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Sustained and Transient Modulation of Performance Induced by Emotional Picture Viewing

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We investigated how viewing task-irrelevant emotional pictures affects the performance of a subsequent nonemotional visual detection task. Subjects performed target-detection trials following the offset of individual unpleasant, pleasant, and neutral pictures. Sustained *interference* occurred when subjects viewed unpleasant pictures (mutilated bodies) in a sequential, "blocked" fashion. Such slowing down of reaction time appeared to *build up* with time, consistent with the instatement of a defensive emotional state. With a randomized picture presentation, only a transient *interference* effect was observed, consistent with increased attentional demands during the processing of unpleasant pictures. During blocked presentation of affiliative pleasant pictures, reaction times were faster, suggesting the activation of appetitive motivational systems. Ultimately, both attentional and motivational systems are intricately tied in the brain and, together, determine behavior.

Keywords: emotion, attention, motivation, interference, affective pictures

The processing of emotional stimuli can have both advantageous and detrimental effects on behavioral performance in general and response time (RT) in particular. For instance, subjects were faster at detecting fearful or threatening target faces relative to neutral ones (Ishai, Pessoa, Bikle, & Ungerleider, 2004; Öhman, Lundqvist, & Esteves, 2001) and showed facilitated search for discrepant fear-relevant pictures among fear-irrelevant pictures (Öhman, Flykt, & Esteves, 2001). At other times, RTs are slowed down when emotional stimuli are presented. For example, determining the orientation (upward/downward) of a target visual stimulus was slowed down following emotional pictures (Hartikainen, Ogawa, & Knight, 2000), and the presence of a central unpleasant picture increased RT when subjects discriminated peripheral target letters (Tipples & Sharma, 2000) or the orientation of bars (Erthal et al., 2005). In both cases, the effects of emotional stimuli on performance are commonly thought to be mediated by attention. Thus, some form of attention-like competitive advantage is believed to be conferred to emotional stimuli, possibly mediated by the amygdala (Anderson & Phelps, 2001), such that the processing of emotional information is prioritized (Pessoa, Kastner, & Ungerleider, 2002). Prioritization is also believed to underlie *interference* effects, which are typically observed when emotional stimuli are presented simultaneously with neutral information or precede the presentation of neutral items by a short amount of time. When interference occurs during the simultaneous presentation of emotional and neutral items, prioritization of the emotional item is thought to divert resources from the processing of the neutral items, thus slowing down RT. A similar reasoning is applied when emotional items precede neutral ones. In this case, it is believed that interference is due to the initial consumption of resources by emotional items or possibly to an increased difficulty in disengaging from emotional information (Bradley, Cuthbert, & Lang, 1996; Koster, Crombez, Verschuere, & De Houwer, 2004).

Another way in which emotional information impacts on behavior is through motivational systems. At a fundamental level, emotion is considered to be organized around two motivational systems, one appetitive and one defensive (Lang, Davis, & Ohman, 2000). The defense system is primarily activated in contexts involving threat, whereas the appetitive system is activated in contexts that promote survival (e.g., food consumption). The processing of emotional stimuli by human subjects can interfere with defensive and appetitive reflexes. For example, Lang, Bradley, and Cuthbert (1990) showed that an emotional state engendered by viewing pictures modulated the startle reflex (see Lang et al. [2000] for a review). In addition, such emotional states have been shown to induce autonomic and somatic responses that support emotional responses (Bradley et al., 1996). In particular, it was shown by Azevedo and colleagues (2005) that viewing highly arousing

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negative images triggers the defense system and produces a freezing-like behavior in humans.

In the present study, we performed four experiments to further investigate how viewing emotional pictures affects performance of a subsequent nonemotional visual task. To attempt to induce a robust emotional state during picture viewing, we employed arousing unpleasant (mutilated bodies) and pleasant (erotic, Experiment 1; babies/families, Experiments 2 and 3) pictures. We probed the time course of potential modulatory effects on RT by having subjects perform a blocked (Experiments 1, 2, and 4) or randomized (Experiment 3) version of the task and by having subjects perform either 6 (Experiments 1, 3, and 4) or 12 (Experiment 2) visual target-detection trials following each picture presentation (lasting 6–12 s). During blocked conditions, 24 same-valence pictures were presented in a sequence (lasting more than 3 min in Experiments 1 and 4 and more than 7 min in Experiment 2; in both cases, times include target-detection trials), which was expected to maximize the induction of an emotional state; during the randomized condition, unpleasant, pleasant, and neutral pictures were shown in a random order, thus preventing the instatement of a consistent emotional state. We reasoned that, on the one hand, modulatory effects observed only for the initial target-detection trials during randomized conditions would provide evidence for a transient modulation of RT by emotional picture viewing that is consistent with short-lived selective attention effects, which are thought to last for 1000 ms or less (Duncan, Ward, & Shapiro, 1994). On the other hand, modulatory effects observed during several target-detection trials during blocked conditions only would be suggestive of affective processes that operate at a longer time scale. To reiterate, transient emotional modulation effects would suggest that relatively short-lived attentional processes mediate the modulation, whereas more long-lasting effects that require repeated (i.e., blocked) emotional picture presentations would suggest the involvement of affective and/or motivational systems. The latter scenario is related, for instance, to results by Bradley and colleagues (1996), who demonstrated that certain emotional modulation effects, such as startle modulation following picture offset, can be revealed only when emotional stimuli are presented in a blocked fashion. Our results revealed both transient and sustained modulatory effects of emotional picture viewing and suggest that both factors affect visuomotor performance, even when a relatively low-level visual detection task is employed.

Experiment 1

In Experiment 1, unpleasant, pleasant, and neutral pictures were shown for 2000 ms in a blocked fashion (Figure 1). Each block consisted of 24 pictures of the same valence from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997). After each picture, subjects performed six trials of target detection. Our objective was to determine how potential modulatory effects evolved throughout the block and how they affected the series of target-detection trials that followed each picture's offset.

Methods

Participants. Twenty-three male volunteers participated in the experiment (ages 18–26). Participants were undergraduate students from the Federal Fluminense University, Niteroi, Brazil, reported no neurological or psychiatric disorders, and were not taking medication. All of them were right-handed according to the Edinburgh Inventory (Oldfield, 1971) and had normal or corrected vision. The local ethics committee approved the experimental protocol, and each participant gave written consent prior to the study.

Apparatus and stimuli selection. Participants were tested in a sound-attenuated room under dim ambient light. Stimulus timing and presentation, as well as collection of responses, were controlled by a computer. Stimulus presentation was programmed using MEL software (Psychology Software Tools Inc., Pittsburgh, PA). The subjects' heads were positioned on a head-and-chin rest at 57 cm from the screen.

Ninety pictures were used from the IAPS, a collection of standardized color photographic material (Lang et al., 1997). Four sets of pictures were employed. One set of 18 pictures of wide-ranging valence and arousal ratings was selected for a practice block. Three sets of 24 pictures each were used in test blocks: pleasant (erotic females or erotic couples), neutral (household and inanimate objects), and unpleasant (mutilated bodies). Mean ratings of the stimuli for North American men (Lang et al., 1997) in terms of valence (nine-point scale from *unpleasant* to *pleasant*) and arousal (nine-point scale from *calm* to *excited*) were as follows: unpleasant, pleasant, and neutral picture valence: 2.1, 7.5, 4.8, respectively; unpleasant, pleasant, and neutral picture arousal: 6.1, 6.8, 2.4, respectively.

Design and procedure. The experimental session consisted of one initial practice block followed by three test blocks. During each test block, a single type of picture was utilized (unpleasant, pleasant, or neutral). The serial position of each test block was counterbalanced across participants using all six possible orders. Pictures were presented in a fixed, but random, order in terms of both valence and arousal scores according to the scale proposed by Lang and colleagues (1997).

Critically, no systematic increases or decreases in valence or arousal occurred within blocks (all ps > 0.2 when valence or arousal were regressed on picture position). In addition, as in the main analyses (see Data Analysis section), we subdivided blocks into "early" (pictures 1–8), "intermediate" (pictures 9–16), and "late" (pictures 17–24) segments and tested for potential differences in valence and arousal as a function of block segment. Separate one-way repeated-measures ANOVAs (segment factor: early, intermediate, and late) were tested for unpleasant, pleasant, and neutral blocks and revealed no significant effect of segment for both valence and arousal (all ps > 0.7). Combined, the two previous analyses demonstrate that there were no systematic changes of valence or arousal as a function of time during the experiment. These results apply for unpleasant and neutral blocks for Experiments 2 and 4 as well, because the same stimulus order was employed.

There was a brief interval (3 to 5 min) between blocks. In a final phase, participants rated the valence and arousal of each picture seen (including during practice), using the paper-and-pencil version of the Self-Assessment Manikin (Bradley & Lang, 1994).

For all test blocks, each picture was presented for 2 s, followed by six trials of target detection (Figure 1). Participants were instructed to attend to each picture as long as it was displayed. Each target-detection trial consisted of a fixation spot presented at the center of the screen 500–700 ms prior to target onset. The target was a small annulus that appeared around the fixation spot; both remained on until the subject's response. Both the fixation spot and the target were presented in white on a black screen. Subjects were required to press a button with the right index finger as quickly as possible after target onset. A new target-detection trial began 500 ms following the subject's response. After six trials, a new picture appeared on the screen. Trials with responses longer than 1000 ms or shorter than 100 ms were considered errors and were discarded.

The training block was similar to test blocks aside from the visual feedback of RT and the warning that an error was made, which appeared on the screen for 1 s. After the offset of the RT (in milliseconds) display,

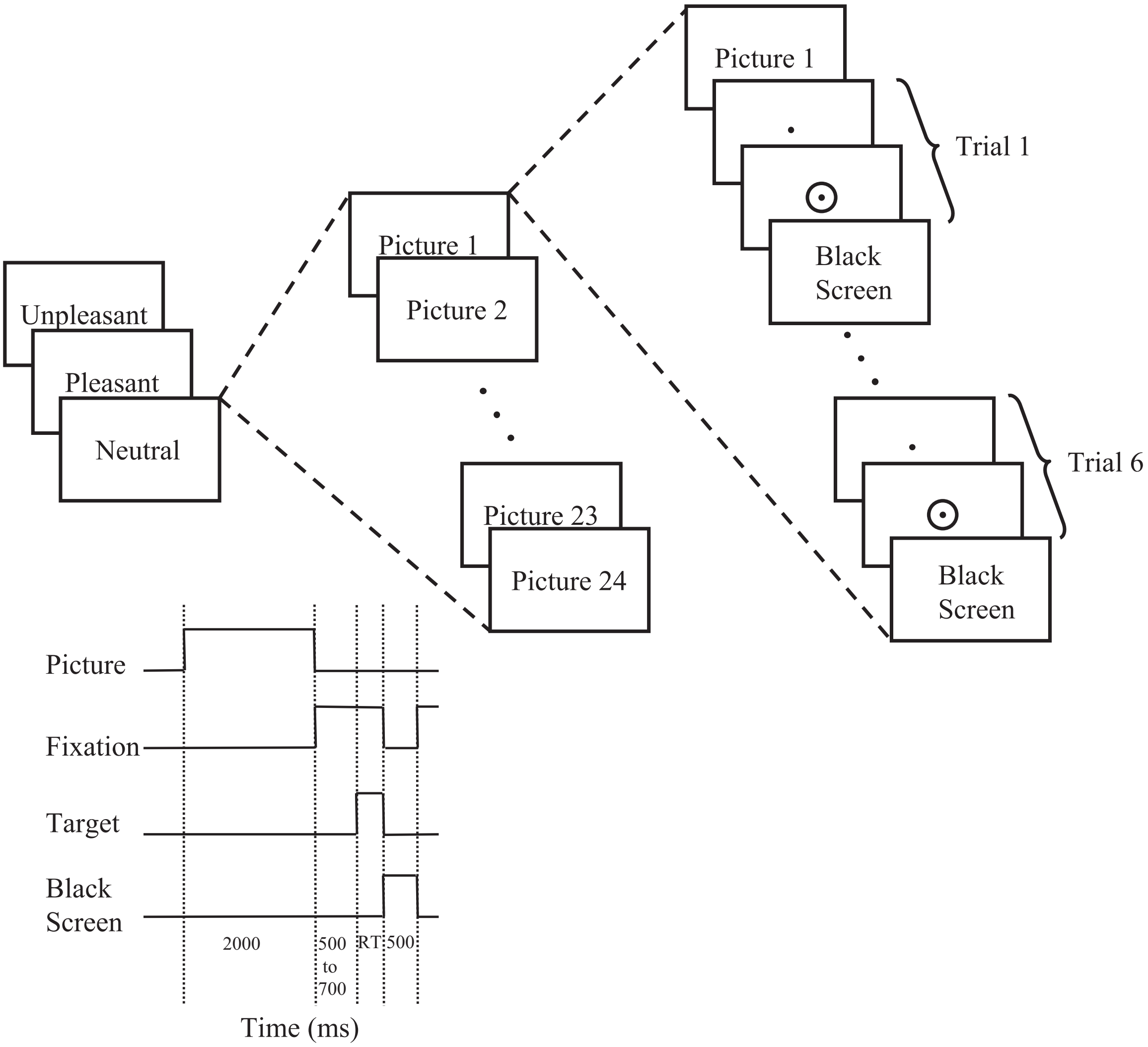

Figure 1. Experimental paradigm. Unpleasant, pleasant, and neutral blocks contained 24 pictures. Each picture was followed by six trials of a simple target-detection task. The inset (lower left) displays the temporal structure associated with each picture presentation and subsequent target-detection trials.

a new target-detection trial began. Errors were displayed on the screen as "anticipation" or "slow response," as specified previously.

For the final rating phase of the experiment, the same 90 pictures utilized during practice and test blocks were presented in random order. Before each picture appeared, subjects saw the following sentence for 5 s: "Get ready to rate picture n." The picture was then presented for 6 s. After the picture's offset, the subject had 10 s to rate its valence and arousal. Before the start of the rating phase, 9 pictures were used to demonstrate the rating scales. Additionally, subjects practiced their ratings on 3 practice pictures. These extra 12 pictures were also picked from the IAPS but were not used in the actual experiment.

Data analysis. Data obtained in the practice block were not analyzed. For test blocks, we used a repeated-measures ANOVA to explore the differences in RT by using valence (unpleasant, pleasant, and neutral) and trial number (1–6) as within-subject factors. Post hoc tests used the Newman–Keuls method. To probe the temporal evolution of potential modulatory effects of picture viewing on RT, we subdivided blocks into "early" (pictures 1–8), "intermediate" (pictures 9–16), and "late" (pictures 17–24) segments. Preplanned ANOVAs then tested for the effects of valence for each segment. Again, post hoc tests used the Newman–Keuls method. Repeated-measures ANOVA tests were also used to evaluate the effects of valence and arousal in the subjective ratings of the pictures. Unless otherwise noted, the p value for statistical significance was 0.05.

Participants performed the target-detection task extremely well and exhibited very few errors overall. Errors rates during unpleasant, pleasant, and neutral blocks were 1.9%, 2.1%, and 2.0%, respectively.

Results

Initially, we analyzed participants' ratings of valence and arousal obtained via the paper-and-pencil version of the Self-Assessment Manikin (Bradley & Lang, 1994) as a function of unpleasant, pleasant, and neutral pictures. Such analysis revealed a main effect of valence, $F(2, 44) = 1696.8$, $p < .001$, and of arousal, $F(2,44) = 497.3$, $p < .001$. Valence ratings of pleasant pictures ($M = 7.5$) were significantly higher and valence ratings of unpleasant pictures ($M = 2.4$) were significantly lower than valence ratings of neutral pictures ($M = 5.1$). Arousal ratings were greater for pleasant ($M = 6.0$) and unpleasant ($M = 6.5$) pictures than for neutral ones ($M = 2.5$). Unpleasant and pleasant pictures differed significantly in arousal level. In addition, the ratings obtained from our Brazilian subjects were compared to those reported for a large group of North American males (Lang et al., 1997). For the 72 pictures used in the test phase of our experiment, a Z test revealed that only 5 and 7 pictures exhibited mean ratings that differed significantly in arousal and valence, respectively, from the North American group. However, although the differences were statistically significant, the differences were numerically small. For instance, the largest difference in arousal was 1.51 (from 6.70 [Brazil] to 5.19 [USA]), and the largest difference in valence was 0.94 (from 1.63 [Brazil] to 2.57 [USA]).

The analysis of RTs revealed a main effect of valence, $F(2, 44) = 4.96$, $p < .01$. Reaction time to targets was significantly slower following unpleasant pictures (251 ms) than those following neutral pictures (237 ms) and pleasant pictures (240 ms) (Figure 2A). There was no significant difference in RT between pleasant and neutral blocks ($p = .45$). There was also a main effect of trial number, $F(5, 110) = 12.27$, $p < .001$, with a slower RT for the initial trial following picture offset compared to all others trials. Post hoc analyses revealed that all trials during unpleasant blocks were significantly slower than those during neutral blocks. This long-lasting effect is illustrated in Figure 2B. During pleasant blocks, *none* of the RTs was significantly different from those during neutral blocks (Figure 2C).

Our blocks included 24 picture presentations so that we could probe the time course of potential modulatory effects. Preplanned ANOVAs then tested for the effects of valence for early, intermediate, and late segments (Figure 3A). No effect of valence was observed during the early segment ($F[2, 44] = 0.71$, $p = .49$), whereas significant effects of valence were observed during the intermediate ($F[2, 44] = 4.29$, $p = .01$) and late ($F[2, 44] = 4.64$, $p = .01$) segments. During the intermediate segment, RT for targets occurring after unpleasant pictures was significantly slower (258 ms) than those after neutral (241 ms) and pleasant pictures (242 ms); no significant RT difference between pleasant and neutral blocks was observed ($p = .85$). During the late segment, we again observed a significant increase in RT for targets that followed unpleasant pictures (255 ms) compared to targets that followed neutral (233 ms) and pleasant (245 ms) pictures; no significant RT difference between pleasant and neutral blocks was observed ($p = .42$). Figure 3C further illustrates that interference effects were sustained during intermediate and late segments; for comparison, we also show individual trials following pleasant pictures (Figure 3B).

Experiment 2

Experiment 1 revealed an *interference* of emotional picture viewing on target detection, which was expressed as a slowing down of RT during unpleasant relative to neutral conditions. The observed modulation was relatively long lasting and persisted until the final (sixth) target detection trial. The goal of Experiment 2 was to further probe the factors influencing the interference effect. Accordingly, for Experiment 2 we doubled the number of target-detection trials that followed picture presentation in an attempt to assess whether the effect would persist beyond the 6 trials employed in Experiment 1.

In Experiment 1, no effects on RT were observed during the pleasant condition. The absence of an RT modulation by pleasant pictures of erotic content may have been due to the potentially conflicting reactions to viewing such images in an experimental setting (Kaviani, Gray, Checkley, Kumari, & Wilson, 1999). Thus, in Experiment 2 we employed a new category of pleasant stimuli consisting of pictures depicting babies and family interactions, which is a stimulus class considered highly pleasant (Bradley, Codispoti, Cuthbert, & Lang, 2001). Finally, we tested whether the interference effect revealed in Experiment 1 would be observed upon reexposure to the same stimulus at a later time. We thus tested whether picture novelty is an important factor for RT modulation or whether participants would habituate to the stimuli. In Experiment 2A, participants performed three test blocks as in Experiment 1 but with 12 target-detection trials following each picture and with a new class of pleasant stimuli (babies/families). In Experiment 2B, the same participants repeated the experiment 24–48 h after the initial session.

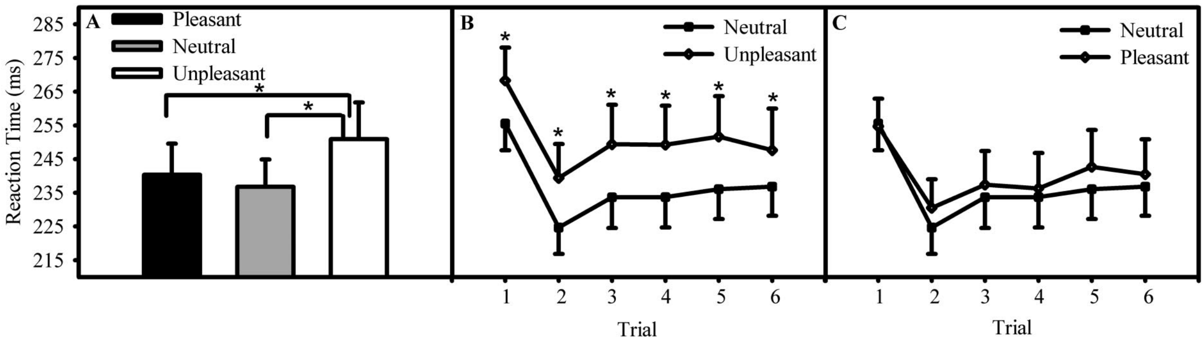

Figure 2. Sustained interference effect (Experiment 1). (A) Reaction time (RT) for pleasant, unpleasant, and neutral blocks. A significant slowing of RT was observed during unpleasant relative to pleasant or neutral blocks. (B) Such interference effect was sustained and was observed for all six target-detection trials. (C) No significant differences in RT were observed when comparing target-detection trials during pleasant and neutral blocks. In all cases, mean RTs are plotted, and error bars indicate *SEM*. * indicate significant differences.

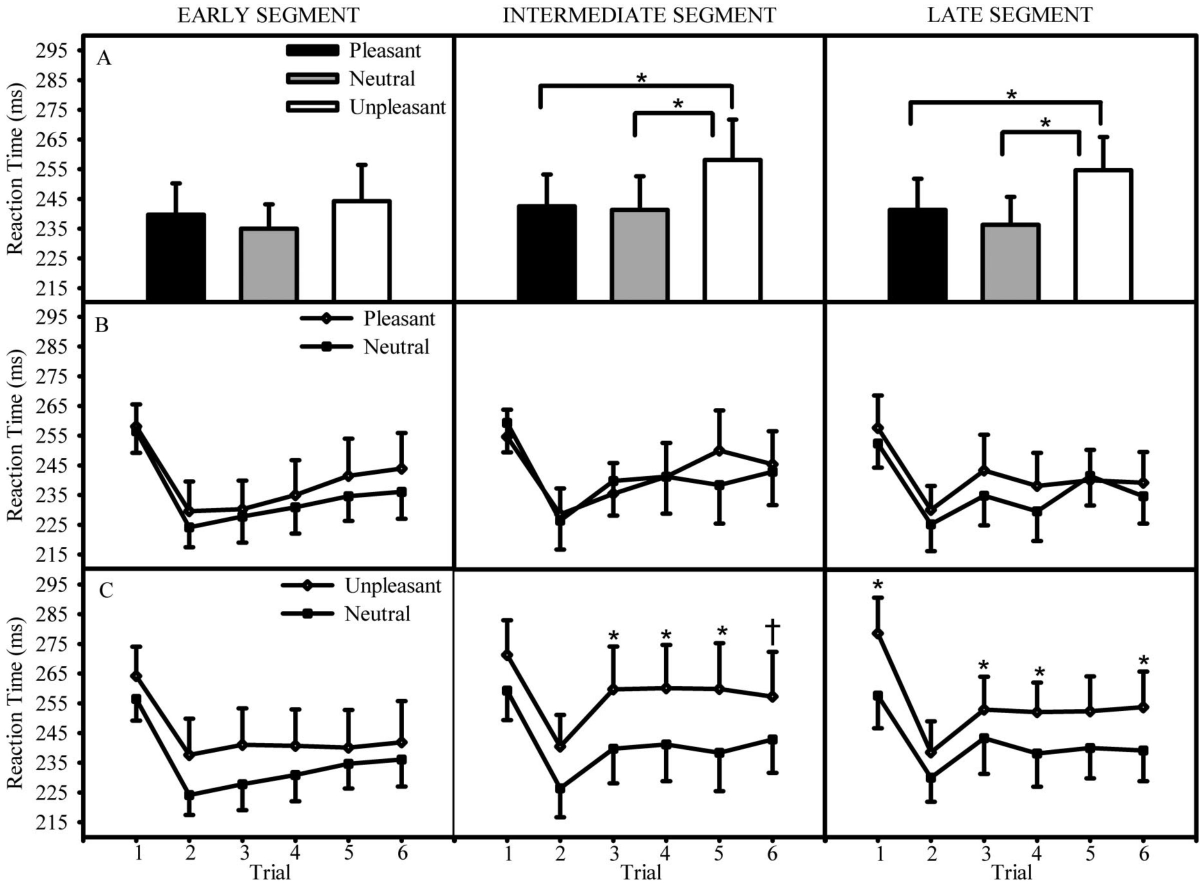

Figure 3. Time course of interference effect (Experiment 1). (A) Reaction time (RT) for pleasant, unpleasant, and neutral blocks for early, intermediate, and late segments. Error bars indicate *SEM*. (B) RT difference (unpleasant–neutral) for early, intermediate, and late segments. (C) RT difference (unpleasant–neutral) for early, intermediate, and late segments. * indicate significant differences, and † indicates $p \leq .1$.

Methods

Because the experimental design and the general procedures used in this experiment were very similar to those of Experiment 1, here we focus on the differences between the two.

Participants. Thirty male volunteers participated in the experiment (ages 18–26). Participants were undergraduate students from the Federal Fluminense University, Niteroi, Brazil, reported no neurological or psychiatric disorders, and were not taking medication. All of them were right-handed according to the Edinburgh Inventory (Oldfield, 1971) and had normal or corrected vision. The local ethics committee approved the experimental protocol and each participant gave written consent prior to the study.

Apparatus and stimuli selection. Ninety pictures were used from the IAPS. Four sets of pictures were employed. One set of 18 pictures of wide-ranging valence and arousal ratings was selected for a practice block. Three sets of 24 pictures each were used in test blocks: pleasant (babies and families), neutral (household and inanimate objects), and unpleasant (mutilated bodies). The unpleasant and neutral pictures were the same as the ones used in Experiment 1. The mean valence and arousal ratings reported for North American men (Lang et al., 1997) for the new set of pleasant pictures were 7.4 and 4.9, respectively.

Design and procedure. The overall experimental sequence (blocks and trials) was the same as that of Experiment 1, but 12 target-detection trials followed each picture. Unlike in Experiment 1, participants received feedback indicating whether RTs were within the appropriate range ($100 < \text{RT} < 1000$ ms). Because in Experiment 1 only slight differences in valence and arousal ratings were observed when comparing Brazilian participants to normed values, in Experiments 2–4 we did not collect individual ratings.

Critically, no systematic increases or decreases in valence or arousal occurred within pleasant blocks involving babies and families (all $ps > 0.2$ when valence or arousal were regressed on picture position). A one-way repeated-measures ANOVA tested for the effect of segment (early, intermediate, and late) during the pleasant block; no significant effect was observed for either valence or arousal ($ps > 0.5$). Note that the stimulus order of other block types was as in Experiment 1.

Data analysis. Data analysis was similar to that employed in Experiment 1. For analyses related to specific target-detection trials, RTs for successive trials 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, and 11 and 12 were averaged together, resulting in six mean RTs. We employed such averaged trials because we sought to analyze the results of Experiment 2 in a manner that was comparable to that of Experiments 1, 3, and 4. In particular, such a strategy equated the number of target-detection RT tests across experiments, allowing for a more direct comparison of the statistical results.

Results

The analysis of RTs revealed a main effect of valence, $F(2, 58) = 5.25$, $p = .008$. RT to targets presented during unpleasant

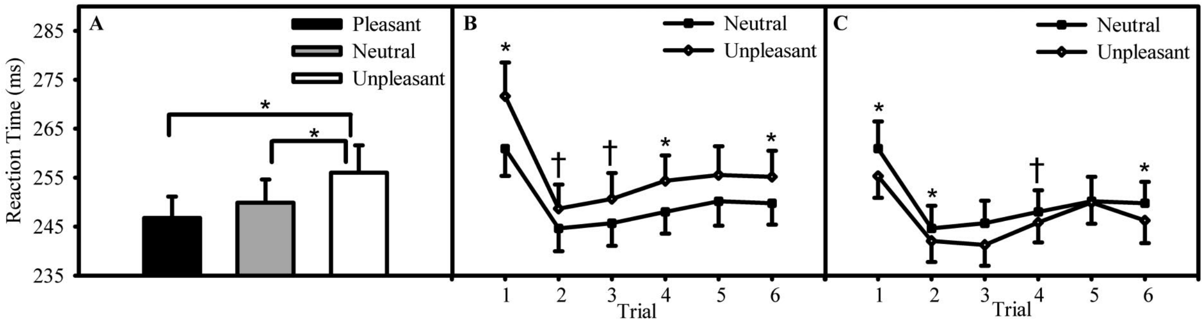

Figure 4. Sustained interference effect (Experiment 2). (A) Reaction time (RT) for pleasant, unpleasant, and neutral blocks. A significant slowing of RT was observed during unpleasant relative to pleasant or neutral blocks. (B) RT during unpleasant and neutral blocks for all averaged trials. (C) RT during pleasant and neutral blocks for all averaged trials. In all cases, mean RTs are plotted, and error bars indicate *SEM*. * indicate significant differences, and † indicates $p \leq .1$.

blocks was significantly slower (256 ms) than the mean RT during neutral (250 ms) and pleasant (247 ms) blocks (Figure 4A). There was no significant difference in RT between pleasant and neutral blocks ($p = .29$). The main effect of averaged trials was also significant, $F(5, 145) = 22.91$, $p < .0001$. The interaction between valence and averaged trials was not significant, $F(10, 290) = 1,32$, $p = .22$. Figures 4B and 4C show RTs for all averaged trials during unpleasant, pleasant, and neutral blocks.

As in Experiment 1, we probed the time course of modulatory effects by investigating early, intermediate, and late segments of blocks. The analyses revealed differential effects of pleasant and unpleasant pictures on target-detection RT. A preplanned ANOVA of the early segment (Figure 5A, left) revealed a significant effect of valence, $F(2, 58) = 3.76$, $p = .03$. Indeed, all averaged trials after pleasant pictures were significantly faster than those after neutral or unpleasant pictures, except for averaged trials 1 and 3, which exhibited strong trends ($p < .09$ and $p < .07$, respectively) (Figure 5B, left). However, *none* of the averaged trials during the unpleasant block differed from those during neutral block (Figure 5C, left). A preplanned ANOVA during the intermediate segment (Figure 5A, middle) also revealed a main effect of valence, $F(2, 58) = 3.45$, $p = .04$. In this case, all averaged trials following unpleasant pictures were slower than when following neutral ones (Figure 5C, middle), except for averaged trial 2 ($p = .1$). *None* of the averaged trials performed after pleasant pictures differed from ones performed after neutral pictures (Figure 5B, middle). A preplanned ANOVA during the late segment (Figure 5A, right) revealed no effect of stimulus type. For the late segment, only the first averaged trial after unpleasant pictures was significantly slower than after neutral pictures (Figure 5C, right); there were no differences between neutral and pleasant blocks for any of the averaged trials (Figure 5B, right).

Experiment 2B

The same subjects who participated in Experiment 2A performed the experiment again 24–48 h later. The analysis of RTs did not reveal a main effect for valence, $F(2, 58) = 0.42$, $p = .66$. RTs for targets presented during the unpleasant block (248 ms) did not differ from those presented during neutral (249 ms) or pleasant blocks (251 ms). Valence effects were also not observed during early ($F[2, 58] = 0.44$, $p = .65$), intermediate ($F[2, 58] = 0.61$, $p = .54$) or late ($F[2, 58] = 0.47$, $p = .63$) blocks.

Experiment 3

In Experiments 1 and 2, we observed sustained modulation of RT lasting several seconds following the viewing of an emotional picture. In Experiment 1, a slowing down of RT was observed during the intermediate and late segments of unpleasant blocks until the sixth and final target-detection trial (approximately 6 s following picture offset). In Experiment 2, a slowing down of RT was observed in the intermediate segment of unpleasant blocks until the final averaged trial (approximately 10–12 s). Thus, the time course of interference indicates that the effect builds with time because interference was not observed during the early block segments (see the General Discussion section for the case of pleasant blocks). If sustained interference effects on RT depended on the instatement of an emotional state, a randomized presentation of unpleasant, pleasant, and neutral pictures would be expected to eliminate such sustained effects because such presentation order should not engender a consistent emotional state. Conversely, if sustained interference effects were not dependent on a consistent emotional state and only depended on the previous picture, such effects should be observed during randomized picture presentations. In addition, it is also conceivable that under randomized conditions interference would be less sustained and only affect a subset of the target-detection trials.

Methods

Participants. Twenty-three volunteers participated in the experiment (ages 18–26; 12 men, 11 women). Participants were undergraduate students from the Federal Fluminense University, Niteroi, Brazil, reported no neurological disorders, and were not taking medication. All of them were right-handed according to the Edinburgh Inventory (Oldfield, 1971) and had normal or corrected vision. The local ethics committee approved the experimental protocol and each participant gave written consent prior to the study.

Apparatus and stimuli selection. The stimuli and order were the same as in Experiment 2.

Design and procedure. The experimental procedure was similar to Experiment 1. Briefly, after an initial training block, participants performed

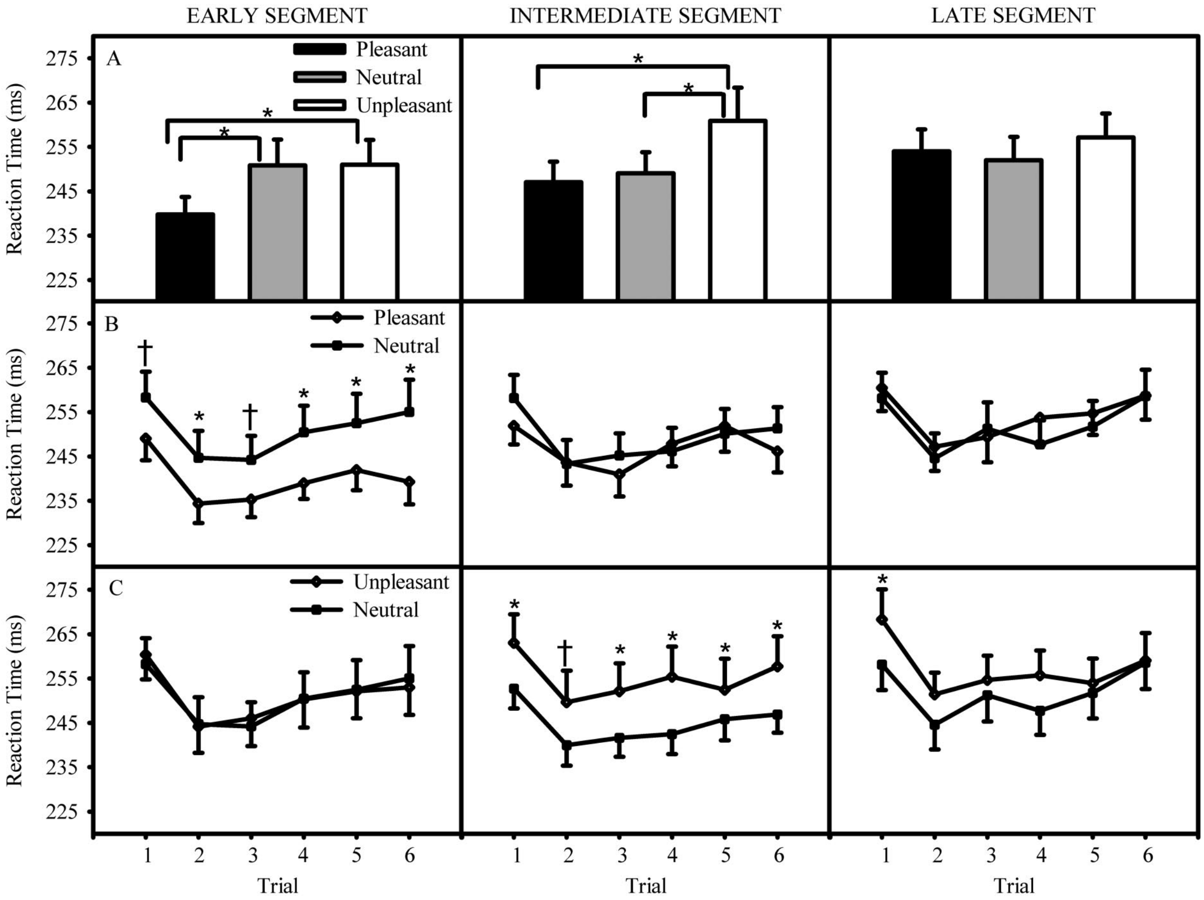

Figure 5. Time course of emotional modulation effects (Experiment 2). (A) Reaction time (RT) for pleasant, unpleasant, and neutral blocks for early, intermediate, and late segments. (B, C) RTs for target-detection averaged trials as a function of block segment. * indicate significant differences, and † indicates $p \leq .1$. See text for details.

three test blocks with a brief interval between them. Following each picture's offset, participants performed six target-detection trials. Unlike in Experiments 1 and 2, each block comprised 8 pictures from each category (total of 24 pictures) presented in a semirandom fashion (a random sequence was created with the restriction that at most two pictures of the same category could be presented consecutively). Unlike in Experiment 1, participants did not rate the pictures in terms of valence and arousal.

Data analysis. For each category, RT was submitted to a repeated-measures ANOVA. Valence (unpleasant, pleasant, or neutral) and target-detection trial number (1–6) were used as within-participant factors. Post hoc tests used the Newman–Keuls method.

Results

The analysis of RTs revealed a main effect of valence, $F(2, 44) = 3.87$, $p = .03$ (Figure 6A), and a significant interaction between valence and target-detection trial number, $F(10, 220) = 2.41$, $p = .01$. Post hoc analyses revealed that the first trial after unpleasant pictures (290 ms) was significantly slower than those after neutral (270 ms) or pleasant (273 ms) pictures (in both cases, $p < .0001$). *None* of the other trials differed from each other (Figure 6B and 6C).

Experiment 4

Previous studies suggest that negative pictures are effective cues in activating emotional responses when participants view them for a relatively long period of time (e.g., 6 s) (Bradley, Moulder, & Lang, 2005; Brown, Bradley, & Lang, 2006; Smith, Bradley, & Lang, 2005). At the same time, it appears that the effects of shorter stimuli are decreased relative to that of longer ones (Codispoti, Bradley, & Lang, 2001). In this experiment, we investigated whether the interference effect observed for unpleasant pictures, which was consistently observed in Experiments 1–3, would also occur for 500-ms stimuli.

Methods

Because the experimental design and the general procedures used in this experiment were very similar to those of Experiment 1, here we focus on the differences between the two.

Participants. Twenty-two volunteers participated in the experiment (ages 18–26; 9 men, 13 women). Participants were undergraduate students from the Federal Fluminense University, Niteroi, Brazil, reported no neurological or psychiatric disorders, and were not taking medication. All of

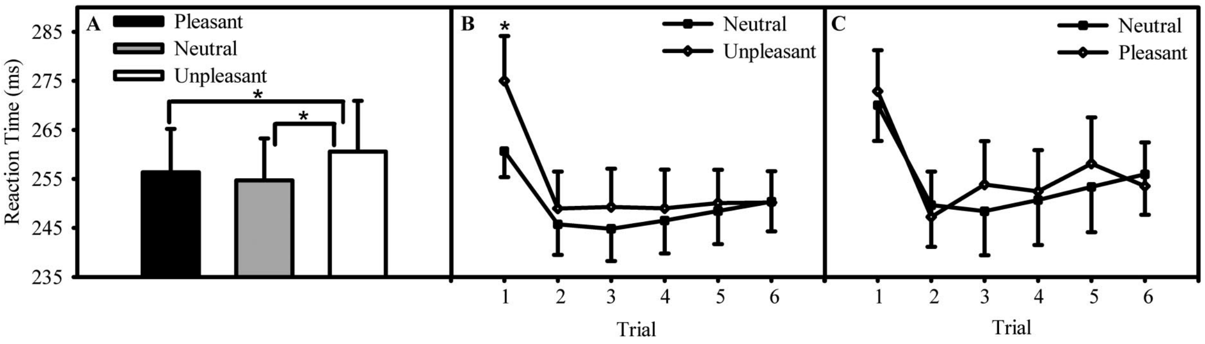

Figure 6. Transient interference effect (Experiment 3). (A) Reaction times (RTs) following pleasant, unpleasant, and neutral pictures, which were presented in a randomized fashion. (B) RT during unpleasant and neutral blocks for all six trials. (C) RT during unpleasant and neutral blocks for all six trials. A slower RT was observed only for the first target-detection trial following unpleasant pictures. * indicate significant differences, and † indicates $p \leq .1$.

them were right-handed according to the Edinburgh Inventory (Oldfield, 1971) and had normal or corrected vision. The local ethics committee approved the experimental protocol, and each participant gave written consent prior to the study.

Apparatus and stimuli selection. Sixty-six pictures were used from the IAPS. Three sets of pictures were employed. One set of 18 pictures of wide-ranging valence and arousal ratings was selected for a practice block. Two sets of 24 pictures each were used in test blocks and were the same as in Experiment 1: neutral (household and inanimate objects) and unpleasant (mutilated bodies).

Design and procedure. The overall experimental sequence (blocks and trials) was the same as that of Experiment 1. In this experiment, for both test blocks (unpleasant and neutral), each picture was presented for 500 ms, followed by six trials of target detection. Unlike in Experiment 1, participants did not rate the pictures in terms of valence and arousal.

Data analysis. Data analysis was the same as employed in Experiment 1.

Results

The analysis of RTs revealed a main effect of valence, $F(1, 21) = 5.12$, $p = .03$. Reaction time to targets presented during unpleasant blocks (265 ms) was significantly slower than RT during neutral blocks (250 ms) (Figure 7A). The main effect of trial was also significant, $F(5, 105) = 8.4$, $p < .0001$. Post hoc analyses revealed that all trials during unpleasant blocks were significantly slower than those during neutral blocks (Figure 7B). The interaction between valence and trial was not significant, $F(5, 105) = 0.52$, $p = .76$.

As in Experiments 1 and 2, preplanned ANOVAs tested for the effects of valence for early, intermediate, and late block segments. No significant effect of valence was observed in the *early* segment, $F(1, 21) = 1.6$, $p = .21$ (Figure 8A, left), whereas a significant effect was observed during the *intermediate* segment, $F(1, 21) = 5.13$, $p = .03$. During the intermediate segment, RTs for targets occurring after unpleasant pictures were significantly slower (270 ms) than those after neutral (251 ms) pictures (Figure 8A, middle). Although the valence effect did not reach statistical significance during the *late* segment, consistent with the results observed in Experiment 1, we observed a trend ($F[2, 44] = 4.64$, $p = .1$) for the slowing down of RT for targets that followed unpleasant pictures (270 ms) compared to targets that followed neutral ones (256 ms) (Figure 8A, right). Figure 8B illustrates RTs for all target-detection trials during early, intermediate, and late segments of both neutral and unpleasant blocks.

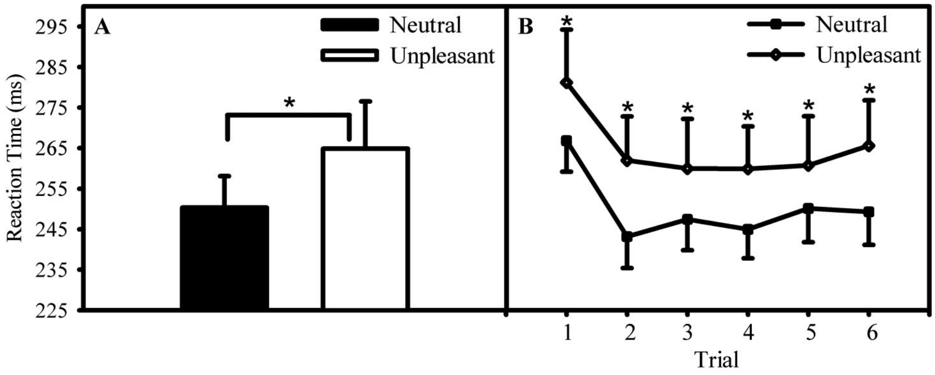

Figure 7. Sustained interference effect after shorter (500 ms) picture presentation (Experiment 4). (A) RTs following unpleasant and neutral pictures. (B) Sustained interference during all six trials. * indicate significant differences, and † indicates $p \leq .1$.

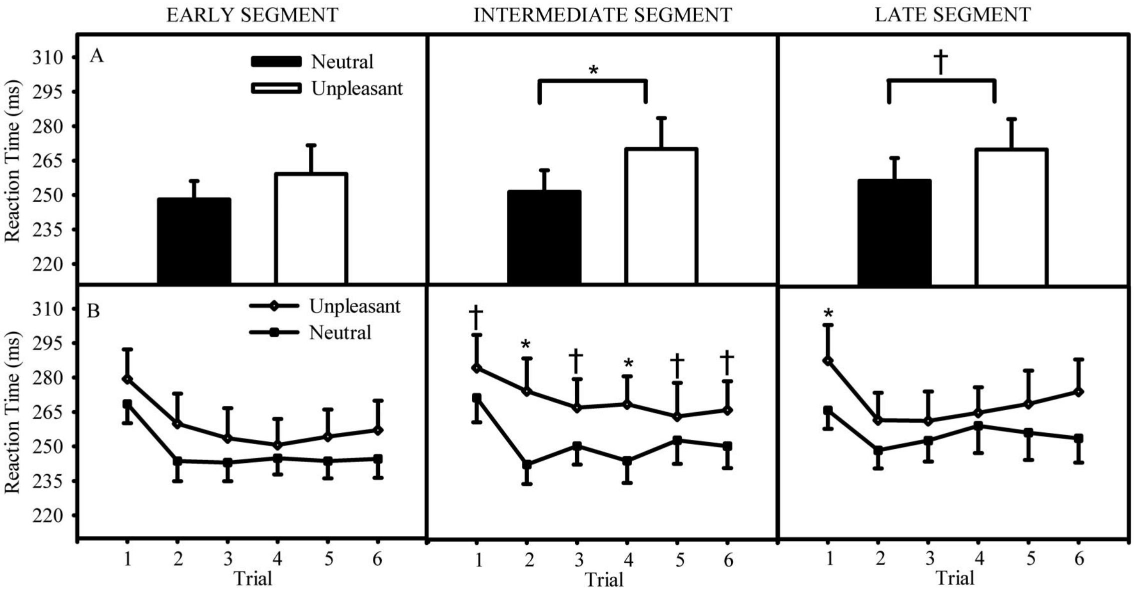

Figure 8. Time course of interference effect after shorter (500 ms) picture presentation (Experiment 4). (A) Reaction time (RT) for unpleasant and neutral blocks for early, intermediate, and late segments. (B) RTs for all target-detection trials as a function of block segment. * indicate significant differences, and † indicates $p \leq .1$.

General Discussion

In this article, we investigated how viewing task-irrelevant emotional pictures affected the performance of a subsequent nonemotional visual detection task. During *unpleasant* blocked conditions, the slowing down of RT occurred for all six target-detection trials following picture offset in Experiments 1 and 4 and all twelve trials following picture offset in Experiment 2. Critically, during the random condition, interference was observed only for the first target-detection trial following the unpleasant picture (Experiment 3). In addition, interference was observed both with longer picture presentations (2 s, Experiments 1 and 2) and with relatively shorter durations (500 ms, Experiment 4). Taken together, these results suggest the existence of a *sustained* interference effect, as evidenced by blocked presentation conditions, and the existence of a *transient* interference effect, as revealed during unblocked (i.e., random) conditions. Moreover, sustained interference was not observed at the beginning of a block and instead was observed only after the initial block segment (comprising pictures 1–8). Finally, during blocks involving *pleasant* pictures, RTs were faster than during neutral blocks only in Experiment 2, in which pictures of babies and families were utilized; no speeding up of RT was observed in Experiment 1, in which the pleasant category comprised erotic images.

Unpleasant Stimuli and Transient Task Interference

Interference effects have been often interpreted in terms of attention. Emotional items appear to attract attention. For example, the detection of threat-related stimuli (e.g., a snake) is associated with relatively flat "search slopes" in visual search tasks (Eastwood, Smilek, & Merikle, 2001; Öhman et al., 2001). Moreover, negative stimuli are a more effective source of involuntary interference to ongoing tasks (White, 1996). For instance, when subjects were asked to indicate whether two houses in a display were the same, RTs were slower when ignored faces were fearful relative to when they were neutral (Vuilleumier, Armony, Driver, & Dolan, 2001); see also Williams, McGlone, Abbot, and Mattingley (2005) for related results.

A potential explanation for the present interference effects by unpleasant pictures is that they captured attention and thereby reduced the resources available for the subsequent target-detection task. In general, selective attention effects are relatively fast and transient. Based on studies of visual search, it has been proposed that attention is a high-speed serial process, with the attentional demands of an object being on the order of 50 ms. Attention, however, may be better described as a sustained state during which representations of relevant objects become available to guide behavior (Duncan et al., 1994; Ward, Duncan, & Shapiro, 1996). Under this framework, attentional dwell time is suggested to last on the order of 500 ms or slightly longer (600–800 ms) (Muller, Teder-Salejarvi, & Hillyard, 1998). In our task, the first target-detection trial followed the offset of the picture by 500–700 ms. Interference effects observed for the first target-detection trial are consistent with the timing associated with attentional processes. Thus, one explanation for the transient interference effect observed in Experiment 3 during randomized picture viewing is that the RT difference may have reflected the additional resources that were recruited by negative pictures. In addition, such attentional effects may underlie the slowing down of RT of the first target-detection trial during blocked picture viewing (Experiments 1, 2, and 4).

An alternative interpretation of the transient interference effect is that it reflected a transient emotional state triggered by the viewing of an unpleasant picture. Indeed, there is evidence that emotional states, as indexed by the startle reflex, can be modulated shortly after viewing an emotional picture. In one study, Larson, Ruffalo, Nietert, and Davidson (2005) presented emotional and neutral pictures while the blink magnitude was recorded at different times after picture onset. For both 300-ms and 6-s picture presentations, they found increased blink magnitude for negative compared to neutral pictures at 1.5 s relative to picture onset. In another study, Volz, Hamm, Kirsch, and Rey (2003) observed larger blink magnitudes when subjects viewed unpleasant relative to neutral pictures even for probes that followed picture onset by only 300 ms. Although short-lived emotional states may have been involved in the transient task interference observed in our studies, we favor an attentional account, given the existence of well-documented effects of emotional stimuli that appear to be mediated by attention.

Unpleasant Stimuli and Sustained Task Interference

Our results revealed a second, more long-lasting interference effect (observed during blocked but not during random presentation conditions) whose origin, we suggest, is not attentional but instead associated with the induction of an emotional state and how the state is linked to approach/withdrawal processes. The unpleasant stimuli employed in the present study consisted of images involving mutilated bodies. Evidence of death, mutilation, and blood of conspecifics is a powerful evoker of fear (Marks, 1987). For instance, primates react with avoidance to signals of mutilation and death of a member of the same species (Hebb, 1949). Rats exhibit strong fearful reactions to blood and muscle exposition of conspecifics, a reaction not observed when tissue of other species is involved (Stevens & Gerzov-Thomas, 1977). Moreover, humans evoke robust physiologic reactions when viewing mutilation pictures (Bradley et al., 2001). More important, in a recent experiment from our group (Azevedo et al., 2005), male subjects viewed the exact *same* sequence of mutilation and neutral pictures as in the present study while posturographic and electrocardiographic recordings were acquired. The results revealed a freezing-like state consisting of immobility, rigidity, and bradycardia when viewing unpleasant relative to neutral pictures. Moreover, these reactions persisted for several seconds and did not recover to basal levels during a 16-s interval that followed the unpleasant blocks. Therefore, even though we did not explicitly assess emotional state in the present experiment, the perceptual conditions associated with the blocked viewing of emotional pictures likely instated a defensive emotional state in the subjects with somatic and vegetative reactions related to freezing. Thus, we suggest that the sustained component of the slowing down of RT during unpleasant blocks was caused by the induction of an emotional state, which was possibly linked to the activation of defensive responses, an interpretation that is consistent with the time course of the slowing down of RT.

Another possible explanation for the long-lasting effects observed in our study relies on the idea that activation of motivational systems prompts *approach* and *avoidance* behavioral tendencies (Lang et al., 2000; Robbins et al., 1998). According to this idea, unpleasant and pleasant pictures would activate avoidance and approach systems, respectively, and such pre-activation would favor motor actions related to the motivational system engaged. For example, Chen and Bargh (1999) revealed that stimulus evaluation resulted in behavioral predispositions toward a stimulus, such that positive evaluations produced approach tendencies and negative evaluations produced avoidance tendencies. Duckworth, Bargh, Garcia, and Chaiken (2002) measured RT to novel stimuli (images and words). Participants in the approach condition were instructed to pull a lever toward them whenever a target appeared, and those in the avoidance condition were instructed to push the lever away from them. Subjects in the approach condition (pull) were faster to positive than to negative novel stimuli, whereas those in the avoidance condition (push) were faster responding to negative than to positive novel stimuli. These authors concluded that just as observed for familiar stimuli (Chen & Bargh, 1999), the evaluation of novel stimuli has immediate and direct consequences for approach and avoidance behavior tendencies. In a related study by Wentura, Rothermund, and Bak (2000), subjects participated in a go/no-go lexical decision task in which they had to withdraw their finger from a pressed key (avoid) or had to press a key (approach) if a word was presented. Responses to negative words were relatively faster in the withdraw condition, whereas responses to positive words were relatively faster in the press condition.

The interpretation of our results in terms of approach and avoidance behaviors predicts that unpleasant pictures should engage the subject in an avoidance-like behavior. The slower RT for unpleasant pictures is consistent with this idea, as the response was emitted by pressing a key, a behavior that may be related to the approach system. Although we did not explicitly test this idea in the present study, the findings by Cacioppo, Priester, and Berntson (1993) revealed a link between the activation of arm flexor muscles and the approach motivational system. Specifically, visual stimuli presented during arm flexion movements were subsequently rated as more positive (*to be approached*) than those presented during arm extension movements (*to be avoided*).

During Experiments 1–3, participants viewed emotional and neutral pictures that were presented for 2 s. It is conceivable that the sustained interference effect that we observed in Experiments 1 and 2 was due to such relatively long exposure duration. To test whether interference would be observed with shorter picture durations, in Experiment 4 participants viewed pictures for 500 ms. The results from Experiment 4 revealed that unpleasant-picture interference for 500-ms pictures was very similar to that observed with longer 2-s stimuli. These findings are consistent with the idea that briefly presented pictures engender affective responses. For instance, similar affective responses, including increased skin conductance responses and corrugator muscle activity, have been observed with brief stimuli (300–500 ms) and while viewing unpleasant pictures for longer (6-s) durations (Codispoti et al., 2001; Larson et al., 2005).

An interesting question for future research concerns the relationship between transient and sustained effects. During randomized conditions (Experiment 3), a "pure" transient effect was observed. However, the interpretation of the interference effect during blocked conditions (Experiments 1, 2, and 4) is less clear cut. One possibility is that both effects would summate such that during blocked conditions, for the first target-detection trial, the interference would correspond to the sum of the slowing down observed in Experiment 3 and that of the later trials (i.e., after the first trial) of Experiments 1, 2, and 4. Such linear combination was not observed, however, as all interference effects were of comparable magnitude; in fact, the slowing down of RT during Experiment 3 (approximately 20 ms) was greater than that of the blocked experiments (11–14 ms). At the moment, we are exploring the possibility that transient and sustained effects can be dissociated based on the pattern of activation during functional magnetic resonance imaging (fMRI).

Pleasant Stimuli and Speeding Up

In Experiment 1, no modulatory effect on visual detection was observed while subjects viewed pleasant erotic images. To test whether the lack of modulation may have been due to the potentially conflicting reactions to viewing erotic images in an experimental setting (Kaviani et al., 1999), in Experiments 2 and 3 we utilized a new category of pleasant images composed of pictures of babies and family interactions, a category which has been shown to be highly pleasant (Bradley et al., 2001). In Experiment 2, pleasant and unpleasant pictures produced opposite modulation on RT with different time courses. During the early block segment, RTs for targets occurring after pleasant pictures were significantly faster than those observed after neutral or unpleasant blocks. During the intermediate segment, responses for targets presented after unpleasant pictures were significantly slower than those generated after pleasant or neutral pictures. Both the increase and the decrease in RT persisted during all target-detection trials. We suggest that the long-lasting increase of speed of RT during the pleasant block may have been due to the activation of appetitive motivational systems (Lang et al., 2000; Robbins & Everitt, 1996). Particularly, pictures of babies and family interactions may be important clues to *inhibit* defense systems and engage in prosocial behavior (Porges, 2003). According to this idea, viewing pleasant pictures would reduce the potential tension state evoked by the experimental setup (resembling the "undoing" role of positive stimulation suggested by Tugade, Frederickson, and Barret [2004]), favoring motor actions related to approach (Cacioppo et al., 1993), and thereby improving task performance.

Additional studies have suggested that mood can improve performance on cognitive tasks. For example, positive mood improves creativity, increases the flexibility with which material can be reinterpreted, and enhances the ability to switch between different cognitive sets (Isen, 1999). Ashby, Isen, and Turken (1999) proposed a neuropsychological theory of the influence of positive affect on cognition. They argued that positive mood results in increased dopamine levels in the brain, particularly in the prefrontal cortex and anterior cingulate, which then results in better cognitive performance on some tasks. Baker, Frith, and Dolan (1997) showed that induced elated mood results in increased cerebral blood flow in a number of regions within the frontal lobes. There is considerable evidence that prefrontal cortex and anterior cingulate are involved in executive functions such as inhibition, task switching, and strategy use (e.g., Cabeza & Nyberg, 2000; Cuenod et al., 1995; Peterson et al., 1999). Thus, it is conceivable that a positive mood instated while viewing positive pictures of babies and families improved the effectiveness with which these processes occur and, therefore, led to an increase in RT for this condition.

Time Course of Modulatory Effects

To evaluate how modulatory effects evolved across time, we subdivided blocks into early, intermediate, and late segments and tested for RT effects for each segment separately. For Experiments 1, 2, and 4, which utilized blocked presentations, the interference produced by unpleasant images appeared to develop across time. Specifically, interference was only observed during intermediate and late segments in Experiment 1 and in the intermediate segment in Experiments 2 and 4. These results appear to suggest that sustained interference builds up across time, further supporting the notion that the effect is caused by the induction of an emotional state, and not attention. A related pattern of sensitization was reported by Bradley and colleagues (1996). In their study, subjects were exposed to blocks of unpleasant, pleasant, or neutral pictures, and the electromyographic activity of the corrugator muscle was shown to increase linearly during the unpleasant condition. More recently, Smith and colleagues (2005) showed that sustained exposure to an unpleasant affective context prompted cumulative effects on the magnitude of the startle eye blink and corrugator responses, supporting a response-sensitization hypothesis. With repeated exposure to different unpleasant exemplars, startle reflexes showed greater potentiation, and corrugator activity increased. In the present study, however, we observed potentiation of an interference effect during a nonemotional, simple visual detection task performed when the affective stimulus was not being displayed. In this context, it is noteworthy that Azevedo and colleagues (2005) revealed a *gradual* slowing of heart rate when subjects viewed the same unpleasant pictures as employed in the present study (the gradual slowdown appeared to asymptote around the fifth or sixth picture presentation). These results suggest a gradual instatement of an emotional state, which may underlie the interference effect observed in the present study. Unlike in Experiment 1, in Experiments 2 and 4, the interference effect appeared to habituate during the late block segment. Additional experiments are needed to further determine the factors that may underlie such potential habituation, such as the longer duration of blocks in Experiment 2 (12 trials followed each picture instead of 6) or the shorter picture duration in Experiment 4 (500 ms instead of 2 s).

Throughout this article, we have probed the time course of modulatory effects in a relatively coarse fashion (via early, intermediate, and late segments). However, additional analyses provide preliminary evidence that a finer temporal evolution may underlie the effect. For instance, Figure 9 shows a fit of the data from Experiment 1 with a model including both a linear and a quadratic component. The linear trend is nearly significant ($p = .06$), and some evidence of a quadratic trend was also evident ($p = .12$; note the leveling of the *increase* in interference for the last half of the block). We suggest that a fruitful strategy for future research will be to investigate these questions in more detail. In particular, the combination of behavioral with physiological and/or neuroimaging data may provide further insights into the mechanisms involved in the build up and habituation of the interference effect.

As stated previously, the time course of the positive modulatory effect differed from the modulation of RT observed during unpleasant conditions. Unlike the interference effect, which appeared to build with time (sustained interference was observed only *after* the initial block segment), sustained increase in speed was observed during the early segment. This result suggests that sustained modulatory effects due to viewing pleasant pictures can occur relatively rapidly. In a related fashion, Smith and colleagues (2005) showed that zygomatic muscle activity was elevated early during blocked picture presentations when viewing pleasant compared to unpleasant pictures. Again, we are currently investigating

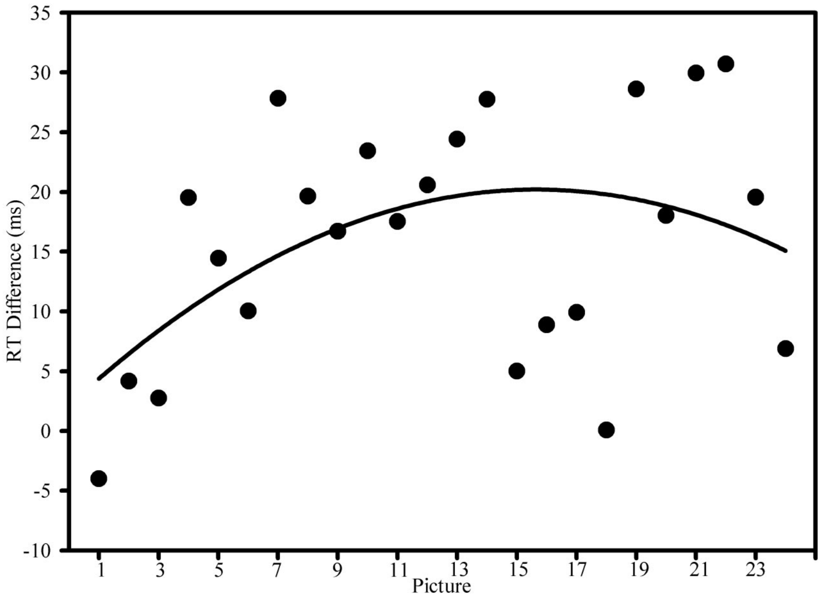

Figure 9. Temporal evolution of interference effect (Experiment 1). RT difference (unpleasant–neutral) is plotted as a function of picture position for the entire block. A near-significant linear trend was observed (p = .06), as well as some evidence of a quadratic trend (p = .12).

with fMRI whether the activation of appetitive and withdrawal systems may underlie the observed differences in time course.

In Experiment 2, we investigated how modulatory effects were affected by repeated experience with the same emotional items by reexposing subjects 24–48 h later to the same stimuli. Upon repeated experience, modulatory effects ceased to occur. In a consistent fashion, in the past, stimulus repetition has been shown to eliminate the differential responses in electrodermal, heart rate, and corrugator muscle responses to emotional and neutral pictures (Bradley, Lang, & Cuthbert, 1993).

Summary

Our findings showed that viewing task-irrelevant emotional pictures modulates RT during a simple, nonemotional visual detection task. Both transient and sustained effects of unpleasant picture viewing were observed. In unblocked viewing conditions (Experiment 3), only a transient effect was observed, namely, the slowing of the first target-detection trial following unpleasant picture offset. The time frame of this interference was at approximately 500–700 ms and is consistent with the effect of increased attentional demands during the processing of unpleasant pictures. Evidence for a sustained effect was revealed during blocked viewing conditions (Experiments 1, 2, and 4). Such sustained interference was not present at the beginning of blocks but instead appeared to build during the block, consistent with the idea that they are linked to the instatement of an emotional state. We hypothesize that the modulation depends on interactions between the affective/motivational system and visuomotor system circuits responsible for the subject's performance in the low-level visual task. Interestingly, in Experiment 2, we also obtained evidence for an increase in speed of RT when subjects viewed pleasant pictures of babies and family interactions. Overall, our results revealed that transient effects, possibly linked to attentional processing, and sustained effects, possibly associated with motivational systems, regulate visuomotor processing. Ultimately, both attentional and motivational systems are intricately tied in the brain (Baxter & Chiba, 1999; Robbins et al., 1998) and, together, determine behavior.

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