled the instruction to attend to the neutral stimulus.

General Discussion

In the present study we used continuous eye-movement monitoring while participants were viewing pairs of pictures, either freely with the instruction to compare the pleasantness of the pictures (Experiment 1) or constrained by instructions to attend to the emotional or the neutral picture of each picture pair (Experiment 2). Three major issues were addressed: the time course of attentional capture by emotional visual scenes, the exogenous versus endogenous nature of the attentional bias toward emotional stimuli, and the type of affective content (pleasant vs. unpleasant) that is capable of selectively drawing and holding attention. The results indicated that both initial orienting and subsequent attentional engagement are biased toward both pleasant and unpleasant emotional stimuli and that this bias occurs even under explicit instructions to attend to a concurrently presented neutral picture. In what follows, we discuss these three issues in more detail.

Attentional Stages in the Selective Processing of Emotional Pictures

First, early attentional capture by emotional content was demonstrated by the probability of making the first fixation in two-picture displays on an emotional versus a neutral picture. We showed that an emotional picture was more likely to be fixated first than a neutral picture, which indicates a bias in attentional orienting. Moreover, once fixated, the emotional pictures received more fixations and were gazed at for a longer time than neutral pictures, which reflects a bias in early attentional engagement (i.e., emotional pictures held attention for longer time than neutral pictures; in gaze duration, unpleasant pictures differed significantly from neutral pictures, whereas the difference did not reach significance for pleasant pictures). These findings are consistent with those obtained by Calvo and Lang (2004), who reported a higher probability of first fixation and longer viewing time during the first 500 ms after the stimulus onset for emotional than for neutral pictures (most of the stimuli were different across the two studies, which supports the generalizability of the effects). Prior research has already shown that people pay special attention to emotional pictures when presented simultaneously with neutral pictures (see the Introduction; e.g., Fox et al., 2001; Mogg & Bradley, 1999; Öhman, Flykt, & Esteves, 2001). The present eye-tracking study contributes to this pool of knowledge by specifying the components of attention that are affected. Other paradigms such as the dot-probe task or the visual search task cannot separate attentional orienting from attentional engagement. On the other hand, the attentional cueing paradigm that is capable of distinguishing between these two components has established an emotional effect for attentional engagement (e.g., Fox et al., 2002; Yiend & Mathews, 2001) but not for orienting (but see Koster et al., 2004). Our continuous recording of overt attention deployment extends the observations obtained by the cueing paradigm, which does not permit an analysis of the time course of attention deployment or that of attentional selection (only one stimulus picture is presented at a time).

Some prior studies have also used continuous eye movement monitoring to investigate selective attention to emotional pictures (Bradley et al., 2000; Hermans et al., 1999; Miltner et al., 2004; Mogg, Millar et al., 2000; Rohner, 2002). There are, however, some important differences between these studies and the present study. First, the prior studies were concerned with the role of individual differences, either in trait anxiety (Rohner, 2002), social anxiety (Bradley et al., 2000), generalized anxiety disorder (Mogg, Millar, & Bradley, 2000), or spider phobia (Hermans et al., 1999; Miltner et al., 2004). Accordingly, the results obtained using these selected samples of participants may not be representative of the cognitive processes characterizing normal people. Second, a reduced set of specific emotional stimuli was used, such as emotional faces (Bradley et al., 2000; Mogg, Millar et al., 2000; Rohner, 2002) or spiders (Hermans et al., 1999; Miltner et al., 2004). Third, these studies report either the probability of making a fixation on a picture (Bradley et al., 2000; Mogg, Millar, & Bradley, 2000), or the duration of fixations (Hermans et al., 1999; Rohner, 2002), but not both. Miltner et al. (2004) used two related measures (i.e., frequency of saccades to distractors prior to targets, and average duration of saccades to targets), but these measures were not specifically used to determine attentional orienting versus engagement, probably because of the nature of the task (i.e., visual search in multiple-stimulus arrays). Fourth, the findings were not totally consistent between the different studies (which is understandable, given the differences in stimuli and the criteria used to establish individual differences). The present study extends the previous eye movement studies by demonstrating an emotional bias both in attentional orienting and engagement among normal participants and with a wider range of emotional pictures.

Endogenous Attentional Control Versus Exogenous Attentional Capture by Emotional Stimuli

The second major issue in the present study concerned the automatic versus strategic nature of attentional bias to emotional pictures. Dual-process theories of attention (see Barrett, Tugade, & Engle, 2004; Corbetta & Shulman, 2002; Egeth & Yantis, 1997) typically distinguish between a stimulus-driven and goal-directed mechanism. In the former case, attention is captured exogenously, preattentively, by the properties of the stimuli, whereas in the latter case, the allocation of attention is controlled endogenously by the individual's intentions and interests. The findings from the present study suggest that there may be genuine exogenous attentional capture by emotional stimuli. Emotional stimuli were more likely to be fixated first than simultaneously presented neutral pictures when participants were freely assessing the pleasantness of the pictures and even when instructions oriented the viewers to attend to the neutral picture first (in both cases, the location of the emotional picture was unpredictable). Moreover, the effectiveness of the instructions to attend to the neutral picture was poorer than the effectiveness to attend to the emotional picture, as measured by gaze duration indexing early attentional engagement (overall, the two types of instructions were equally effective, as indexed by the total fixation time). This suggests that emotional content is likely to engage attention in early processing stages, which are less susceptible to voluntary control, whereas voluntary avoidance of emotional content becomes possible with additional time. Our results supporting the hypothesis of preattentional capture by emotional stimuli are consistent with those obtained in subliminal perception studies (e.g., Dimberg, Thunberg, & Elmehed, 2000; Mogg & Bradley, 1999; Öhman & Mineka, 2001).

Nevertheless, two pieces of evidence indicate that the attentional capture by emotional pictures is not completely exogenous and that there was some endogenous control. First, the mean latency of making an initial fixation on a picture was significantly longer (between 460 and 490 ms) than what is typically observed for reflexive saccades (i.e., between 150 and 175 ms; e.g., Rayner, 1998). This suggests that participants may have taken some time to determine to which picture to move their eyes, which implies that some endogenous control was also involved. Alternatively, these saccades with relatively long latencies could have been due to the competition for resources with two simultaneous stimuli to be attended to, which would have delayed the decision about where to look first. Second, the probability of a first eye fixation on an emotional picture was reduced in the attend-to-neutral versus attend-to-emotional condition of Experiment 2 (i.e., from .63 to .54 for unpleasant pictures and from .69 to .61 for pleasant pictures). This suggests that participants were, to some extent, able to inhibit their first eye fixation on an emotional picture in the attend-to-neutral condition.

The overt orienting bias to emotional pictures, either endogenously controlled or exogenously determined, suggests that some aspect of the picture content is perceived peripherally. Otherwise, the first fixation would have been directed equally toward the emotional and the neutral pictures. Peripheral perception of emotional content brings about a covert shift of visual attention followed by an overt gaze shift (the delay is due to saccadic latency) to the attended spatial location (e.g., Henderson, 1992; Hoffman, 1998). Recent findings of Calvo and Lang (2005) are consistent with this account. With a recognition priming paradigm, two pictures (one neutral, one emotional) were simultaneously presented parafoveally, one at each side of a central of fixation point, followed first by a mask and then by a probe picture. Calvo and Lang found that emotional probes were more likely to be recognized than neutral probes when primed by a picture of identical semantic content but different in size, orientation, and color. As the improved recognition for emotional pictures occurred even when the prime was presented only for 150 ms and in conditions preventing any saccadic eye movements to the parafoveal stimulus, this facilitation effect may be attributed to early covert orienting of attention to the emotional prime.

Attentional Bias as a Function of Emotional Content

The third main issue addressed in the present study is whether attention is drawn specifically by threat-related or unpleasant content (negativity hypothesis), by pleasant content (positivity hypothesis), or by affective content in general (emotionality hypothesis). The present findings clearly support the emotionality hypothesis, as both pleasant and unpleasant pictures were significantly more likely to be attended than neutral pictures. However, there were some differences in orienting of attention to pleasant and unpleasant stimuli. In Experiment 1 and in the attend-to-neutral condition of Experiment 2, pleasant pictures were more likely to be fixated first than unpleasant pictures. This may have been due to the so-called happy-face advantage (see Mack & Rock, 1998; Leppänen & Hietanen, 2003), as some (but not all) of the pleasant stimulus pictures depicted smiling people. However, on the basis of the present data, we cannot make strong conclusions about whether pleasant and unpleasant pictures are equally prone to attract attention as they were presented in separate trials. The point we want to make here is that both pleasant and unpleasant pictures captured attention more readily than emotionally neutral pictures.

Taken together, the results are inconsistent with those indicating preferential attention to threatening faces, in comparison with happy faces (Fox et al., 2000; Mogg & Bradley, 1999; Öhman, Lundqvist, & Esteves, 2001; Tipples, Atkinson et al., 2002), which supports the negativity hypothesis. On the other hand, our results are consistent with those of Calvo and Lang (2004, 2005, 2005), and of Lang, Greenwald, Bradley, and Hamm (1993; see also Bradley, Cuthbert, & Lang, 1996; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp, Junghöfer, Weike, & Hamm, 2004), who found enhanced attention to pictures depicting both pleasant and unpleasant scenes (or animals; see Tipples, Young, et al., 2002). There are, however, important methodological differences between the two groups of studies, such as the type of emotional stimuli (e.g., facial pictures vs. pictures representing a variety of real-life events). Stimulus differences may account for the discrepant results, as emotional face stimuli are judged less emotional (pleasant or unpleasant), have lower emotional arousal ratings, and produce less extensive functional activity (fMRI) in the visual cortex than pictures of emotional scenes (Bradley et al., 2003). In our study, we used pictures that, in addition to showing facial expressions, portrayed people acting (or reacting) in scenes. This probably increased the emotionality of the stimuli. The hypothesis is, therefore, that with highly emotional stimuli, the threat advantage disappears in favor of an emotionality hypothesis, at least when there are no arousal differences between pleasant and unpleasant stimuli, as was the case in the present study.

In conclusion, the present study provides evidence for attentional capture by the affective content of pictures of both pleasant and unpleasant valence, when emotional pictures are competing for attentional resources with simultaneously presented nonemotional pictures. This emotional bias is seen both in initial orienting and subsequent engagement of attention. The present study also demonstrates that attention is captured exogenously by the stimulus content. This early involuntary capture of attention can be counteracted by endogenous control in later stages of picture processing. Attentional capture by emotional pictorial stimuli cannot be attributed to low-visual features such as luminance, color, or contrast, as the neutral and emotional stimuli were comparable in these respects. Orienting to and engaging attention with potentially harmful and beneficial stimuli in the environment fulfils an important function for survival and well-being. It guarantees that relevant stimuli for adaptation are selected early (over less relevant stimuli) for further processing to determine the exact nature of the potential threat or opportunity and to readily initiate defensive or approach behavior.

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Appendix

IAPS Numbers for the Target and Control Picture Stimuli

Unpleasant target pictures: 2095, 2375.10, 2750, 2800, 2900, 3015, 3051, 3181, 3301, 3550, 6243, 6570, 6838, 9040, 9421, and 9435

Pleasant target pictures: 2040, 2050, 2057, 2070, 2091, 2165, 2209, 2216, 2340, 2352, 2550, 4608, 4641, 4653, 4700, and 8490

Neutral target pictures: 2190, 2191, 2215, 2235, 2393, 2487, 2516, 2745.1, 2840, 2850, 2870, 7493, 7496, 7550, 8311, and 9070

Neutral control pictures: 5130, 7031, 5390, 5395, 5661, 5900, 6000, 6150, 6610, 6900, 6930, 7000, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7034, 7035, 7036, 7037, 7038, 7039, 7040, 7041, 7050, 7060, 7080, 7090, 7095, 7096, 7100, 7110, 7130, 7140, 7150, 7160, 7161, 7170, 7175, 7179, 7182, 7183, 7184, 7185, 7186, 7187, 7180, 7190, 7205, 7207, 7211, 7217, 7224, 7233, 7234, 7235, 7236, 7237, 7490, 7491, 7495, 7500, 7504, 7510, 7560, 7590, 7595, 7600, 7705, 7710, 7950, 9110, 9360, 9390, 9401, and 9472

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