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Attentional Interference Effects of Emotional Pictures: Threat, Negativity, or Arousal?

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Attentional interference arising from emotional pictures was examined. Participants had to ignore emotional pictures while solving math problems (Study 1, $N = 126$) or detecting the location of a line (Study 2, $N = 60$). Data analyses tested predictions of 3 theories. Evolutionary threat theory predicts interference by snake pictures. Categorical negativity theory predicts interference by negative pictures regardless of their intensity. According to arousal theory, arousal level predicts interference effects. The results supported arousal theory, with the most arousing pictures (strong unpleasant pictures, opposite-sex models) producing the strongest interference. The findings are interpreted in the context of process models of emotions that postulate an initial relevance check before further processing of valence and other appraisal dimensions.

Keywords: emotion, attention, negativity bias, arousal, pictorial stimuli, evolution

The influence of affective stimuli on attention has been investigated in numerous ways. Clinical psychologists have examined the influence of anxiety disorders and depression on attention toward threatening stimuli (e.g., Williams, Mathews, & MacLeod, 1996). Social psychologists have examined the influence of positive and negative traits on attention (e.g., Pratto & John, 1991), and evolutionary psychologists have examined the influence of threatening pictorial stimuli on attention (Öhman, Flykt, & Esteves, 2001). Unfortunately, these research traditions have evolved relatively independently of each other and have produced different theories about the influence of emotion on attention.

Another limitation of many studies (e.g., Pratto & John, 1991; Williams et al., 1996; but see Öhman et al., 2001, for an exception) was the predominant reliance on words as stimuli. Words differ in important ways from other stimuli, and it is uncertain whether the results obtained with words generalize to other stimuli (cf. Constantine, McNally, & Hornig, 2001; Harris & Pashler, 2004; Mansell, Clark, Ehlers, & Chen, 1999). Compared with words, pictures have the advantage of being more ecologically valid than words (Kindt & Brosschot, 1999). Another important difference is that people have encountered words thousands of times. Hence, their meaning may be directly accessible. In contrast, it may be more difficult to process a new picture of a gun or puppy that was never seen before. Consistent with this hypothesis, some studies have reported stronger effects for word stimuli than for pictorial stimuli (Kindt & Brosschot, 1999; Lavy & Van den Hout, 1993; but see Kindt & Brosschot, 1997).

Relatively few studies have examined the influence of affective pictures on attention (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001; Buodo, Sarlo, & Palomba, 2002; Constantine et al., 2001; Kindt & Brosschot, 1997, 1999; Mogg, McNamara, Powys, Rawlinson, Seiffer, and Bradley, 2000; Öhman et al., 2001). Furthermore, the few existing studies have used different sets of stimuli and different measures of attention, so that it is difficult to compare the results across studies. The lack of a sound empirical basis may explain the existence of several contemporary theories with different predictions about the influence of affect on attention. The aim of the present investigations was to provide information about attentional effects of a diverse set of affective pictures within the same experimental procedure. The pictures were selected so that it would be possible to directly compare predictions of the three major theories about the influence of emotion on attention, namely categorical negativity theory (Pratto & John, 1991), evolutionary threat theory (Öhman et al., 2001), and arousal theory (Anderson, 2003; Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, 1995).

Categorical Negativity

Pratto and John (1991) proposed that people constantly evaluate stimuli in their environments and that these evaluations take place automatically, outside of conscious awareness. Furthermore, these evaluations are assumed to be relatively simple, leading to a mere categorical distinction between positive and negative stimuli. Stimuli that are automatically evaluated as negative automatically attract attention because the detection of negative stimuli is more critical for survival than the detection of positive stimuli. Not all negative stimuli threaten survival, but it may have been easier to evolve a simple detection mechanism for all negative stimuli than a specific detector of threatening stimuli.

The categorical negativity theory makes two predictions. First, it assumes that attention is guided by an initial evaluation of valence

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and that only stimuli that are evaluated as negative attract attention. Second, the theory assumes that the automatic evaluation of valence provides only categorical information about valence. That is, the mechanism does not provide information about the degree of unpleasantness along the valence dimension. As a result, mild negative stimuli have the same effect on attention as strong negative stimuli.

Empirical support for categorical negativity theory stems from a set of studies with the emotional Stroop task (Pratto & John, 1991). Trait words (e.g., *honest*, *mean*) were presented in different colors. Participants had to name the color as fast as possible. The studies showed that negative words produced longer response latencies than positive words. In addition, the extremity of negative words had no effect. That is, slightly undesirable words had the same effect on response latencies as extremely undesirable traits. On the basis of this evidence, the authors concluded that "people's attention is drawn to negative information without their intention and the cause of this effect lies in the valence of the traits" (p. 388).

Although Pratto and John's (1991) article is widely cited as evidence for a negativity bias in attention, more recent findings are not always consistent with categorical negativity theory (e.g., Harris & Pashler, 2004; Mackintosh & Mathews, 2003). For example, Mogg et al. (2000) found that more extreme negative pictures attracted more attention than milder ones. Indeed, mild negative pictures did not attract more attention than positive pictures. Other studies have found that some positive stimuli (erotic stimuli) attracted more attention than some negative stimuli (Anderson, 2003; Buodo et al., 2002). Pratto (1994) also found that the negativity bias disappeared when a list of positive words included arousing stimuli (kissing) and concluded that "it remains to be seen whether special classes of positive stimuli (e.g., 'sexy' ones) might also be attention grabbing" (p. 127).

Although the latter studies challenge categorical negativity theory, they were not designed to test the theory and did not systematically manipulate different degrees of valence. Thus, one goal of the present study was to test categorical negativity theory with pictorial stimuli. For this purpose, the stimulus set manipulated the degree of pleasantness and unpleasantness of pictures. Categorical negativity theory makes two predictions. First, all negative pictures should attract more attention than neutral and positive pictures. Second, the degree of unpleasantness of negative pictures should have no influence on attention.

Evolutionary Threat Hypothesis

The evolutionary threat hypothesis is based on the same evolutionary argument made by Pratto and John (1991). Namely, the detection of stimuli that threaten survival has more adaptive value than the detection of other stimuli. However, evolutionary threat assumes that this adaptive pressure has resulted in a specific detection mechanism for stimuli that presented a threat to survival during the history of human evolution. Thus, the evolutionary threat theory makes different predictions than categorical negativity theory about the types of stimuli that influence attention. Namely, the influence of affect on attention should be limited to stimuli that signaled a threat to survival during evolution such as snakes, spiders, or angry faces.

Empirical evidence for evolutionary threat theory stems from studies with a visual search task. In a visual search task, participants have to indicate whether a particular target stimulus (e.g., a snake) is in an array of pictures or not. Participants tend to be faster to find a snake in an array with mushrooms than a mushroom in an array of snakes. Similarly, they are faster to find an angry face in an array of happy faces than vice versa (Hansen & Hansen, 1988; Öhman et al., 2001).

However, studies with other attentional tasks (e.g., emotional Stroop task) sometimes show no differences between evolutionary threat stimuli and other stimuli. For example, Constantine et al. (2001) used a pictorial version of the emotional Stroop task and found that both snakes and bunnies produced longer response latencies than cow pictures, and there was no significant difference between snakes and bunnies. Other studies also failed to find evidence that pictures of snakes or spiders attract more attention than neutral pictures in low-phobic individuals (Kindt & Brosschot, 1997; Thorpe & Salkovskis, 1998) or even in phobic participants (Kindt & Brosschot, 1999; Lavy, Van den Hout, & Arntz, 1993; Merckelbach, Kenemans, Dijkstra, & Schouten, 1993).

One aim of the present studies was to compare evolutionary threat stimuli with other affective stimuli within the same study. For this purpose, the stimulus set included pictures of snakes. Evolutionary threat theory predicts that snake pictures attract more attention than other pictures. It makes no predictions about the influence of other affective stimuli on attention.

Arousal Hypothesis

An extensive research program by Lang and colleagues has examined experiential, behavioral, and physiological responses to affective pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Bradley et al., 2003; Keil et al., 2002; Lang, 1995; Lang, Greenwald, Bradley, & Hamm, 1993). The evidence suggests that responses to affective pictures form two factors that vary with the level of valence and the level of arousal of the pictures. Some indicators, such as experiences of pleasure and displeasure, facial expressions, the startle probe, and heart rate, vary with the valence of the picture. In contrast, interest ratings, voluntary exposure, skin conductance, the magnitude of initial heart rate deceleration after picture onset, the P300 in the event-related potential, and activation in the occipital cortex in functional magnetic resonance imaging scans vary with the arousal level of pictures.

It is possible to link the correlates of arousal to attention. For example, interest ratings are likely to be related to attention because people attend more to interesting stimuli in their environments. Voluntary exposure is the second important variable. Participants were allowed to watch pictures as long as they wanted. Participants chose to look longer at arousing pictures independently of their valence. That is, participants chose to look for a longer time at both erotic stimuli and gory pictures of mutilated bodies (Lang et al., 1993). Other studies suggest that arousal is also linked to attention when people are not voluntarily allocating attention to emotional stimuli. Gronau, Cohen, and Ben-Shakhar (2003) found that skin conductance, another correlate of arousal (Lang et al., 1993), was related to interference effects in the emotional Stroop task. Personally relevant words delayed response latencies in the emotional Stroop task and elicited a stronger skin conductance response than control stimuli.

Anderson (2003) provided further evidence for the importance of arousal in predicting performance on an attentional task, using the attentional-blink paradigm. In this paradigm, stimuli are presented in a rapid sequence. Each word is presented for 100 ms. Participants have to detect two words that are marked by a specific color and report the two target words after all stimuli are presented. *Attentional blink* refers to the phenomenon that people are often unable to report the second target if it is presented 200–500 ms after the first target. Anderson demonstrated that the attentional blink is attenuated if the second target is an affective word. Importantly, the affective modulation of the attentional blink was related to the arousal level of the word rather than to its valence.

In summary, several independent lines of research suggest that the arousal level of emotional stimuli is closely linked to the influence of emotional stimuli on attention. Furthermore, studies that seem to support the negativity bias theory or the evolutionary threat theory often failed to control for arousal. As negative stimuli and threatening stimuli tend to be more arousing than other stimuli (Lang et al., 1993), it is possible that the significant effects in these studies were also the result of arousal.

To test arousal theory, all stimuli were rated on arousal. In addition, pictures of attractive male and female models were added to the stimulus set. These pictures fulfilled several important purposes. First, arousal is strongly correlated with the degree of unpleasantness of negative pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang et al., 1993). That is, mild unpleasant pictures are less arousing than moderate unpleasant pictures, and strong unpleasant pictures are more arousing than moderate unpleasant pictures. Thus, it is virtually impossible to separate arousal from degree of unpleasantness. However, for positive pictures, the correlation between arousal and extremity of valence is weaker (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang et al., 1993). In particular, sexual pictures are more arousing than other pleasant pictures (e.g., a tropical beach). Thus, sexual pictures are needed to separate effects of arousal from effects of valence. Second, sexual stimuli provide an opportunity to rule out several artifacts that may arise from the use of ready-made stimuli that vary in other characteristics (e.g., familiarity, distinctiveness, complexity) that may influence attention (Harris & Pashler, 2004). For model pictures, arousal effects and artifacts should produce different effects. Whereas arousal effects should depend on the match or mismatch of participants' sex and sex of model, artifacts should produce main effects of the stimulus materials. As a result, only arousal predicts stronger effects for pictures of opposite-sex models than for pictures of same-sex models.

In summary, arousal theory predicts that affective influences on attention can be predicted by arousal ratings of affective pictures. On the basis of previous studies of arousal, arousal theory also predicts the strongest effects for strong unpleasant pictures and pictures of opposite-sex models because these pictures elicit the highest level of arousal (Bradley, Codispoti, Cuthbert, & Lang, 2001).

Attention

Most of the research on emotion and attention has focused on involuntary[1] processes rather than voluntary allocation of attention. Besides the distinction of voluntary and involuntary allocation of attention, Posner and Peterson (1990) distinguished three major components of attention, namely alerting, orienting, and executive control. *Alerting* refers to nonselective modulation of attention that enhances performance on sensory processing tasks (e.g., better performance after a warning cue). The orienting component is responsible for the shifting of attention to a new location. The executive control component is involved in resolving conflicting demands on attention and inhibiting dominant response tendencies.

Some studies have failed to demonstrate effects of emotional stimuli on orienting or shifting of attention (Fox, 1994; Gronau et al., 2003; White, 1996; but see Öhman et al., 2001). In contrast, there is considerable evidence that emotional stimuli produce interference effects when they are competing with other stimuli for attentional resources (Anderson, 2003; Buodo et al., 2002; Gronau et al., 2003; Pratto & John, 1991). Thus, the present article focused on the influence of emotional pictures on the executive control component of attention.

The most widely used task for the study of emotional influences on executive control processes is the emotional Stroop task (Pratto & John, 1991; Williams et al., 1996). In this task, executive control processes are needed to focus attention on the task-relevant attribute (color) and to ignore task-irrelevant attributes (e.g., emotional significance, personal relevance). Importantly, the nature of the primary task (i.e., color naming) is irrelevant (Harris & Pashler, 2004). As color naming is impractical in a study with colored pictorial stimuli, I used a different primary task to study interference by emotional pictures. In the first study, I asked participants to solve simple math problems that were presented in front of pictures. In the second study, participants had to detect a line that appeared above or below pictures. The logic of these tasks is the same as in the emotional Stroop task: Slower responses suggest that an emotional picture interfered with the voluntary allocation of attention to the primary task. The main purpose of the present studies was to determine the affective attribute of emotional pictures that predicts interference effects. Evolutionary threat theory predicts that evolutionary threat stimuli (snakes) produce more interference than other pictures. Categorical negativity theory predicts that negative pictures produce more interference than other pictures and that there are no differences between negative pictures. Arousal theory predicts that interference increases with the arousal level of emotional pictures.

Study 1

Study 1 used 12 types of pictures (5 pictures for each type) to manipulate the level of valence, level of arousal, and evolutionary threat value. Seven types manipulated different degrees of valence from extreme displeasure to extreme pleasure. There were three degrees of pleasantness, three degrees of unpleasantness, and one set of neutral pictures. An eighth set included pictures of snakes

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[1] Many researchers in this field assume that the influence of emotional stimuli on attention is automatic. However, most tasks, including the tasks in these studies, are unable to distinguish automatic from controlled processes (Matthews & Wells, 2000; Pashler, 1998). Thus, I use the term *involuntary* allocation of attention in this article, which I define as the allocation of attention to a stimulus without a participant's intention to do so (Pratt & Hommel, 2003).

because they have been used in previous tests of evolutionary threat theory (Öhman et al., 2001).

The large number of picture types may produce spurious findings. However, the test of the competing theories requires only a few planned comparisons. Categorical negativity theory predicts that all negative pictures produce interference effects, and the other pictures do not. Furthermore, the effect should be the same for all negative pictures. This prediction was tested with a simple contrast between negative and non-negative pictures. Evolutionary threat theory predicts that snake pictures produce more interference effects than other pictures, and it predicts no differences between other pictures. This prediction was tested with a simple contrast between snake pictures and all other pictures. Arousal theory predicts that interference effects vary with the arousal level of picture types. This prediction was tested with arousal ratings as continuous predictor of interference effects.

Method

Participants

All participants were first-year psychology students at the University of Toronto, Ontario, Canada, Mississauga, who participated for course credit. The average age was typical for a student sample ($M = 20$). The total sample consisted of 126 students (63 women and 63 men). Students participated in slight variations of the study, which manipulated the stimulus onset asynchronies (SOA) between the onset of the affective picture and the onset of the math problem.[2] The datasets were combined because the main focus of this article is on the type of affective pictures that attract attention and because a combined analysis has more power than separate analyses of each dataset.

Materials

Pictures were obtained from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) and from additional sources if appropriate stimuli were missing in the IAPS. All pictures were edited to fit the same size (10 in. [25.4 cm] wide and 15 in. [38.1 cm] tall). The fitting slightly altered the content of some IAPS pictures. All pictures were rated on valence in several pilot studies. These pilot data were used to find pictures for the seven sets that manipulated degree of valence. For the present study, pictures were selected on the basis of two criteria. First, the mean rating of a picture had to be close to the mean level of valence of its group. For example, neutral pictures were selected to have a mean rating close to the mean of the neutral pictures (i.e., 0). Second, pictures had to have small standard deviations to reduce the influence of individual differences. It is noteworthy how these criteria influenced the types of pictures in the seven sets that manipulated degree of valence. First, the picture set did not include erotic stimuli, which tend to produce large gender effects and variability in responses. Second, the picture set did not include some of the most unpleasant IAPS pictures (mutilations) because the picture set did not include sufficiently strong pleasant pictures to match the intensity of these unpleasant pictures. Third, the picture set did not include pictures of snakes or spiders because there are large individual differences in the affective responses to the pictures.

The selected pictures had the following content: Neutral pictures were a hairdryer, a car wheel, a rolling pin, a light bulb, and a pipe. Mild pleasant pictures were an old man with a white beard, brownies, a tower, a pagoda, and Hindu temples. Moderate pleasant pictures were a duck with duckling, a beach, a cherry tree, a white rabbit, and a meadow with sheep. Strong pleasant pictures were a beach with palm trees, a sunset, a kitten, a baby, and a sunset on a beach. Mild unpleasant pictures were an angry man, a crying boy, a rundown housing complex, a trash can, and dead fish. Moderate unpleasant pictures were a gun (not pointed at viewer), a prison cell, a dead fish carcass, garbage in a street, and a dirty canister. Strong unpleasant pictures were a gun pointed at viewer, a battered woman, a dead dog, a shark, and a drug addict with syringes. Three of the five snake pictures showed snakes' bodies with their heads toward the camera. The other two pictures showed a close-up of a snake's head ready for attack. Pictures of attractive models were obtained from a pilot study, in which the models were rated on attractiveness by male and female participants. Pictures of male and female models were matched on attractiveness. For each sex, five pictures showed only models' faces, and five pictures showed faces and bodies in swimwear or underwear. Face pictures were included to examine whether attractive faces would be sufficient to produce an interference effect.

To assess the arousal level of the pictures, 20 male and 20 female participants in a pilot study saw all pictures on a computer screen for 2 s and rated their affective reaction on the affect grid (Russell, Weiss, & Mendelsohn, 1989). The x-axis of the grid was labeled *unpleasant to pleasant*. The y-axis was labeled *aroused-sleepy*. The diagonals were labeled *tense-relaxed* and *excited-bored*. Participants responded by a mouse click in 1 of the 81 squares of the grid, with nine levels of valence and nine levels of arousal. The results of the pilot study are shown in Table 1.

Procedure

The studies were conducted in groups of 1–4 participants. Each participant was seated in a separate cubicle in front of a computer. Written instructions informed them that they had to solve simple math problems. The problems consisted of two products of single digits (e.g., 3×5). Participants had to determine as fast as possible which of two products was larger (e.g., $3 \times 5 <> 2 \times 8$). They were also instructed to ignore the pictures. Each trial started with a red square presented for 250 ms, which signaled the beginning of a trial. Afterward, the picture and the math problem were presented with varying SOAs (see the *Participants* section). The math problem was presented in black letters on a white background in the middle of the picture. The math problem was 4.67 in. (11.86 cm)

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[2] Forty-six students had a fixed SOA of 300 ms. Forty-two students had a variable SOA of 0 ms, 200 ms, and 400 ms. Thirty-eight students had variable SOA of -200 ms (math problem before picture), 0 ms, and 200 ms. The purpose for the manipulations of SOAs was to examine the time course of emotional effect on attention. SOA had a main effect on participants' performance because of shorter delays with increasing SOAs. The largest interference effect was observed for SOAs of -200 ms, when the emotional picture appeared after the math problem. The weakest effect was obtained when the math problem was presented 400 ms after the onset of the picture. However, no significant interactions between SOAs and type of picture were obtained.

Table 1
Predictor Variables for Studies 1 and 2

Variable	ET	CN	AR	VAL
Picture type				
Neutral	0	0	−1.43	−0.63
Snakes	1	1	1.45	−2.41
Strong unpleasant	0	1	1.35	−2.92
Moderate unpleasant	0	1	0.38	−2.14
Mild unpleasant	0	1	−0.43	−1.61
Mild pleasant	0	0	−0.27	0.84
Moderate pleasant	0	0	−0.47	1.70
Strong pleasant	0	0	−0.22	2.55
Same-sex bodies	0	0	−0.69	−0.22
Same-sex faces	0	0	−0.36	0.16
Opposite-sex bodies	0	0	2.11	1.67
Opposite-sex faces	0	0	1.69	1.16
Correlation among predictors				
ET	—			
CN	.43	—		
AR	.34	.28	—	
VAL	−.39	−.87	−.10	—

Note. ET = contrast for evolutionary threat theory; CN = contrast for categorical negativity theory; AR = standardized arousal scores based on pilot study; VAL = standardized valence scores based on pilot study.

wide and 0.83 in. (2.11 cm) tall. The pictures and the math problem remained on the screen until the participants responded or the computer terminated trials 4 s after the onset of the math problem.

A new math problem was generated for each trial by randomly selecting four digits in the range from 1 to 9 (e.g., 1 × 5 vs. 6 × 9). If the two products happened to be identical, the computer generated a new problem until the products were no longer identical. Participants responded using Microsoft Wheel Mouse Optical mice, which were connected to the computer via a USB port. Participants pressed the left or the right mouse button to indicate whether the left or the right product was larger. The experiment started with four practice trials with neutral pictures that were not included in the stimulus set. Each picture was presented three times, for a total of 180 experimental trials.

Results

Response Latencies

Exploratory analyses revealed that participants became increasingly faster over the course of the experiment. In addition, the difficulty of the math problem (the difference between the two products) had a significant effect on their performance. Furthermore, SOA had a significant main effect on response latencies (see Footnote 1). To eliminate these sources of variance, response latencies were regressed onto SOA, trial number, and problem difficulty. The unstandardized residuals were retained for the main analyses. For the model pictures, males' response times for female models and females' response times for male models were assigned to a common variable (opposite-sex model). Similarly, males' response times for male models and females' response times for female models were assigned to a common variable (same-sex model).

The response latencies were first analyzed using traditional analysis of variance (ANOVA). Subsequently, the data were analyzed with hierarchical linear modeling (HLM) to examine how well the predictors in Table 1 explain variation in response latencies across picture types. To perform these analyses, I used HLM5 (Raudenbush, Bryk, Cheong, & Congdon, 2000). One major advantage of HLM over ANOVA is that it is possible to use categorical as well as continuous predictors, which allows a direct quantitative comparison of the categorical predictions of evolutionary threat theory and categorical negativity theory with the continuous arousal predictor.

The first ANOVA addressed the simple question of whether type of picture had any effect on response latencies and whether sex of participants interacted with type of picture. An ANOVA, with sex of participant as the between-subjects variable and picture type (12 types) as the within-subject variable, revealed a main effect of sex, $F(1, 124) = 5.30$, $p < .05$, $\eta^2 = .04$; a main effect of picture type, $F(11, 1364) = 11.60$, $p < .01$, $\eta^2 = .09$; and a significant interaction, $F(11, 1364) = 3.97$, $p < .01$, $\eta^2 = .03$. Figure 1 shows males' and females' response latencies for the 12 types of pictures. A casual inspection of the data pattern shows that evolutionary threat theory and categorical negativity theory are inconsistent with some of the findings, in particular the strong interference effects for opposite-sex models. The following analyses provide a more thorough assessment of the data pattern by means of HLM.

Omnibus test and test of individual contrasts. The first HLM analysis focused on the main effect for picture type that was revealed in the ANOVA. To examine the contribution of individual picture types to the overall effect, I computed a model with 11 dummy variables that contrasted each picture type with the neutral pictures. HLM5 estimates a fixed effect for each dummy variable that can be directly interpreted as the difference in response latencies between a particular picture type and neutral pictures. In addition, HLM5 offers the possibility of testing the overall significance of the model compared with the null hypothesis that response latencies do not vary systematically with picture type. This omnibus test is equivalent to the ANOVA results presented above.

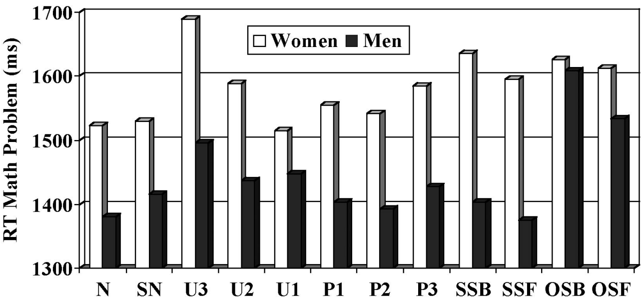

Figure 1. Mean response latencies for male and female participants in Study 1. RT = response time; ms = millisecond; N = neutral; SN = snakes; U3 = strong unpleasant; U2 = moderate unpleasant; U1 = mild unpleasant; P1 = mild pleasant; P2 = moderate pleasant; P3 = strong pleasant; SSB = same-sex bodies; SSF = same-sex faces; OSB = opposite-sex bodies; OSF = opposite-sex faces.

Not surprisingly, the test also rejected the null hypothesis, $\chi^2(11) = 89, p < .0001$. More importantly, the model revealed that 7 of the 11 contrasts were significant (see Table 2). The strongest effects were obtained for strong unpleasant and opposite-sex model pictures. The next HLM analyses directly tested the ability of the various theories to predict the significant variation in response latencies by picture type.

Evolutionary threat theory. To test evolutionary threat theory, I used a direct contrast between evolutionary threat pictures and all other pictures as a Level-1 predictor in an HLM analysis.

$$\text{Formula: Response latencies} = \gamma_{00} + \gamma_{01}\,\text{D[SN]} + \text{R} \quad (1)$$

D[SN] represents the contrast between snake pictures and all other pictures (see Table 1). The model revealed a significant effect for γ_{01}, $t(125) = 3.16$, $p < .01$; but the effect is in the opposite direction than the one predicted by evolutionary threat theory (−44 ms). The effect is negative in this model because it compares evolutionary threat stimuli with the average latency for all other conditions rather than just neutral pictures. As some picture types produced significantly longer latencies than neutral pictures, response latencies for evolutionary threat pictures were significantly faster than the latencies for the average of all other picture types.

Categorical negativity theory. The test of categorical negativity theory followed the same procedure. The model predicted response latencies from a dummy variable that contrasted all negative picture types (mild, moderate, strong unpleasant, and snakes) with all other picture types (D[NEG]).

$$\text{Formula: Response latencies} = \gamma_{00} + \gamma_{01}\,\text{D[NEG]} + \text{R} \quad (2)$$

The model revealed no significant effect for the difference between negative and non-negative pictures for γ_{01}, $t(125) = 0.20$, $p > .50$; and the estimated parameter value for γ_{01} was close to zero (2 ms). Thus, the data show no categorical attentional bias for negative pictures. The same result was obtained, when the continuous valence scores (see Table 1) were used as predictors (γ_{01} = 3 ms). Thus, the results fail to support a general negativity bias in response latencies.

Arousal theory. To test the arousal theory, the pilot ratings on the arousal dimension of the affect grid were used as predictor variables (see Table 1). Male ratings were used for male participants, and female ratings were used for female participants.

$$\text{Formula: Response latencies} = \gamma_{00} + \gamma_{01}\,\text{AROUSAL} + \text{R} \quad (3)$$

The model showed a significant effect for arousal, $t(125) = 7.11$, $p < .001$. The estimate for γ_{01} was 40 ms. This means that each increase in arousal by one standard deviation prolongs response latencies by 40 ms. The effect size of the effect of arousal can be computed by comparing the residual Level-1 variance in a model without arousal (VAR = 34,116) with the residual variance in the model with arousal as a predictor (VAR = 29,484) (Nezlek, 2001). Arousal leads to a 14% reduction in variance, which translates into an effect size of $r = .37$.

Combined analysis. It is possible that the evolutionary threat theory and the categorical negativity theory are incomplete theories. That is, they may explain some aspects of the contribution of emotion to attention, whereas other processes produce additional effects. To test these weaker versions of the two theories, I examined a model that included the contrast between evolutionary threat pictures and other pictures, the contrast between negative and other pictures, and arousal as predictors.

$$\text{Formula: Response latencies} = \gamma_{00} + \gamma_{01}\,\text{AROUSAL} + \gamma_{02}\,\text{D[NEG]} + \gamma_{03}\,\text{D[SN]} + \text{R} \quad (4)$$

The model produced similar results for arousal (γ_{01} = 49 ms) and categorical negativity (γ_{03} = −3 ms), but the estimate for evolutionary threat stimuli became even stronger in the opposite direction, predicted by evolutionary threat theory (γ_{01} = −106). The reason for the change in the fixed effect for snake pictures is the high arousal rating for snake pictures (see Table 1). On the basis of the arousal ratings, evolutionary threat stimuli should have produced significantly longer latencies simply because these stimuli are arousing. Thus, the failure of snake pictures to produce significantly longer latencies than neutral pictures is a problem not only for the evolutionary threat theory but also for categorical negativity theory and arousal theory.

Sex differences. The initial ANOVA revealed an interaction between sex and picture type. To test the nature of this interaction, I computed a model with the 11 dummy variables for picture type and an intercept as Level-1 variables. Each Level-1 parameter was moderated by sex as a Level-2 variable.

The model revealed the following effects for sex: First, sex moderated the intercept, indicating that men were on average 148 ms faster than women, $t(125) = 2.36$, $p < .05$. Second, the model revealed that sex moderated the effect of model pictures, but none of the effects for nonmodel pictures was significant. Women's delays for same-sex bodies (112 ms) and same-sex faces (72 ms) were significantly longer than those for men (23 ms, −6 ms), ts > 2, $p < .05$. In contrast, men's delay in response latencies for opposite-sex bodies (227 ms) was significantly longer than the women's delay (103 ms), $t(124) = 2.19$, $p < .05$. For faces, the difference between men's delay (153 ms) and women's delay (89 ms) did not reach significance, $t(124) = 1.52$, $p = .13$. These findings suggest that opposite-sex models produced more interference for men than for women, whereas same-sex models produced more interference for women than for men. However, the results are not conclusive because they can also be due to a general effect

Table 2
Fixed Effects of Dummy Variables Contrasting Each Picture Type With Neutral Pictures (Study 1)

Variable	Effect (ms)	t	p
Intercept	1,452	47.17	<.001
Snakes	20	1.06	.289
Strong unpleasant	141	5.75	<.001
Moderate unpleasant	60	2.89	.004
Mild unpleasant	29	1.49	.136
Mild pleasant	27	1.37	.171
Moderate pleasant	15	0.90	.369
Strong pleasant	54	2.59	.010
Same-sex bodies	68	3.26	.002
Same-sex faces	34	2.22	.027
Opposite-sex bodies	165	5.72	<.001
Opposite-sex faces	121	5.72	<.001

of stimulus materials that were not controlled between pictures of male models and female models. However, the present results for opposite-sex models are consistent with a general trend for men to respond more strongly to sexual stimuli than women (Baumeister, Catanese, & Vohs, 2001). The effect for same-sex models may be due to women's tendency to use models as social comparison standards (Mills, Polivy, Herman, & Tiggeman, 2002).

Accuracy

One concern regarding response latencies is the possibility of a speed–accuracy trade-off. To examine this possibility, I examined the percentages of accurate responses for each picture type. Participants responded correctly on 93% of the trials. An ANOVA, with sex of participants as the between-subjects variable and picture type as the within-subject variable, revealed no significant effects of sex, $F(1, 124) = 0.02$, $p > .50$, $\eta^2 = .00$, no significant effect of picture type, $F(11, 1364) = 1.37$, $p > .15$, $\eta^2 = .01$, and no significant interaction, $F(11, 1364) = 0.83$, $p > .50$, $\eta^2 = .01$. Thus, response latencies were not influenced by a speed–accuracy trade-off.

Discussion

Study 1 examined the influence of emotional pictures on attention. The results can be summarized as follows: First, the pattern of response latencies revealed that strong unpleasant pictures and pictures of opposite-sex models produced the longest delays. This finding is consistent with previous studies that also found strong effects for sexual stimuli (Buodo et al., 2002; Pratto, 1994) and stronger effects for strong unpleasant compared with moderately unpleasant pictures (Mogg et al., 2000). Second, evolutionary threat theory and categorical negativity theory failed to predict the data pattern. In contrast, arousal theory was able to predict 14% of the variance in response latencies. One unexpected finding was the lack of a significant difference between neutral and snake pictures. All three theories predict a difference between these stimuli because snakes posed a threat to survival during evolution and are rated as negative and arousing.

Study 2

One concern about the previous study was the complexity of the cognitive task. To solve the math problems, participants had to not only attend to the math problem but also compute products, store the results in short-term memory, and compare them with each other. It is possible that affective pictures interfered with working and short-term memory processes rather than with visual attention to the display of the math problem. To address this concern, Study 2 used a simpler cognitive task. Specifically, a line was displayed either at the top or at the bottom of the affective pictures. The task was to report as quickly as possible the location of the line. This task also had the additional advantage of the display of the target stimulus not interfering with the presentation of the emotional stimulus. In the previous study, the math problem partially covered the emotional picture, and it is possible that this procedure interfered with the processing of the emotional content.

Method

Participants

Sixty (30 men and 30 women) students from the same population as in Study 1 participated for course credit.

Materials

The same pictures were used as in Study 1.

Procedure

The procedure was identical to the procedure in Study 1 with the exception of the main task. For each trial, the location of a black line was randomly determined. The line either appeared 0.55 in. [1.40 cm] above or below the affective picture. The line was 2.78 in. [7.06 cm] long and 0.03 in. [0.08 cm] high. The background of the screen was a light gray. The line appeared with varying SOAs (0 ms, 200 ms, and 400 ms). The SOA was manipulated for two reasons. First, Study 1 used presentations with varying SOAs, and Study 2 was designed to be identical to Study 1, except for the behavioral task. Second, varying SOAs are important to reduce expectancy effects. That is, line detection may be easy if the line always appears after a fixed interval of the onset of the picture. Each of the 60 pictures was fully crossed with the three SOAs for a total of 180 experimental trials. Participants were instructed to indicate as fast as possible whether the line appeared on the top, by pressing the left mouse button, or at the bottom, by pressing the right mouse button.

Results

Analyses of response latencies are based only on trials with correct responses. Overall, response latencies were much faster ($M = 520$ ms) in Study 2 than in Study 1 ($M = 1{,}513$ ms). The faster responses in Study 2 demonstrated that the detection of lines was indeed a simpler task than the solving of math problems in Study 1. Responses to the five pictures from each set were averaged (see Figure 2). The data analyses followed the same procedure as in Study 1, starting with the traditional ANOVA and followed by HLM analyses to test more specific patterns in the data. The ANOVA revealed no significant main effect for sex ($F <$

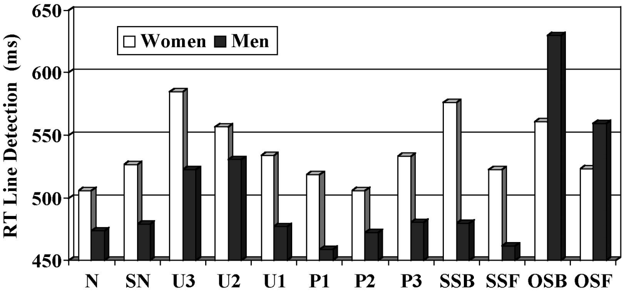

Figure 2. Mean response latencies for male and female participants in Study 2. RT = response time; ms = millisecond; N = neutral; SN = snakes; U3 = strong unpleasant; U2 = moderate unpleasant; U1 = mild unpleasant; P1 = mild pleasant; P2 = moderate pleasant; P3 = strong pleasant; SSB = same-sex bodies; SSF = same-sex faces; OSB = opposite-sex bodies; OSF = opposite-sex faces.

1), indicating that the line-detection task was more gender neutral than the math task in Study 1. The ANOVA replicated a significant main effect for picture type, $F(11, 638) = 11.97$, $p < .01$, $\eta^2 = .17$, and a significant Picture Type × Sex interaction, $F(11, 638) = 5.57$, $p < .01$, $\eta^2 = .09$.

Omnibus Test and Test of Individual Contrasts

Response latencies were the dependent Level-1 variable. Eleven dummy variables coded the effect of picture type, with neutral pictures as the contrast type. A multivariate test of significance revealed that picture type had a significant effect, $\chi^2(11) = 60.76$, $p < .01$. Of the 11 contrasts, 5 were significant, and all 5 significant effects were also significant in Study 1 (i.e., strong unpleasant, moderate unpleasant, same-sex bodies, opposite-sex bodies, opposite-sex faces). Thus, the general pattern of response latencies was similar to the pattern in Study 1 (see Table 3).

Evolutionary threat theory. To test evolutionary threat theory, I used a direct contrast between evolutionary threat pictures and all other pictures as a Level-1 predictor. As in Study 1, the model revealed a significant effect for γ_{01}, $t(59) = 2.14$, $p < .05$, and the effect was in the opposite direction than the one predicted by evolutionary threat theory (−18 ms). Thus, the results replicate Study 1 and demonstrate again that evolutionary threat is not a viable explanation for the interference effects of emotional pictures.

Categorical negativity theory. Categorical negativity theory was tested with a dummy variable that contrasted all negative picture types (mild, moderate, strong unpleasant, and snakes) with all other picture types. As in Study 1, the contrast between negative and non-negative pictures was not a significant predictor of response latencies, γ_{01}, $t(59) = 1.61$, $p > .10$. The estimated parameter for γ_{01} was 10 ms. Thus, the data replicate the finding of Study 1 that negative pictures did not produce categorically longer response latencies than other pictures.

Arousal theory. To test arousal theory, the pilot ratings on the arousal dimension of the affect grid were used as predictor variables. Male ratings were used for male participants, and female ratings were used for female participants. As in Study 1, the model showed a significant effect for arousal, $t(59) = 5.91$, $p < .001$. The estimate for γ_{01} was 24 ms. This means that each increase in arousal by one standard deviation prolongs response latencies by 24 ms. The effect size of the effect of arousal is $r = .50$ ($r^2 = .25$). Thus, Study 2 provides further support for arousal theory.

Table 3
Fixed Effects of Dummy Variables Contrasting Each Picture Type With Neutral Pictures (Study 2)

Variable	Effect (ms)	t	p
Intercept	490	31.30	<.001
Snakes	13	1.54	.129
Strong unpleasant	64	4.70	<.001
Moderate unpleasant	54	4.43	<.001
Mild unpleasant	16	1.99	.051
Mild pleasant	−1	0.18	.861
Moderate pleasant	−1	0.10	.921
Strong pleasant	17	1.63	.108
Same-sex bodies	38	3.38	.002
Same-sex faces	2	0.34	.736
Opposite-sex bodies	105	5.42	<.001
Opposite-sex faces	52	3.16	.003

Combined analysis. As in Study 1, I tested a model with combined predictors for the evolutionary threat, categorical negativity, and arousal theory. This analysis also replicated the findings of Study 1. Namely, arousal remained a significant predictor (28 ms), $t(59) = 5.66$, $p < .01$, and the contrast between snakes and other pictures became an even stronger predictor (−59 ms), $t(59) = 4.65$, $p < .01$. The contrast for the categorical negativity theory remained nonsignificant (7 ms), $t(58) = 0.86$, $p > .30$.

Sex differences. There were no significant sex differences in the intercept, indicating that the line-detection task was not as gender-biased as the math task in Study 1 (females' $M = 506$ ms, males' $M = 447$ ms), $t(58) = 1.02$, $p > .30$. As in Study 1, there were also no sex differences for the nonmodel pictures. As in Study 1, women's delays for same-sex bodies (71 ms) and same-sex faces (17 ms) were significantly longer than those for men (6 ms, −13 ms), $ts(58) > 2$, $p < .05$. In contrast, men's delay in response latencies for opposite-sex bodies (156 ms) and opposite-sex faces (86 ms) were significantly longer than the women's delay (55 ms, 18 ms), $t(58) > 2$, $ps < .05$. Thus, the sex differences in Study 2 were consistent with those in Study 1.

Quantitative comparison with Study 1. I also used the response latencies of Study 1 as a predictor of the response latencies in Study 2 for a quantitative comparison of the two studies.

$$\text{Formula: Response latencies for Study 2} = \gamma_{00} + \gamma_{01}\ \text{Response latencies Study 1} + R \quad (5)$$

The model revealed a significant effect ($\gamma_{01} = 0.52$), $t(59) = 5.91$, $p < .01$, with a large effect size ($r = .61$, $r^2 = .37$). A model with response latencies of Study 1 and arousal as predictors revealed that response latencies of Study 1 were the only predictor with unique variance. As arousal explained 25% of the variance in Study 2 latencies, and all of this variance was shared with Study 1 latencies, the results suggest that arousal explained 66% (24%/36%) of the task-invariant variance in response latencies as a function of picture type.

Accuracy

Participants provided accurate responses on 97% of all trials. An ANOVA, with sex of participants as the between-subjects variable and picture type as the within-subject variable, revealed no significant effects of sex, $F(1, 58) = 2.42$, $p > .10$, $\eta^2 = .04$, no significant effect of picture type, $F(11, 638) = 1.09$, $p > .30$, $\eta^2 = .02$, and no significant interaction, $F(11, 638) = 1.22$, $p > .20$, $\eta^2 = .02$. Thus, it is possible to rule out a speed–accuracy trade-off in Study 2.

Discussion

Study 2 examined whether the results in Study 1, with a complex cognitive task, could be replicated with a simple line-detection task. The results demonstrated that this was indeed the case, as all key findings of Study 1 were replicated in Study 2. Most importantly, evolutionary threat produced a significant effect in the opposite direction predicted by evolutionary threat theory, negative pictures did not have a categorically stronger effect on response latencies, and arousal was a significant predictor of response latencies. Furthermore, arousal explained two thirds of the common variance in response latencies across Studies 1 and 2. Thus, the results support arousal theory, whereas evolutionary threat theory and categorical negativity theory were not supported.

In addition, Study 2 replicated the unexpected finding of Study 1 that snake pictures attracted significantly less attention than predicted by any of the three theories, including arousal theory. This finding is discussed further in the General Discussion section. Study 2 also replicated sex differences in responses to model pictures. Same-sex models produced more interference effects for female participants than for male participants, whereas opposite-sex models produced more interference for male participants than for female participants.

General Discussion

The present article examined a simple, yet important question: Do emotional pictures produce interference in a primary cognitive task, and if so, which attribute of emotional pictures predicts this effect? The present study confirmed results of previous studies that some emotional pictures interfere with performance on a cognitive task (Buodo et al., 2002; Mogg et al., 2000). The types of pictures that produced interference effects were also consistent with previous studies. Namely, strong unpleasant stimuli produced interference, but moderate or mild unpleasant stimuli had a weaker or no effect (Mogg et al., 2000). Sexual stimuli produced a strong effect that matches the effect of strong unpleasant pictures (Buodo et al., 2002). In contrast, evolutionary threat pictures had a much weaker effect that failed to reach significance in the present studies (Merckelbach et al., 1993). Subsequently, I discuss the implications of the results for the three major theories of emotional influences on attention and for process models of emotions.

The Evolutionary Threat Hypothesis

The present study included pictures of snakes and compared the responses to snakes with those for neutral stimuli and other unpleasant stimuli. This approach addresses the limitations of previous studies that have compared the effects of evolutionary stimuli on attention only with neutral stimuli. A comparison of neutral pictures with evolutionary threat pictures provides a weak test of the evolutionary threat theory because snake pictures are also unpleasant and arousing (Kindt & Brosschot, 1999; Lang et al., 1999). Thus, support for the evolutionary threat hypothesis requires not only a demonstration that evolutionary threat stimuli have a significant effect on attention in comparison to neutral pictures but also that evolutionary threat stimuli attract more attention than equally unpleasant or arousing stimuli.

The present results are inconsistent with these predictions of evolutionary threat theory. First, evolutionary threat pictures failed to be significantly different from neutral pictures. It is important to note that several other studies with similar stimuli (snakes or spiders) have failed to find significant differences between neutral and evolutionary threat stimuli (Kindt & Brosschot, 1999; Lavy et al., 1993; Merckelbach et al., 1993). Other studies have found differences between neutral and evolutionary threat stimuli of the same magnitude (~20 ms), and the difference was significant because of larger power (e.g., Thorpe & Salkovskis, 1998). Thus, it is possible that evolutionary threat stimuli have a reliable, yet small effect in comparison to neutral stimuli.

More problematic for the evolutionary threat theory was the finding that other emotional pictures had much larger effects on attention. As a result, a direct test of the evolutionary threat hypothesis showed that the direct contrast of snake pictures and all other pictures produced a significant effect in the opposite direction predicted by evolutionary threat hypothesis. Thus, it is not possible to attribute the null effect for the comparison of snakes and neutral pictures to a lack of power.

One possible explanation for the present findings could be confounding factors of the stimulus materials. For example, snake pictures may have been less complex than other pictures, and complex stimuli may have been more interesting (Berlyne, Ogilvie, & Parham, 1968). I compared the kilobytes of snake pictures and other pictures after extreme compression as a measure of complexity. On average, snake pictures were as complex as female face pictures (21.6k), slightly less complex than female body pictures (23.0k), and slightly more complex than strong unpleasant pictures (17.6kb). Future research with other measures of complexity is warranted, but the present results suggest that responses to snake pictures were not influenced by low complexity.

Another explanation for the failure to support evolutionary threat theory is the distinction between different components of attention. Evolutionary threat may influence orienting of attention because it was adaptive to detect threatening stimuli that are not already attended to. It may have been less important to have a special mechanism for threatening stimuli that are already in the focus of attention such as the stimuli in the present studies. Consistent with this assumption, the strongest support for evolutionary threat stimuli has been obtained with visual search tasks (Öhman et al., 2001). However, some of these studies compared evolutionary threat stimuli with neutral stimuli. Thus, it remains possible that other emotional stimuli also influence orienting. Only future studies with a broader range of stimuli can answer this question.

An interesting finding of the present studies was that snake pictures had a significantly weaker effect on attention than predicted by the arousal ratings of snake pictures. This finding closely mirrors Kindt and Brosschot's (1999) finding that spider-phobic children rated pictures of spiders as unpleasant and arousing, yet spider pictures failed to show an effect on a behavioral measure of attention. Thus, evolutionary threat stimuli seem to produce a reliable dissociation between arousal ratings and behavioral measures of attention. The existing literature has ignored this phenomenon, and explanations are lacking. One possible explanation could be that performance in interference tasks is partially influenced by voluntary control of attention, and some participants responded more quickly after presentations of snake pictures to avoid looking at these pictures. However, this explanation is inconsistent with Lang et al.'s (1993) finding that people voluntarily engage in processing of extremely negative stimuli. Alternatively, arousal ratings of snake pictures may be invalid. Future research needs to examine these issues.

The failure of evolutionary threat theory may reveal fundamental problems with its assumption that humans have a hard-wired mechanism that is triggered by any encounter with a specific stimulus. A more plausible alternative would be a theory that is open to the influence of learning experiences. A flexible system that is open to learning would also be more consistent with functional theories of emotions. Accordingly, one of the main functions of emotions is a decoupling of more primitive stimulus–response patterns (reflexive behaviors; e.g., Scherer, 1994). Emotions allow people to first assess the significance of a stimulus, and then to vary responses accordingly. As a result, humans should be able to discriminate between stimuli that are truly threatening (e.g., poisonous snakes) and those that are not threatening (e.g., pictures of snakes, toy snakes, nonpoisonous snakes).

Empirical evidence supports the idea that responses to evolutionary threat stimuli are influenced by learning experiences and are not hardwired. Animal studies indicate that laboratory monkeys have relatively little fear of snakes in comparison to monkeys in the wild (Nelson, Shelton, & Kalin, 2003), suggesting that fear of snakes in monkeys has a large learning component. Evidence with human participants stems from a study by Gerull and Rapee (2002). The authors demonstrated that toddlers' approach and avoidance behavior toward toy snakes and spiders was influenced by mothers' expression of positive or negative emotion. Learning effects have also been demonstrated in treatment studies of spider or snake phobia (e.g., Teachman & Woody, 2003). One study suggests that treatment of spider phobia also influences attention to spider stimuli (Thorpe & Salkovskis, 1997). Thus, one plausible explanation for the present findings is that most participants in the present studies did not suffer from snake phobia and had learned that snakes, especially mere pictures of snakes, are not threatening.

Categorical Negativity

Pratto and John (1991) introduced another influential theory about the influence of affect on attention. The authors proposed that all negative stimuli automatically attract attention. The effect is categorical because each stimulus is quickly evaluated as either positive or negative. The quick evaluation mechanism does not distinguish between mild or strong negative stimuli, and it is equally responsive to threats and other negative stimuli. As noted in the introduction, previous empirical findings were not always consistent with categorical negativity theory (Anderson, 2003; Buodo et al., 2002; Pratto, 1994). Similarly, the present studies failed to support a categorical effect of negative stimuli on attention. Rather, strong unpleasant pictures had a stronger effect on attention than mild unpleasant pictures. In addition, opposite-sex models produced significant effects. Thus, interference effects are not limited to negative stimuli, nor are they categorical across different types of negative stimuli.

The present results do not necessarily undermine the common notion of a negativity bias in the affect system (Cacioppo & Berntson, 1994; Rozin & Royzman, 2001; Taylor, 1991). The general notion of a negativity bias is typically probabilistic and merely states that on average, the effect of negative stimuli is stronger than the effect of positive stimuli. The present study demonstrated that interference effects for positive stimuli are limited to one type of positive pictures, namely sexual stimuli. As a result, it seems likely that a negativity bias would emerge if stimuli were randomly sampled from the population of all positive and all negative stimuli. However, rare exceptions, such as the effect for opposite-sex models, often provide valuable information about underlying processes (Cacioppo & Berntson, 1994). In the present case, the finding suggests that interference effects are not the consequence of an automatic assessment of valence that guides attention.

Arousal Theory

The main contribution of the article is the demonstration that interference effects were predicted by the arousal level of pictures. Although arousal has been an important concept in emotion research and in research with pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Lang, 1995), arousal has been neglected in the vast literature on emotion and attention. The present findings suggest that the first appraisal of a stimulus is related to arousal.

Although arousal ratings are commonly used in emotion research with pictures, the nature of arousal in these studies has remained ambiguous. Numerous studies have demonstrated that arousal is not a unidimensional construct (e.g., Matthews, Jones, & Chamberlain, 1990; Schimmack & Grob, 2000; Schimmack & Reisenzein, 2002). The present study used the aroused-sleepy dimension of the affect grid to assess arousal. The relation of this global arousal dimension to more specific arousal dimensions needs to be examined in future research. Theoretically, it makes sense that arousal ratings reflect cognitive arousal and states of alertness because cognitive arousal is more likely to be related to attentional mechanisms than bodily arousal.

The relation between arousal and attention also has interesting implications for process models of emotions. One important question regarding such models has been the sequence in which different emotion-related aspects of a stimulus are appraised. One of the most prominent and influential theories is Scherer's (2001) sequential evaluation check (SEC) model. The model postulates a series of appraisals that influence the nature of the unfolding emotion process in response to an emotional stimulus. Importantly, the theory assumes that the appraisal process does not start with an immediate and automatic assessment of valence or threat, as is often implied in other theories (e.g., Öhman et al., 2001; Pratto & John, 1991). Rather, the first check determines "How relevant is this event for me" (Scherer, 2001, p. 94). Furthermore, Scherer (2001) explicitly postulates that the initial relevance check is responsible for the regulation of attention, as the main function of the relevance check is the "detection of stimulus characteristics that require attention deployment and further information processing" (p. 99).

Scherer's SEC model can explain the relation between arousal and interference effects. The increase in arousal in response to a relevant emotional stimulus reflects the increase in processing capacity that facilitates further processing of a relevant stimulus. The interference effect reflects the reallocation of attentional resources to the emotional stimulus. The physiological correlates of arousal are also consistent with this interpretation. For example, the P300 event-related potential has been related to the reorganization of processing resources, which may reflect the change in processing priorities when confronted with a relevant stimulus. Similarly, skin conductance is a correlate of emotional significance (Gronau et al., 2003). Furthermore, Lang et al.'s (1993) finding that people spend more time looking at arousing pictures provides evidence that arousing stimuli are processed more deeply, which also leads to enhanced memory for these stimuli (Bradley, Greenwald, Petry, & Lang, 1992). Finally, Bradley et al.'s (2003) finding that arousing stimuli produce more cortical activity also suggests that arousing stimuli are processed more deeply.

Several findings in the attention literature are also consistent with the hypothesis that relevance is a predictor of attention. For example, ornithologists had longer response latencies than other participants in an emotional Stroop task with bird names (Dalgleish, 1995), and smokers attended more to smoking-related stimuli than nonsmokers (Mogg, Bradley, Field, & De Houwer, 2003). Admittedly, the notion of relevance is vague and makes it difficult to make a priori predictions about the effects of stimuli on attention. This problem may reflect the flexibility of the mechanism that determines relevance. Virtually any stimulus can be relevant for a specific individual in a specific situation. For example, Gronau et al. (2003) demonstrated that ordinarily irrelevant stimuli that were relevant to the primary task had a stronger influence on attention than personally relevant stimuli that were irrelevant to the primary task. Thus, relevance is a more complex construct than threat or negative valence. However, the hypothesis of a relevance check is much more consistent with the empirical evidence than the latter explanations. Thus, future research should focus on elucidating the situation-specific and general determinants of relevance that guide the allocation of attentional resources.

It also remains to be determined why strong unpleasant pictures, such as guns and victims of violence, and pictures of opposite-sex models tend to be more relevant than other pictures. Although the findings seem to be consistent with the everyday observation that sex and violence never cease to attract people's attention, it remains to be explained why this is the case. In summary, the main contribution of this article is to counteract a negativity bias in the research on emotion and attention. People are not hardwired to attend only to the negative or threatening aspects of their lives.

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