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Allocation of Spatial Attention to Emotional Stimuli Depends Upon Arousal and Not Valence

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Attentional allocation to emotional stimuli is often proposed to be driven by valence and in particular by negativity. However, many negative stimuli are also arousing leaving the question whether valence or arousal accounts for this effect. The authors examined whether the valence or the arousal level of emotional stimuli influences the allocation of spatial attention using a modified spatial cueing task. Participants responded to targets that were preceded by cues consisting of emotional pictures varying on arousal and valence. Response latencies showed that disengagement of spatial attention was slower for stimuli high in arousal than for stimuli low in arousal. The effect was independent of the valence of the pictures and not gender-specific. The findings support the idea that arousal affects the allocation of attention.

Keywords: spatial attention, arousal, valence, negativity bias

Numerous studies have found attentional biases to emotional stimuli, such as facilitated orienting of attention to angry faces (Fox, Russo, Bowles, & Dutton, 2001) and signals for aversive events (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004). It is still unclear which dimension of emotional events accounts for such biases. Many researchers assume that attentional biases are driven by valence, and that they prioritize negative information (Larsen, in press; Pratto & John, 1991). In line with this view, Pratto and John (1991) found stronger interference for negative compared to positive stimuli in a Stroop task. The preference to allocate attention to negative events is most often explained by the high relevance of negative stimuli as potential dangers for the organism.

Emotional stimuli do not differ merely in terms of valence, but also in terms of arousal (Lang, Bradley, & Cuthbert, 1997; Russell, 1980). Indeed, many studies on attention for emotional information compare negative highly arousing to positive low arousing stimuli (e.g., Fox et al., 2001; Öhman, Flykt, & Esteves, 2001). It could therefore well be that attentional biases are driven by the arousal level of the stimuli rather than by their valence. Indirect support for this assumption was found by Buodo, Sarlo, and Palomba (2002) who showed facilitated allocation of attention to positive stimuli with high arousal levels such as erotic stimuli in a dual-task paradigm. More direct evidence was reported by Schimmack (2005). In his study, participants had to ignore emotional pictures that varied in valence and arousal while performing a nonemotional primary task. Slowest reaction times in this task emerged when strong arousing pictures were presented, independent of the valence of these pictures.

Despite these initial studies, important issues remain unresolved. First, the data by Schimmack (2005) do not allow one to distinguish unambiguously between interference because of attentional processes and interference because of response effects. According to an attentional explanation, highly arousing pictures attract attention away from the main task and therefore slow down responding in the primary task. A response effect explanation, on the other hand, proposes that highly arousing pictures temporarily result in a generic slow-down and thus delay all motor responses (e.g., Algom, Chajut, & Lev, 2004; De Ruiter & Brosschot, 1994). If this is the case, highly and low arousing pictures might receive the same amount of attention but differ only in their effects at the response stage. Therefore, it is necessary to replicate and extend the findings of Schimmack using attentional paradigms that render interpretations in terms of response effects less plausible.

Second, it remains unresolved which component of spatial attention is affected by arousal. Spatial attention has received particular interest in research on attention (e.g., Posner, 1980) and attentional processing of emotional stimuli (e.g., Fox et al., 2001). In spatial attention, a distinction can be made between attentional engagement and disengagement (e.g., Fox et al., 2001; Koster et al., 2004). Different studies have revealed that spatial attention to threat is best characterized as a difficulty to disengage from threatening information (Fox et al., 2001; Yiend & Mathews, 2001). Because threatening stimuli are most of the time highly arousing, it seems plausible that arousal modulates spatial attention and that it affects primarily the disengagement component.

The aim of the present study was to examine whether valence or arousal modulates the allocation of spatial attention in a modified spatial cueing paradigm. This paradigm allows studying covert attentional orienting to peripheral cues and has been used to examine attentional engagement with and disengagement from emotional stimuli (Fox et al., 2001; Koster et al., 2004). In this task participants have to detect visual targets presented at the left or

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right side of a fixation cross. The target is preceded by a visual cue at the same location (validly cued trials) or opposite location (invalidly cued trials). Valid cues typically lead to response time benefits (because of engagement of attention at the validly cued location), whereas invalid cues lead to response time costs (because of delayed disengagement of attention from the invalidly cued location), a difference referred to as cue validity effect. Studies using this paradigm have shown that emotional cues lead to a larger cue validity effect than neutral cues (Koster et al., 2004; Van Damme, Crombez, & Ecclestone, 2004). The paradigm allows distinguishing between attentional and response effects. If an effect is caused by a response effect, reactions on both valid and invalid trials should be retarded (or speeded). In contrast, attentional orienting to cues is evidenced by a modulation of the difference in reaction times between valid and invalid trials. If a particular class of emotional cues influences attentional orienting, this would decrease reaction times on valid trials (engagement) or increase reaction times on invalid trials (disengagement) for these particular cues.

In this study we used pictures of the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) to examine the effects of arousal and valence on attentional processing of emotional stimuli. We chose pictures as cues because pictures offer a higher ecological validity (Mogg & Bradley, 1999). To test the effects of valence and arousal independently, we manipulated the valence (positive or negative) and arousal (high or low) of the stimuli orthogonally.

Method

Participants

Fifty-three students (31 women) at Ghent University participated. They took part to fulfill course requirements or were paid 4 €. All participants had normal or corrected-to-normal vision and were naive as to the purpose of the experiment.

Apparatus and Materials

Emotional Pictures

Seventy-three emotional pictures were obtained from the IAPS. Five additional neutral pictures were selected for the practice block. The pictures were categorized in four groups according to valence (positive vs. negative) and arousal level (high vs. low) based on the normative IAPS ratings. IAPS ratings have been validated for experimental use in a Flemish student population (Verschuere, Crombez, & Koster, 2001). Because IAPS ratings differ between men and women, we selected pictures for men and women separately based on the gender-specific ratings provided in the IAPS manual (Lang et al., 1999). This resulted in 10 pictures for each condition and for each gender: (1) high arousal, negative (both threatening and disgusting); (2) low arousal, negative (mostly poverty scenes); (3) high arousal, positive (mainly exciting sports and erotica); (4) low arousal, positive (both nature and family scenes). See Appendix for further information.

These pictures were selected based on two criteria: First, the overall mean of each category for arousal and valence was matched as closely as possible for the corresponding categories. For example, the arousal level of the high arousal, negative category should match the arousal level of the high arousal, positive category but the valence level of the low arousal, negative category. Second, the mean rating of a picture had to approximate the mean rating of its category.

In line with previous studies (e.g., Mogg & Bradley, 2002), we added filler trials with neutral picture cues. The neutral cues had valence ratings near the midpoint of the rating scale. These ratings differed to the same extent from the valence ratings of the selected positive and negative pictures. The mean arousal ratings of the neutral pictures were, however, more similar to those of the low arousal pictures than those of the high arousal pictures (see Appendix). Moreover the number of trials of the neutral cue category was doubled so that cues with a neutral content were presented equally often as cues with a positive respectively negative valence and as high respectively low arousing cues. As such, the data of these trials cannot be used (nor were they intended to be used) as a baseline for assessing the effects of valence and arousal. Because of this, the data of the neutral filler trials were not included in the analyses (but see Table 1 for the relevant means).

Modified Spatial Cueing Task

The experiment was programmed and presented using the INQUISIT Millisecond software package (Inquisit 2.0., 2005) on a Dell Dimension 5000 computer with an 85 Hz, 17-inch CRT monitor. All stimuli were presented against a black background. On every trial, a black fixation cross (5 mm high) placed in the center of a white rectangle (5.2 cm high × 6.3 cm wide) was presented in the middle of the screen. Along with this, two other white rectangles of the same size were presented, one to the left and one to the right of the middle rectangle. The middle of each of these two peripheral rectangles was 9.2 cm from the fixation cross. Cues and targets were presented within the peripheral rectangles. Cues consisted of emotional pictures from the IAPS as described above. The pictures were digitized to a size of 4.8 cm height × 6.2 cm width and were presented in full color. Targets consisted of black squares (0.8 cm × 0.8 cm) presented in the center of the rectangles on the left or right side. Responses were made by pressing one of two keys (target left: "*q*"; target right: "*5*") with the left and right index finger on an AZERTY keyboard.

As can be seen in Figure 1, each sequence of a test trial started with the presentation of the fixation cross and the white rectangles.

Table 1
Mean Reaction Times and Standard Deviations (in ms) as a Function of Cue Category and Cue Validity

	Valid		Invalid		Cue validity indices	
Cue category	*M*	*SD*	*M*	*SD*	*M*	*SD*
Highly arousing, negative	364	48	403	53	39	31
Highly arousing, positive	364	49	401	56	37	36
Low arousing, negative	370	47	395	60	25	32
Low arousing, positive	364	51	395	52	31	30
Filler	366	48	399	53	33	26

Note. Cue validity indices were calculated by subtracting mean reaction times on valid trials from mean reaction times on invalid trials.

After 500 milliseconds, a cue appeared for the duration of 150 milliseconds. Target onset followed immediately after cue offset. A trial ended after a response was registered or 1,500 milliseconds had elapsed since the onset of the target. The next trial started after a pause of 200 milliseconds.

On 75% of the test trials, the cue correctly predicted target location (validly cued trials). On the remaining 25% of the test trials, cue location incorrectly predicted target location (invalidly cued trials). To control for responses to cues instead of targets, catch trials were presented. On these trials, the cue was not followed by a target and no response was required. To ensure that participants maintained fixation at the middle of the screen, digit trials were presented. On these trials, the fixation cross was followed only by a randomly selected digit between 1 and 9 for a duration of 50 milliseconds. Participants were instructed to report the digit aloud. Responses were not recorded on digit trials.

Procedure

Instructions and practice phase. Participants were informed that an attentional task would be presented, and gave a written informed consent. They were seated approximately 60 cm from a computer screen. All further instructions were presented on the computer screen. Participants were asked to respond as quickly and accurately as possible to the location of the target by pressing the corresponding key. They were informed that a cue would precede the presentation of the target and that the cue would correctly predict the location of the target on most but not on all trials. Participants were instructed to maintain attention at the fixation cross. Participants practiced the attentional task during 12 trials.

Test phase. This phase consisted of 216 trials. These were 192 test trials (32 trials for each of the four cue categories with an emotional picture as cue and 64 trials with a neutral picture as cue), 20 catch trials, and 4 digit trials. During the task, each emotional picture was presented three to four times and each neutral picture was presented six to seven times. The order of trials was determined randomly and for each participant separately.

Results

Data Preparation

Data from one participant were removed because she gave an incorrect response on more than 25% of the trials. Trials with errors were also removed (1.29%). In line with previous studies using this modified version of the spatial cueing paradigm (Koster et al., 2004), reaction times (RTs) shorter than 150 milliseconds and longer than 750 milliseconds were excluded from the analysis (1.05%). Means and standard deviations can be found in Table 1.

During the test phase, participants responded on 9.21% of the catch trials. The mean number of responses on highly arousing (3.53%) and low arousing cues (3.45%) catch trials did not differ significantly ($t < 1$), suggesting that the arousal value of the cues was not associated with a systematic response bias.

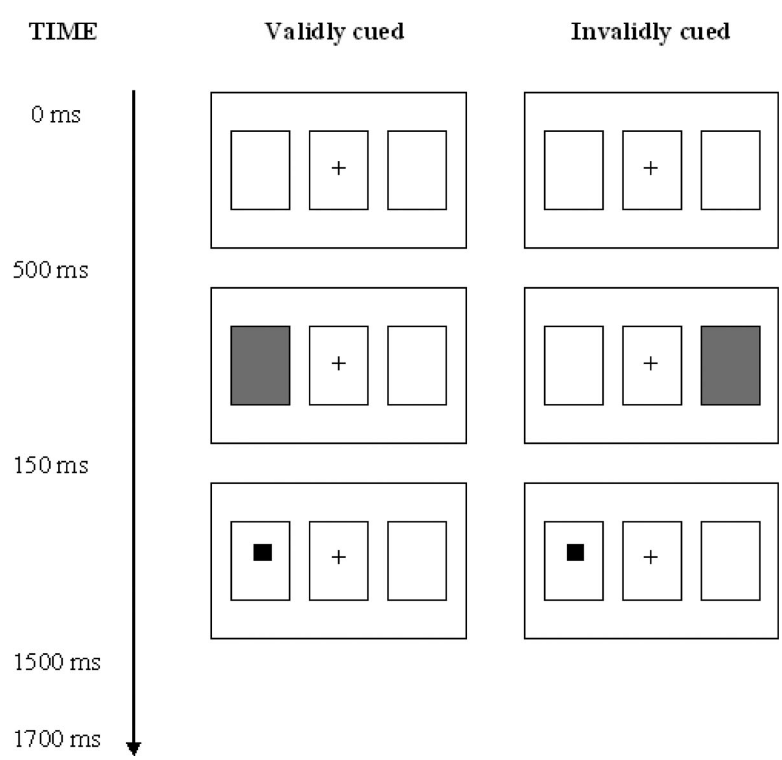

Figure 1. Schematic overview of valid and invalid trials. Cues consisted of pictures. (Note that the target was present incorrectly at the depiction of the invalid trial).

Overall Effects

We performed a 2 (valence: positive, negative) $\times$ 2 (arousal: high, low), $\times$ 2 (cue validity: valid, invalid) repeated measures analysis of variance (ANOVA) on the RTs with gender as between-subjects factor.[1] Cohen's *d* was calculated to see if the expected differences had a small (.20), medium (.50) or large (.80) effect size (Cohen, 1992). There was a strong effect of cue validity, $F(1, 50) = 106.75$, $p < .001$. Responses were significantly faster on validly cued trials ($M = 366$ ms, $SD = 47$ ms) than on invalidly cued trials ($M = 399$ ms; $SD = 52$ ms). The main effects of arousal and valence did not reach significance, $Fs < 1.53$.

The predicted interaction of cue validity and arousal, $F(1, 50) = 8.03$, $p < .01$, $d = .59$, showed that the cue validity effect was larger for highly arousing than for low arousing cues. The interaction between cue validity and valence did not reach significance, $F < 1$, neither did the three-way interaction between cue validity, valence, and arousal, $F < 1.27$.[2]

Planned comparisons revealed that on valid trials, participants responded as fast after highly arousing ($M = 364$ ms; $SD = 47$ ms) than after low arousing cues ($M = 367$ ms; $SD = 48$ ms), $F(1, 51) = 2.41$, *ns*, $d = .30$. On invalid trials, participants reacted significantly slower after highly arousing cues ($M = 402$ ms; $SD = 52$ ms) than after low arousing cues ($M = 395$ ms; $SD = 54$ ms), $F(1, 51) = 5.90$, $p < .02$, $d = .48$. This indicates delayed disengagement of attention from the highly arousing pictures.

Discussion

The aim of this study was to examine whether the valence or arousal level of emotional pictures modulates the allocation of spatial attention. Results can be readily summarized: We found delayed disengagement of attention from highly arousing pictures independent of their valence. There was no effect of gender. Herewith our data replicate and extend the findings of Schimmack (2005) who demonstrated that highly arousing pictures interfere with performance on a nonemotional primary task. Our data go beyond those of Schimmack (2005) in two important ways. First, in our study, the effect of arousal on the deployment of attention cannot easily be explained in terms of response effects. Second, our data provide the first evidence regarding the effect of arousal and valence on one important component of attention, namely spatial attention. They highlight that the disengagement component of spatial attention is modulated by arousal.

The results of our study add to recent findings on the effects of highly arousing stimuli. For instance, Most, Smith, Cooter, Levy, and Zald (2007) showed that erotic and aversive pictures cause an attentional blink. It thus seems to be the case that arousal modulates different components of attention (see Posner & Rothbart, 2005, or Luck & Vecera, 2002, for an analysis of the different components of attention). Our data, however, allow only for conclusions regarding the allocation of spatial attention. Nonetheless, the existing findings already challenge theoretical accounts that focus merely on valence as the underlying dimension of attentional biases to emotional stimuli (Larsen, in press; Pratto & John, 1991). In addition, the available data provide an explanation for the fact that attentive processing of threatening information is particularly efficient. Usually, these attentional biases to threat are explained as result of a rough and fast appraisal of threat value (Mogg & Bradley, 1998; Öhman et al., 2001). Findings such as ours suggest that these biases might be driven not by the threat value as such but by the high arousal level of threatening stimuli.

The idea that arousal controls attention is in line with general theories of emotional processing. The work of Lang and colleagues (e.g., Lang et al., 1997) conceptualizes arousal as an indicator of relevant events that should be facilitated by attentional processes for further processing. In line with this reasoning, it has been shown that highly arousing stimuli lead to activation of the amygdala (e.g., Lewis, Critchley, Rothstein, & Dolan, 2007) that has been described as a relevance detector (Sander, Grafman, & Zalla, 2003). Following the relevance hypothesis, it makes sense that highly arousing stimuli lead primarily to a difficulty with disengagement of attention or to interference effects (Schimmack, 2005; Verbruggen & De Houwer, 2007). Holding of attention at a stimulus as well as interruption of ongoing activities allows the organism to further process this stimulus and to decide how it has to deal with it.

The finding that arousal and not negativity accounts for the attentional biases to emotional stimuli also fits well with motivational accounts of attentional biases (Derryberry & Tucker, 1994; Rothermund, Voss, & Wentura, 2008). According to these accounts, a system that responds only to negative events would be maladaptive as functional behavior requires responding also to stimuli offering positive consequences. Because arousal provides an indication of the motivational relevance of both positive and negative stimuli, it allows both kinds of events to grab attention.

Four potential limitations of our study need to be addressed. First, the crucial interaction between cue validity and arousal is of medium size. Such an effect size is comparable to what has been found in other related studies (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Second, the picture sets were not perfectly matched (see Appendix). The arousal level of the low arousing negative pictures was higher than the arousal level of the low arousing positive pictures, $t(9) = 2.82$, $p = .02$, for the male set, and $t(9) = 3.46$, $p < .01$, for the female set. However, this difference could not have produced the crucial interaction between arousal and cue validity. Another problem was that the pleasantness of the positive highly arousing pictures tended to be higher than the valence of the positive low arousing pictures in the male picture set, $t(9) = 2.16$, $p = .059$. However, we also found the significant interaction between arousal and cue validity in the data of the female participants even though this problem was not present in the female picture set, $t < 1$. Third, some of the high arousing positive pictures displayed erotic scenes. Such stimuli could have unique effects on attention. Additional analyses showed, however, that the same effects were obtained when trials with erotic pictures were discarded. Finally, an inspec-

[1] None of the interactions with gender reached significance, $F < 2.01$, and will not be reported further.

[2] We ran the female version of the experiment with an additional sample of 27 female participants. The same crucial interaction of cue validity and arousal was found, $F(1, 26) = 4.20$, $p = .051$. The main effects of arousal and valence, the interaction between cue validity and valence and the three-way interaction between cue validity, arousal and valence were not significant, $Fs < 1$.

tion of Table 1 suggests that the effect of arousal on the cue validity effect was most pronounced for negative pictures cues. This could indicate that the effect of arousal is not fully independent of valence.[3] Such a conclusion is, however, premature. The fact that the three-way interaction between valence, arousal, and cue validity was not significant shows that the effect of arousal on cue validity was not significantly different for negative than for positive cues. Nevertheless, future research should consider the possibility that the impact of arousal on spatial attention is more pronounced for negative stimuli than for other stimuli.

In conclusion, the present study is the first one to show that the arousal level of emotional stimuli modulates the allocation of spatial attention independent of the valence of these stimuli. Future research is needed to further examine the influence of arousal on other attentional processes (Luck & Vecera, 2002; Posner & Rothbart, 2005) and to explore the possibility of a functional relation between arousal, relevance, and attentional processing.

[3] One reviewer noted that the mean reaction times after filler cues did not seem to differ from the mean reaction times after highly arousing cues (see Table 1). Because the filler cues were on average less arousing than the highly arousing cues (see Appendix), this finding could suggest that stimuli need to have a valence to find an effect of arousal. However, any comparison between the effects of filler and highly arousing cues should be interpreted with caution because the filler stimuli were presented twice as often as the emotional stimuli.

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Appendix

Overview of the Selected Pictures

An overview of the selected pictures of different subsets for gender, valence and arousal. The mean valence rating and the mean arousal rating of the IAPS pictures are in parentheses.

Female, negative/High Arousal: 1052, 1120, 2730, 3500, 6230, 6313, 6350, 6821, 8230, 8480

(Mean Valence = 2.20; Mean Arousal = 6.98)

Female, negative/Low Arousal: 2490, 2702, 2722, 2800, 3181, 4635, 9090, 9220, 9280, 9830

(Mean Valence = 2.79; Mean Arousal = 4.38)

Female, positive/High Arousing: 2216, 4572, 4660, 5621, 5629, 5910, 8080, 8185, 8190, 8370

(Mean Valence = 7.71; Mean Arousal = 6.50)

Female, positive/Low Arousing: 1610, 1620, 1750, 1812, 2304, 2311, 2360, 2370, 5001, 5982

(Mean Valence = 7.89; Mean Arousal = 3.67)

Female, Filler: 2214, 5510, 5531, 5920, 7006, 7009, 7025, 7034, 7640, 8160

(Mean Valence = 4.90; Mean Arousal = 4.14)

Male, negative/High Arousal: 3500, 3530, 6230, 6260, 6313, 6350, 6821, 9410, 9810, 9250

(Mean Valence = 2.47; Mean Arousal = 6.70)

Male, negative/Low Arousal: 2141, 2590, 2750, 2800, 3181, 9090, 9220, 9280, 9421, 9830

(Mean Valence = 2.70; Mean Arousal = 4.46)

Male, positive/High Arousing: 4002, 4001, 4660, 5621, 5629, 5910, 8080, 8185, 8190, 8370

(Mean Valence = 7.50; Mean Arousal = 6.69)

Male, positive/Low Arousing: 1610, 1620, 1750, 1812, 2170, 2260, 2311, 2360, 2370, 5760

(Mean Valence = 7.19; Mean Arousal = 3.59)

Male, Filler: 1230, 1300, 1301, 1945, 2214, 5510, 7006, 7009, 7034, 7640

(Mean Valence = 4.83; Mean Arousal = 4.04)

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