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Attentional bias during emotional processing: evidence from an emotional flanker task using IAPS

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Abstract

Attention is biased towards threat-related stimuli. In three experiments we investigated the mechanisms, processes, and time course of this processing bias. An emotional flanker task simultaneously presented affective or neutral pictures from the IAPS database either as central response-relevant stimuli or surrounding response-uninformative flankers. Participants' response times to central stimuli was measured. The attentional bias was observed when stimuli were presented either for 1500 ms (Experiment 1) or 500 ms (Experiment 2). The threat-related attentional bias held regardless of the stimuli competing for attention even when presentation time was further reduced to 200 ms (Experiment 3). The results indicate that automatic and controlled mechanisms may interact to modulate the orientation of attention to threat. The data presented here shed new light on the mechanisms, processes, and time course of this long investigated by still largely unknown processing bias.

Keywords: Attention; emotion; threat-related attentional bias; flanker tasks

Introduction

Attention is oriented towards threat-related stimuli faster than towards neutral stimuli. This processing bias has been observed in experimental settings using different types of stimuli such as pictures, faces, objects, or electrodermal conditioning (Fox & Damjanovic, 2006; Fox, Griggs, & Mouchlianitis, 2007; Koster, Crombez, Van, Verschuere, & de Houwer, 2004a; Ohman & Dimberg, 1978) delivered via different sensory modalities such as visual, auditory, or somatosensory (Hygge & Ohman, 1978; Ohman & Dimberg, 1978; Ohman, Lundqvist, & Esteves, 2001). This response has attracted considerable amount of attention and has been investigated within social, clinical, and cognitive neuroscience. Nevertheless, the actual involvement of attention remains enigmatic and issues such as mechanisms (i.e., controlled vs. automatic), processes (i.e., orienting, engagement, disengagement, avoidance), and time course of attentional events still need further clarification (see Yiend, 2010). The current study was aimed at shedding light on these outstanding issues.

Several behavioural paradigms have been developed to investigate the threat-related attentional bias yet none have fully addressed these knowledge gaps. For example Koster et al. (2004a) used the dot-probe paradigm developed by MacLeod, Mathews, and Tata (1986) to investigate whether highly or mildly threatening affective pictures taken from the International Affective Picture System (IAPS; Lang, Ohman, & Vaitl, 1988), would impact on the attentional control in normal and high anxiety individuals. The authors found a robust effect of threatening pictures (more for highly threatening) on attention in both groups of participants. They interpreted this evidence as a difficulty to disengage attention from threatening pictures (see also Koster, Verschuere, Crombez, & Van Damme, 2005; Tipples & Sharma, 2000; Yiend & Mathews, 2001). However, this paradigm would not inform about mechanisms of attention (i.e., controlled vs. automatic) as the information causing emotional interference falls within the focus of attention and appears earlier than the response-relevant targets, thus not competing for attentional resources (see for example Calvo, Dolores Castillo, & Fuentes, 2006).

Horstmann, Borgstedt, and Heumann (2006) used a flanker task similar to that devised by Eriksen and Eriksen (1974) to investigate the threat-related attentional bias to faces showing different emotional expressions. The authors found that people's responses to central faces (targets) flanked by angry faces were slower than to those flanked by happy or neutral faces. Horstmann and Bauland (2006) argued that this effect represents an adaptive response to stimuli that convey potential threats (see also Dennis, Chen, & McCandliss, 2008). The flanker paradigm would allow investigation of the involuntary orientation of attention (i.e., automatic/bottom-up mechanisms) as threatening stimuli shown as flanking images fall outside the focus of attention. It also allows investigation of the contribution of attention processes such as orienting attention as the emotionally interfering stimuli compete with central targets. By manipulating exposure times, this paradigm would permit investigation of whether attention is exogenously or endogenously oriented towards response-uninformative emotional flankers (Koster, Crombez, Verschuere, Vanvolsem, & De, 2007; Koster et al., 2005). Zhou and Liu (2013) proposed that emotion processing can be influenced both by top-down and bottom-up mechanisms. The saliency of emotional information can render the attentional orienting process less reliant on top-down modulation and more driven by perceptual features of images appearing in the visual field.

The literature reporting on the threat-related attentional bias has been skewed towards research involving people with anxiety traits. Such an effect has often proven larger in people with high anxiety than in those with low anxiety (Bishop, Duncan, Brett, & Lawrence, 2004; de Jong & Martens, 2007; Fox, Derakshan, & Shoker, 2008; Fox, Mathews, Calder, & Yiend, 2007; Fox, Russo, Bowles, & Dutton, 2001; Koster et al., 2005; Vasey, el-Hag, & Daleiden, 1996; Yiend & Mathews, 2001). However, other authors have emphasized that biasing attention to threat is an adaptive response also observed in non-anxious individuals (Bishop, 2008; Koster et al., 2004a; Wilson & MacLeod, 2003). It is therefore necessary to expand the literature on attentional bias and emotional processing in individuals not selected based on anxiety levels.

The present study further investigated the attentional bias during emotional processing by focusing on three main issues. First, it investigated whether response-uninformative threat-related flankers interfere with co-occurring response-relevant central targets, thus suggesting competition for attention. To this aim we used affective pictures of real-life events taken from the IAPS database (Experiments 1 and 2). Second, it investigated the extent to which such a competition for attention is modulated via bottom-up or top-down attentional mechanisms. To this aim the exposure time of the stimuli was manipulated (Experiments 2 and 3). Third, it investigated whether the nature of the information competing for attention may have an impact on the threat-related attention bias. Stimuli from IAPS were presented simultaneously with line drawings of common objects (Experiment 3) shown either as targets or as flankers. Finally, as theories of attention to threat have proposed that this processing bias can be observed in everyone (Bishop, 2008; Koster et al., 2004; Wilson & MacLeod, 2003), participants were not preselected on anxiety levels. We predicted that response-uninformative threat-related flankers taken from IAPS would interfere with response-relevant central targets regardless of the time given to process such stimuli and the type of stimuli competing for attention.

Experiment 1

Aims

Using an emotional flanker task we investigated whether response-uninformative threat-related flankers would interfere with responses to central targets when such stimuli were images taken from the IAPS database.

Methods

Participants

Twenty healthy young volunteers with mean age of 24 (SD = 8) and average education of 15 (SD = 1) were recruited for this experiment. Participants were students enrolled in university courses who took part in the study on volunteer basis. None of them reported psychiatric or neurological problems. In the series of experiments reported here we recruited non-selected samples of undergraduate students who were not chosen based on levels of anxiety. Previous power calculation run with data collected in a pilot study suggested that with samples of around 10 participants we could achieve over 90% power. We therefore aimed at sample sizes of around 20 subjects to control for the variability that could be introduced by the type of stimuli, tasks parameters, and individual differences (see Supplementary Material 1 and 3). They all signed a consent form prior to participation. The study was approved by the University's Ethics Committees.

Task

The stimuli were pictures selected from the IAPS (Lang et al., 1988). Sixty threatening and sixty neutral pictures were selected, according to the normative ratings for valence and arousal. To present the stimuli we created a layout similar to that used by the faces/house matching task (Bishop, Duncan, & Lawrence, 2004a; Vuilleumier, Armony, Driver, & Dolan, 2001; Wojciulik, Kanwisher, & Driver, 1998). In our task we presented a picture as a central stimulus instead of a fixation cross. This layout enables assessment of whether attention is shifted away from the central picture (target) when the surrounding pictures (4 flankers) show emotional information (see Figure 1A). Our task design also resembles the design of the flanker task devised by Eriksen and Eriksen (1974) and adapted by Horstmann and Bauland (2006) to investigate the attentional capture elicited by affective faces. The difference between our current design and that by Horstmann and Bauland (2006) is that in the current task flankers where all around the target rather than aligned to the left and to the right of the target.

If the surrounding stimuli can shift attention away from the focus, this effect would be stronger with the current layout as the distance between flankers and the target will always be the same. One other difference is that in the current task we presented images of real-life events rather than emotional faces. Figure 1A shows the layout used to present stimuli in the current task.

The stimuli were presented on a Personal Computer using an e-prime script devised for this study (Psychology Software Tools Inc., 1996). Screen were placed 60 cm away from participants' eyes. At this viewing distance, the layout subtended 12^{o} horizontally and vertically, with each image subtending 4^{o} and separated from each other by 2^{o}. Using a 2x2 repeated-measures design, the task presented stimuli following four experimental conditions. Images from IAPS could be presented either as Targets or Flankers and they could show either Neutral or Threat-related information. This led to four different combinations of pictures: Target Neutral/Flanker Neutral, Target Threat/Flanker Threat, Target Neutral/Flanker Threat, and Target Threat/ Flanker Neutral. These combinations of pictures resemble those used by Koster, Crombez, Verschuere, and De Houwer (2004b) in a dot-probe task with which the authors investigated the attentional processes underlying the processing bias.

During the task, and at the beginning of each trial, participants were presented with a fixation cross for 1000 ms. The fixation screen was followed by a test display which presented the stimuli using the layout described above. The ratio for trials showing Target Neutral/Flanker Neutral // Target Threat/Flanker Threat and Target

Neutral/Flanker Threat // Target Threat/Flanker Neutral was 50% each. The test display was presented for 1500 ms. Participants were requested to press a key of a standard keyboard of two previously allocated keys, as quickly and accurately as possible, depending on whether the central image showed a "Neutral" or a "Threatening" picture. There was then an inter-trial interval of 2000 ms during which responses were still recorded. Each of the sixty images was used twice as Targets and twice as Flankers. Six practice trials were followed by 240 test trials. Trials belonging to the four combinations described above were fully randomized across participants. Figure 1B shows the trial design of the current task.

Insert Figure 1 A-C about here

Data analysis

The dependent variables were accuracy and response time (RT) which were recorded for each combination of pictures and entered to the analyses separately. However, initial analyses revealed no significant differences when accuracy was entered into the ANOVA model nor was there evidence of speed/accuracy trade-off. Therefore, the analysis presented here focused on RT as the dependent variable. Only correct responses were used to obtain mean RT. Careful inspection of the data (2 SD > mean) did not reveal outliers. A two-way repeated measure ANOVA was used. We label the first repeated measure Position (*Same emotion on both positions*: Target Threat/Flanker

Threat compared to Target Neutral/Flanker Neutral vs. *Different Emotions on each position*: Target Neutral/Flanker Threat compared to Target Threat/ Flanker Neutral). It is worth noting that the effect of Position could also be interpreted as a Congruency effect (Horstmann et al., 2006) in so far as trials showing the "*Same Emotion on both positions*" would be "*congruent*" and those presenting "*Different Emotions on each position*" would be "*incongruent*"[1]. We label the second repeated measure Emotion (*Differential impact of Neutral images:* Target Threat/Flanker Threat compared to Target Threat/ Flanker Neutral vs. *Differential impact of Threatening images:* Target Neutral/Flanker Neutral compared to Target Neutral/Flanker Threat). Identifying the "Targets' Emotional Identity" across different levels of Congruency was the purpose of this factor. The interaction between Position and Emotion would enable investigation of whether detecting the identity of images presented as targets would be differentially affected by the identity of the images presented as flankers. For main effects and interactions we report effect size as informed by eta (η) calculated as $\sqrt{\eta^2}$, (η^2=partial eta-squared provided by SPSS) (see Field, 2013 p. 389 and Leech, Barrett, & Morgan, 2005 p.133). Based on this calculation values of 0.1, 0.24, and 0.31 correspond to small, medium and large effect size. We also calculated power (β). For post-hoc

[1] The main motivation for the series of experiments presented here was not to further investigate the well-known congruency effect during emotional processing (e.g., Horstmann, Borgstedt, & Heumann, 2006). Our interest was to reveal the extent to which responses to targets could be affected by threatening flankers when such stimuli compete for attention under different experimental manipulations. Nevertheless, we acknowledge that in our Experiments 1 and 2, the factor Position assesses an effect akin to that described by Congruency. However, for the sake of consistency across the series of experiments presented here we opted for the term Position rather than Congruency.

analysis the effect size was calculated using the Cohen's *d* (0.2 = small, 0.5 = medium, and 0.8 large) (Cohen, 1988). Significant interactions were further assessed using paired-sample t-tests.

Results

Mean RT data is shown in Figure 2. There was no effect of Position [$F(1,19) = 2.21$, p = ns; η=0.12, β=0.08]. That is, performance was not differentially affected by whether the emotion shown by the target (central position) and that shown by flankers (periphery) were the same or different. Emotion did not have a significant effect [$F(1,19) = 0.28$, p = ns; η=0.32, β=0.29]. This was because the influence of threatening flankers on performance was larger than that of neutral flankers but this effect was the same across the two levels (*Differential impact of Neutral images* vs. *Differential impact of Threatening images*). The Position by Emotion interaction resulted in a significant effect [$F(1,19) = 6.69$, $p = 0.018$, η=0.51, β=0.70].

Paired-sample t-tests performed across Position (i.e., Same emotion on both positions vs. Different Emotions on each position) showed that responses during Target Threat/Flanker Threat trials were significantly slower than during Target Neutral/Flanker Neutral trials ($t(19) = 2.75$, p=0.013; d=0.75). Responses to Target Neutral/Flanker Threat trials were also significantly slower than to Target Threat/ Flanker Neutral trials ($t(19) = 2.40$, p=0.014; d=0.73). This led to a cross-over interaction. The analysis across Emotion (i.e., Differential impact of Threatening images vs. Differential impact of Neutral images) showed that Target Threat/Flanker Threat trials yielded slower RT than Target Threat/ Flanker Neutral trials ($t(19) = 2.41$, $p=0.025$; $d=0.68$). Target Neutral/Flanker Threat trials also resulted in slower RT than Target Neutral/Flanker Neutral trials ($t(19) = 2.70$, $p=0.014$; $d=0.73$). Therefore, these results suggest that when images with threatening value were response uninformative (i.e., flankers), they slowed down responses to targets, an effect that was independent of the content of such targets. Hence, although response uninformative, threat-related flankers seem to be attentionally relevant.

Insert Figure 2 about here

Comments on Experiment 1

The results from Experiment 1 provide support to the hypothesis that response-uninformative threat-related flankers interfere with response-relevant central targets. Buetti, Lleras, and Moore, (2014) argued that the magnitude of such interference may reflect different types of processes e.g., the ability to keep attention on targets while we inhibit a response-related activity elicited by distractors (i.e., because flankers have also appeared as targets). Based on the authors' views, this may result from spatial biasing of response inhibition at the response selection stage (i.e., inhibitory processes fail due to the saliency of the flanker). This suggests that in the context of the flanker task, automatic and controlled process may operate in orchestra. However, the extent to which the interplay of such attention mechanisms (i.e., automatic and controlled) mediated the interfering effect found in Experiment 1 would be difficult to disentangle from these data. It is possible that participants may have voluntarily looked at the threatening flankers. The stimulus presentation time was long enough as to allow for such voluntary shifts (overtly) of attention towards response-uninformative threat-related flankers. In Experiment 2 we explored this hypothesis by reducing the presentation time to 1/3 of that used in Experiment 1. If the threat-related attentional bias seen in Experiment 1 was the result of such overt shifts of attention, thus suggesting a more voluntary response, it should not be observed under this new experimental manipulation.

Experiment 2

Aims

To investigate if the threat-related attentional bias observed in Experiment 1 resulted from the long presentation time of the stimuli which may have enabled voluntary shifts of attention towards the response-uninformative flankers.

Methods

Participants

A new sample of twenty healthy young volunteers with mean age of 22 (SD = 3) and average education of 16 (SD = 3) entered Experiment 2. Participants were students enrolled in University Courses who took part in the study on volunteer basis. None of them reported psychiatric or neurological problems. None had taken part Experiment 1. They all signed a consent form prior to participation.

Task

The same task described in Experiment 1 was used in Experiment 2. The only difference was that in Experiment 2 the test display was presented for 500 ms (see Figure 1B). The other task parameters remained the same as in Experiment 1. The same ANOVA model was used in the data analysis.

Results

There was a marginal effect of Position [$F(1,19)=3.46$, $p=0.078$; $\eta=0.36$, $\beta=0.42$]. Emotion had no significant effects [$F(1,19)=0.006$, $p=0.941$; $\eta=0.0$, $\beta=0.05$]. However, the Position by Emotion interaction resulted in a significant effect [$F(1,19)=5.13$, p=0.035; $\eta=0.46$, $\beta=0.58$].

Paired-sample t-tests performed across Position showed that responses to Target Threat/Flanker Threat trials were significantly slower than to Target Neutral/Flanker Neutral trials ($t(19)=2.75$, $p=0.013$; $d=0.14$). Responses to Target Neutral/Flanker Threat trials were significantly slower that to Target Threat/ Flanker Neutral trials ($t(19)=2.40$, p=0.021; $d=0.14$). The analysis across Emotion showed that Target Threat/Flanker Threat trials and Target Threat/ Flanker Neutral trials did not differ ($t(19)=1.46$, $p=0.161$; $d=0.09$). Target Neutral/Flanker Threat trials attracted slower responses than Target Neutral/Flanker Neutral trials ($t(19)=2.53$, $p=0.021$; $d=0.19$).

Insert Figure 3 about here

Comments on Experiment 2

We predicted that if the threat-related attentional bias seen in Experiment 1 was the result of task allowances which permitted overt shifts of attention, such a response bias would disappear when such allowances are reduced. The results from Experiment 2 did not support this hypothesis. When the presentation time was reduced from 1500 ms to 500 ms, threatening pictures presented as response-uninformative flankers still significantly interfered with attention to central targets. Horstmann and Bauland (2006) found a similar effect using angry faces. Taken together these earlier findings and the findings from Experiments 1 and 2 we may suggest that the threat-related attentional bias is independent of the type stimuli that compete for attention and of time these stimuli remain available on the visual field.

This reinforces the view that the threat-related attentional bias is a robust, automatic, adaptive mechanism (see Calvo et al., 2006). The robustness of such an effect is further supported by the outcomes from these experiments as stimuli presented as flankers are part of the attention set which are also linked to responses and yet they automatically captured attention (see Folk, Remington, & Wright, 1994). The results from Experiment 2 suggest that by reducing processing time both the effect size and power of the threat-related dissociation observed in Experiments 1 was reduced (Exp 1: F=6.69, η=0.51, β=0.70; Exp 2: F=5.13, η=0.46, β=0.58). To test whether the threat-related attentional bias could have been removed by such an experimental manipulation we ran an additional three-way ANOVA adding Experiment as a between-subjects factor. Experiment only yielded a marginal effect [$F(1,38)=4.01$, $p=0.052$; η=0.31, β=0.50]. However, the key Position x Emotion interaction remained significant [$F(1,38)=9.14$, $p=0.004$; η=0.45, β=0.84] and was not significantly modified by Experiment.

A potential explanation for such a change in performance could be that the temporal constraint imposed by the shorter presentation time may have increased visual interference (i.e., increased uncertainty) due to the nature of the information competing for attention. Relying on overt and covert attention mechanisms to simultaneously elicit and inhibit responses to perceptually similar images, such as those drawn from IAPS, may introduce visual interference. If this is the case, increasing distinctiveness between targets and flankers should enhance the threat-related effect even if the time constraints are further increased. The latter would further reduce the possibility of voluntary shifts of attention.

Experiment 3

Aims

To investigate whether visual interference, as imposed by the nature of the information competing for attention, would account for the threat-related attentional bias observed in Experiments 1 and 2 and for the reduction of such a response bias found in the latter experiment. We subjected this hypothesis to investigation in conditions where the possibility to overtly allocate attentional resources to response-uninformative flankers was further controlled by reducing the presentation time to 200 ms.

Methods

Participants

Twenty seven new healthy young volunteers with mean age of 22 (SD = 3) and average education of 14 (SD = 1) entered Experiment 3. Participants were University students who took part in the study on volunteer basis. None of them reported psychiatric or neurological problems. None had taken part Experiments 1 or 2 or in related pilots studies. They all signed a consent form prior to participation.

Task

For Experiment 3 we used the same task structure described in Experiments 1 and 2 (see Figure 1C). Affective pictures were presented together with line drawings of objects belonging to two categories, living (e.g., cat) and non-living (e.g., broom). Objects with naming frequency above 80% were selected from the International Picture Naming Project database - IPNP (Szekely et al., 2004). To keep the number of stimuli balanced across emotional and non-emotional stimulus sets, we chose 60 objects form the IPNP database. Of these, 30 corresponded to living and 30 to non-living objects. The design was similar to that used in Experiments 1 and 2. As the attentional bias to response-informative or uninformative stimuli was the focus of this and previous experiments, we analysed responses when affective pictures (Threat vs. Neutral) were presented as Targets or as Flankers. During the task, participants were instructed to respond to the central images and ignore the flanking images. Two keys of the PC keyboard were allocated to the two response categories (one key for Threating IAPS images/Living Object and other key for Neutral IAPS images /Non-living Objects). A pilot study using coloured doors instead of line drawings of objects confirmed that the results reported here would unlikely be accounted for by participants' propensity to associate categories by mapping them to keys (e.g., living/threat; see Supplementary Material 1). In Experiment 3 we further reduced the stimulus presentation time to 200 ms. This presentation time would make it difficult to voluntarily shift attention towards the distracting flankers.

Analysis

For Experiment 3 we followed the same methodological approach of Experiments 1 and 2. The effect of Object Category (i.e., Living vs. non-Living) did not prove significant [$F(1,28) = 1.34$, $p=0.256$; $\eta=0.21$, $\beta=0.20$] nor did it modify the key interactions reported here. We therefore collapsed responses across these stimuli and refer to them as "Object" in the following analysis. There were two repeated measures. The first repeated measure was Position (*Neutral as Target and Flanker*: Target Neutral/Flanker Object compared to Target Object/Flanker Neutral vs. *Threat as Target and Flanker*: Target Threat/Flanker Object compared to Target Object/Flanker Threat).

As in Experiment 3 the target could show either images from IAPS or emotionally irrelevant line drawing of objects, instead of Emotion we called the second factor Target Identity (*Emotion as Targets*: Target Neutral/Flanker Object compared to Target Threat/Flanker Object vs. *Objects as Targets:* Target Object/Flanker Neutral compared to Target Object/Flanker Threat). As for Experiments 1 and 2, the interaction between Position and Target Identity would enable investigation of whether detecting the identity of images presented as Targets would be differentially affected by the identity the images presented as Flankers when these images hold completely different perceptual properties. The other aspects of the analysis were identical to those described in Experiment 2. Additionally, we calculated an Emotional Interference Score based on analytic strategies reported in previous studies (Dennis et al., 2008; Thomas, Gonsalvez, & Johnstone, 2013). For Experiments 1 and 2 the score was calculated as the absolute difference in RT in Target Neutral/Flanker Threat - Target Neutral/Flanker Neutral trials. For Experiment 3 the score was calculated as the absolute difference in RT in Target Object/Flanker Threat - Target Object/Flanker Neutral trials. We compared these scores across Experiments using a one-way ANOVA model. We also calculated the effect size (Cohen's *d*) of the discrepancies yielding these scores.

Results

Mean RT data is shown in Figure 4A. There was a significantly large effect of Position [$F(1,26) = 23.38$, $p<0.001$; $\eta=0.69$, $\beta=1.0$]. Target Identity yielded no significant effects

[F(1,26) = 0.89, p=0.353; η=0.18, β=0.15]. The Position x Target Identity interaction resulted in a significantly large effect [F(1,26) = 13.62, p=0.001; η=0.59, β=0.94].

Paired-sample t-tests performed across Position showed that Target Neutral/Flanker Object trials attracted slower responses than Target Object/Flanker Neutral (t(26) = 7.79, p < 0.001; d=0.54). Target Threat/Flanker Object did not differ from Target Object/Flanker Threat (t(26) = 0.88, p =0.386; d=0.08). Paired-sample t-tests performed across Target Identity showed that Target Object/Flanker Threat trials attracted significantly slower responses than Target Object/Flanker Neutral trials (t(26) = 2.32, p =0.029; d=0.16). Target Neutral/Flanker Object trials resulted in slower RT than Target Threat/Flanker Object trials (t(26) = 2.43, p =0.022; d=0.27). In sum, and in line with the results form Experiments 1 and 2, we have found two relevant effects: (1) faster RT when targets are threatening compared to when they are neutral (in both cases flanked by Objects) and 2) slower RT when Objects are flanked by threatening than by neutral images. Of note, such an effect held even when images were presented for only 200 ms.

The results from the analysis of the Emotional Interference Score are shown in Figure 4B. There was a significant effect of Experiment [F(2,64) = 16.84, p<0.001]. Post-hoc contrasts revealed that the Interference Score was significantly larger in Experiment 1 than in both Experiments 2 (Mean Difference=175.60, p<0.001) and 3 (Mean Difference=184.65, p<0.001). The Interference Score did not differ across Experiments 2 and 3 (Mean Difference=9.04, p=ns). The effect size of the discrepancies yielding these scores (see analysis above) decreased from Experiment 1 to 2 and remained stable in Experiment 3.

Insert Figure 4 A and B about here

General Discussion

This study was set out to investigate whether the threat-related attentional bias reported in the literature could be observed with an emotional flanker task that (1) simultaneously presented response-relevant (targets) and response-uninformative stimuli (flankers) which competed for attention, (2) that manipulated both the exposure time of the stimuli and the nature of the information competing for attention, and (3) that was applied to subjects not preselected on anxiety levels. Based on these experimental manipulations we predicted that the emotional flanker task presented here would shed light on the mechanisms and processes of attention involved in the threat-related attentional bias as well as on the time course of this effect. Our key findings indicate that response-uninformative flankers presenting threat-related information do interfere with response-relevant targets across a range of presentation times which posed different constraints on overt attention mechanisms. Moreover, such an effect was found regardless of the nature of the information presented by these competing stimuli. We discuss the implications of these findings in turn.

The emotional flanker task presented here offers a rather naturalistic approach to investigate the well-known threat-related attentional bias. This task presents information competing for attention in a way akin to daily living experiences. When navigating crowded spaces, our visual system is constantly bombarded with inputs which we filter and process online extracting meaningful information which holds survival value. The emotional flanker task assesses the individuals' ability to keep attention on targets while they inhibit the influence of threat-related flankers. In a series of experiments we found that healthy subjects not preselected on anxiety levels display a threat-related attentional bias whether or not the time images remain visible enable shifting attention overtly. This suggests that such an adaptive response is triggered by automatic mechanisms which can then activate top-down functions responsible for orientating attention (see Calvo et al., 2006). Zhou and Liu (2013) proposed that emotion processing can be influenced both by attentionally controlled and automatic mechanisms. Here we show that the influence of threat-related stimuli is completely unrelated to what a person is gazing at (Folk et al., 1994). In the series of experiments presented here and in the pilot study shown in Supplementary Material 1, we have demonstrated that it would not matter whether we are gazing at coloured doors, line drawings of objects from different semantic categories, or real life scenes. As long as the distracting information holds threatening value, it would disrupt attention significantly. We have also shown that the threat-related bias observed with the emotional flanker task reported here does not seem to be accounted for by the different cognitive demands of the stimuli competing for attention (see

Supplementary Material 2). The saliency of emotional information (as it happens with threating flankers) can render the process of orienting attention less reliant on top-down modulation and more driven by perceptual features of images appearing in the visual field. Based on the experiments presented here this seems to be the case when time constraints prevent overtly attending to response-uninformative threat-related flankers. However, when time allows for overtly shifting attention, top-down mechanisms may be subsequently triggered. It seems plausible to think that the threat-related attentional bias is automatically initiated but can be purposely kept. The emotional flanker task suggests that is the saliency of emotional information what triggers such a bias as this effect was not found when non-threating stimuli flanked response-relevant targets. Detecting/ saliency is in fact one of the main purposes of emotional processing (Faucher & Tappolet, 2002).

The analysis of the Emotional Interference Score provided interesting clues about the mechanisms subserving the threat-related attentional bias. The effect was larger when images from IAPS competed for attention in conditions of long presentation times. When the presentation time was severely reduced, the magnitude of the effect dropped but it remained significant regardless of the nature of the information competing for attention. This temporal constancy of the threat-related attentional bias has been previously found in non-clinical anxiety samples using words rather than real life scenes presented in an attentional cueing paradigm (Mogg, Bradley, de Bono, & Painter, 1997). However, the attentional cueing paradigm not always seems to yield these outcomes. Using natural scenes from IAPS as cues, Koster et al. (2007) reported the threat-related attentional bias only when they were presented for 100 ms but not for shorter (28 ms) or longer (200 or 500 ms) periods of time. Therefore, the attentional cueing paradigm seems to be sensitive to the nature of the cueing information, a feature not shared by the emotional flanker task reported here. We observed the attentional bias with presentation times similar to those used by Mogg et al. (1997). A potential reason for the robustness of the effect found with the emotional flanker task may be the way the attentional bias is elicited by this task. Whereas the attentional cueing paradigm probes processes responsible for the engagement/disengagement of attention, the emotional flanker task probes the mechanisms responsible for orienting attention in conditions of interference. That is, it informs about the outputs of the competition between top-down and bottom-up mechanisms. The former facilitates attentional engagement towards Targets and inhibits attentional shifts towards response-irrelevant flankers whereas the latter drives attention towards response-uninformative flankers due to the saliency of the emotional information competing for attention (Cisler & Koster, 2010; Faucher & Tappolet, 2002; Zhou & Liu, 2013). Another interesting aspect to highlight from the Emotional Interference Score is the observation that such score did not differ between Experiments 2 and 3. In the introduction of Experiment 3, we predicted that reducing visual interference (Experiments 1 and 2: Targets and Flankers all from IAPS images; Experiment 3: IAPS images competed with line drawing of objects – see also Supplementary Material 1 and 2) would enhance the threat-related effect even if the demands imposed by temporal constraints were further increased. Our data suggest that by making the competing stimuli perceptually more distinct but reducing their encoding time, the emotional flanker task yields Emotional Interference Scores similar to those found in conditions where the task presents less perceptually distinct stimuli which can be encoded for longer.

Finally, in addition to the temporal constancy of the threat-related attentional bias elicited by the emotional flanker task we also observed a stimulus-invariance property of this effect. The threat-related attentional bias has been reproduced with a wide variety of threatening stimuli such as pictures, faces, objects, or electrodermal conditioning (Fox & Damjanovic, 2006; Fox et al., 2007; Koster et al., 2004; Ohman & Dimberg, 1978). However, tasks traditionally used to investigate the attentional bias to emotional stimuli (e.g., attentional cueing tasks, faces/house matching task) were not designed to assess competition for attention between central targets and peripheral flankers (e.g., Bishop, 2008; Koster et al. 2004 a & b; MacLeod et al., 1986; Vuilleumier et al., 2001; Wojciulik et al., 1998) and those that did (Fenske & Eastwood, 2003; Horstmann et al., 2006), have not assessed competition between different types of information. In the series of experiments presented here we have shown that, in the context of the emotional flanker task, the attentional bias to threat-related stimuli is stimulus invariant. This reinforces our view about the naturalistic approach of this task to assess such an effect as this would be what we expect in real life situations. While navigating and exploring natural environments, it would not matter whether we are gazing at the colour of a pair of shoes, the items on an advertisement, or a car accident, if threat-related events unexpectedly approach they would trigger this adaptive response which holds important survival value. In addition to informing about the mechanisms of attention underlying the threat-related attentional bias, these properties of the emotional flanker task open new opportunities to investigate the integrity of the emotional processing system in the context of psychopathology.

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References

Bishop, S. J. (2008). Neural mechanisms underlying selective attention to threat. *Annals of the New York Academy of Sciences, 1129*, 141-152.

Bishop, S. J., Duncan, J., & Lawrence, A. D. (2004a). State anxiety modulation of the amygdala response to unattended threat-related stimuli. *Journal of Neuroscience, 24*, 10364-10368.

Bishop, S. J., Duncan, M., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: controlling attention to threatrelated stimuli. *Nature Neuroscience, 7*, 188.

Calvo, M. G., Dolores Castillo, M., & Fuentes, L. J. (2006). Processing of "unattended" threat-related information: Role of emotional content and context. *Cognition and Emotion*, *20*, 1049-1074.

Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*, 203-216.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

de Jong, P. J., & Martens, S. (2007). Detection of emotional expressions in rapidly changing facial displays in high- and low-socially anxious women. *Behaviour Research and Therapy, 45*, 1285-1294.

Dennis, T. A., Chen, C. C., & McCandliss, B. D. (2008). Threat-related attentional biases: an analysis of three attention systems. *Depression and Anxiety, 25*, E1-E10.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*, 143-149.

Faucher, L., & Tappolet, C. (2002). Fear and the focus of attention. *Consciousness & Emotion, 3*, 105-144.

Fenske, M. J., & Eastwood, J. D. (2003). Modulation of focused attention by faces expressing emotion: evidence from flanker tasks. *Emotion, 3*, 327-343.

Field, A. (2013). Discovering statistics using IBM SPSS Statistics (Fourth ed.). London: Sage.

Folk, C. L., Remington, R. W., & Wright, J. H. (1994). The structure of attentional control: contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology. Human Perception and Performance*, *20*, 317-329.

Fox, E., & Damjanovic, L. (2006). The eyes are sufficient to produce a threat superiority effect. *Emotion, 6*, 534-539.

Fox, E., Derakshan, N., & Shoker, L. (2008). Trait anxiety modulates the electrophysiological indices of rapid spatial orienting towards angry faces. *Neuroreport, 19*, 259-263.

Fox, E., Griggs, L., & Mouchlianitis, E. (2007). The detection of fear-relevant stimuli: are guns noticed as quickly as snakes? *Emotion, 7*, 691-696.

Fox, E., Mathews, A., Calder, A. J., & Yiend, J. (2007). Anxiety and sensitivity to gaze direction in emotionally expressive faces. *Emotion, 7*, 478-486.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology. General, 130*, 681-700.

Horstmann, G., & Bauland, A. (2006). Search asymmetries with real faces: testing the anger-superiority effect. *Emotion, 6*, 193-207.

Horstmann, G., Borgstedt, K., & Heumann, M. (2006). Flanker effects with faces may depend on perceptual as well as emotional differences. *Emotion, 6*, 28-39.

Hygge, S., & Ohman, A. (1978). Modeling processes in the acquisition of fears: vicarious electrodermal conditioning to fear-relevant stimuli. *Journal of Personality and Social Psychology, 36*, 271-279.

Koster, E. H., Crombez, G., Van, D. S., Verschuere, B., & De Houwer, H. J. (2004a). Does imminent threat capture and hold attention? *Emotion, 4*, 312-317.

Koster, E. H., Crombez, G., Verschuere, B., & De Houwer, J. (2004b). Selective attention to threat in the dot probe paradigm: differentiating vigilance and difficulty to disengage. *Behaviour Research and Therapy, 42*(10), 1183-1192.

Koster, E. H., Crombez, G., Verschuere, B., Vanvolsem, P., & De, H. J. (2007). A time-course analysis of attentional cueing by threatening scenes. *Experimental Psychology, 54*, 161-171.

Koster, E. H., Verschuere, B., Crombez, G., & Van Damme, S. (2005). Time-course of attention for threatening pictures in high and low trait anxiety. *Behaviour Research and Therapy, 43*, 1087-1098.

Lang, P. J., Ohman, A., & Vaitl, D. (1988). *The International Affective Picture System (photographic slides)* Gainesville: The Center for Research in Psychophysiology, University of Florida.

Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). SPSS for Intermediate Statistics: Use and Interpretation. london (Second ed.). London: Lawrence Erlbaum Associates.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal Abnormal Psychology, 95*, 15-20.

Mogg, K., Bradley, B. P., de, B. J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy, 35*, 297-303.

Ohman, A., & Dimberg, U. (1978). Facial expressions as conditioned stimuli for electrodermal responses: a case of "preparedness"? *Journal of Personality and Social Psychology, 36*, 1251-1258.

Ohman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: a threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*, 381-396.

Psychology Software Tools Inc. (1996). E-Prime (Version 1.1.4.15) Psychology Software Tools. Retrieved from http://www.pstnet.com/products/e-prime/

Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D. et al. (2004). A new on-line resource for psycholinguistic studies. *Journal of Memory and Language, 51*, 247-250.

Thomas, S. J., Gonsalvez, C. J., & Johnstone, S. J. (2013). Neural time course of threat-related attentional bias and interference in panic and obsessive-compulsive disorders. *Biological Psychology, 94*, 116-129.

Tipples, J., & Sharma, D. (2000). Orienting to exogenous cues and attentional bias to affective pictures reflect separate processes. *British Journal of Psychology, 91*, 87-97.

Vasey, M. W., el-Hag, N., & Daleiden, E. L. (1996). Anxiety and the processing of emotionally threatening stimuli: distinctive patterns of selective attention among high- and low-test-anxious children. *Child Development, 67*, 1173-1185.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron, 30*, 829-841.

Wilson, E., & MacLeod, C. (2003). Contrasting two accounts of anxiety-linked attentional bias: selective attention to varying levels of stimulus threat intensity. *J Abnormal Psychology, 112*, 212-218.

Wojciulik, E., Kanwisher, N., & Driver, J. (1998). Covert visual attention modulates face-specific activity in the human fusiform gyrus: fMRI study. *Journal of Neurophysiology, 79*, 1574-1578.

Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology, 54*, 665-681.

Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition and Emotion*, *24*, 3-47.

Zhou, P., & Liu, X. (2013). Attentional modulation of emotional conflict processing with flanker tasks. *PLoS.One.*, *8*, e60548.

Figure Captions

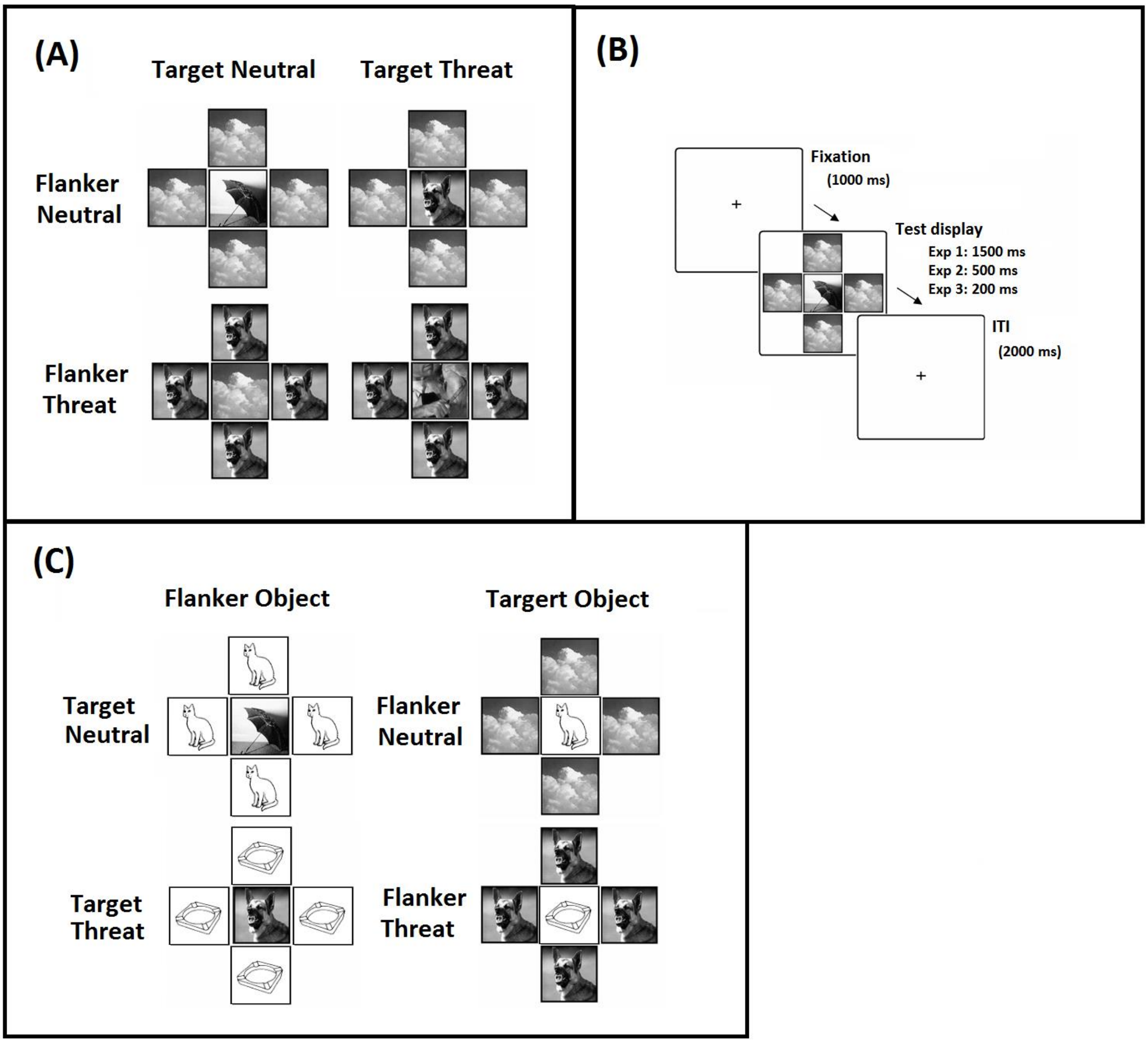
Figure 1. **(A)** Stimuli layout and types of trial used in Experiments 1 and 2. **(B)** An example trial of the emotional flanker task illustrating the trial sequence. **(C)** Stimuli layout and types of trial used in Experiments 3.

Figure 2. Mean RT data from Experiment 1 (Error Bars = (95% CI for the interaction).

Figure 3. Mean RT data from Experiment 2 (Error Bars = 95% CI for the interaction).

Figure 4. **(A)** Mean RT data form Experiment 3 (Error Bars = 95% CI for the interaction). **(B)** Analysis of the Emotional Interference Score in three experiments (see Analysis section above for a description). The statistics shown underneath reflects the outcomes from the paired-sample t-tests contrasting RT to the relevant conditions that yielded this score across the different experiments reported here.

Figure 1.



(A)
Target Neutral
Target Threat
Flanker Neutral
Flanker Threat
(B)
Fixation
(1000 ms)
Test display
Exp 1: 1500 ms
Exp 2: 500 ms
Exp 3: 200 ms
ITI
(2000 ms)
(C)
Flanker Object
Targert Object
Target Neutral
Target Threat
Flanker Neutral
Flanker Threat

Figure 2.

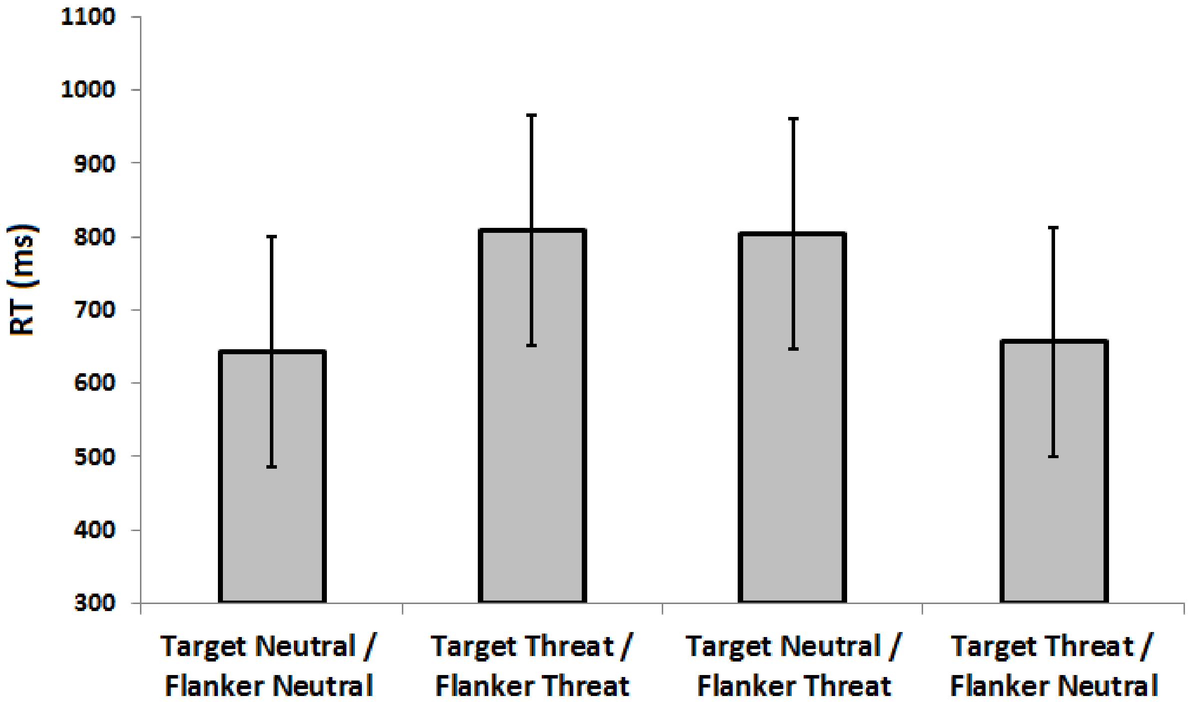

1100
1000
900
800
700
600
500
400
300
RT (ms)
Target Neutral / Flanker Neutral
Target Threat / Flanker Threat
Target Neutral / Flanker Threat
Target Threat / Flanker Neutral

Figure 3.

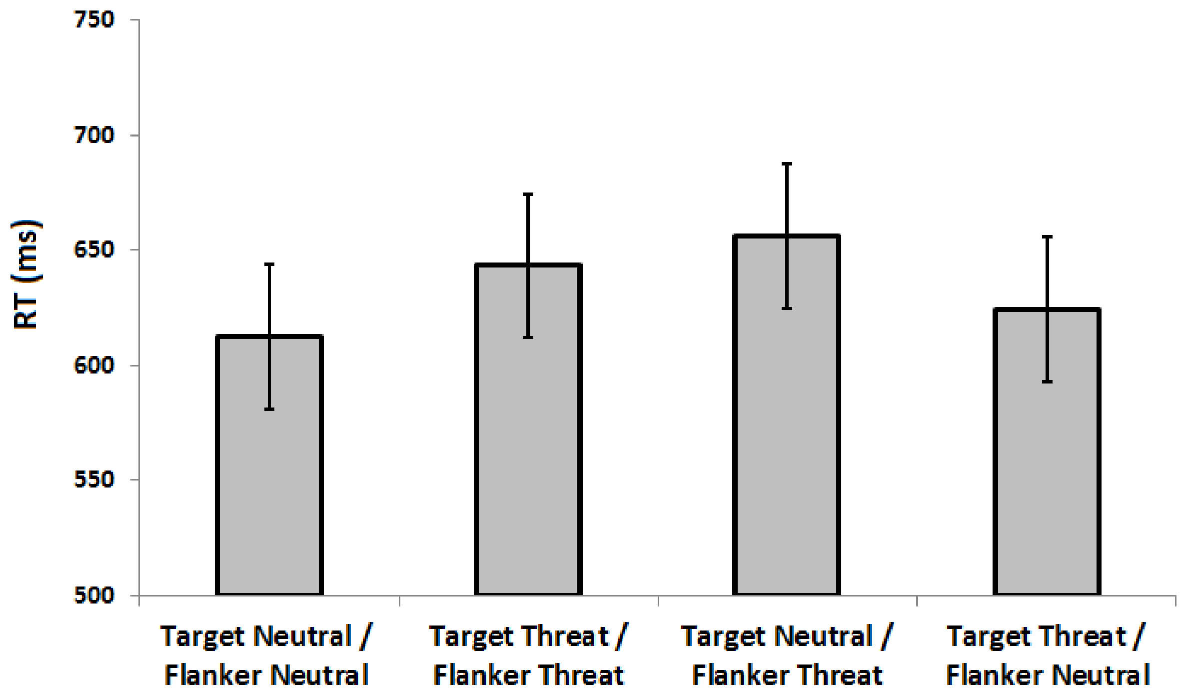
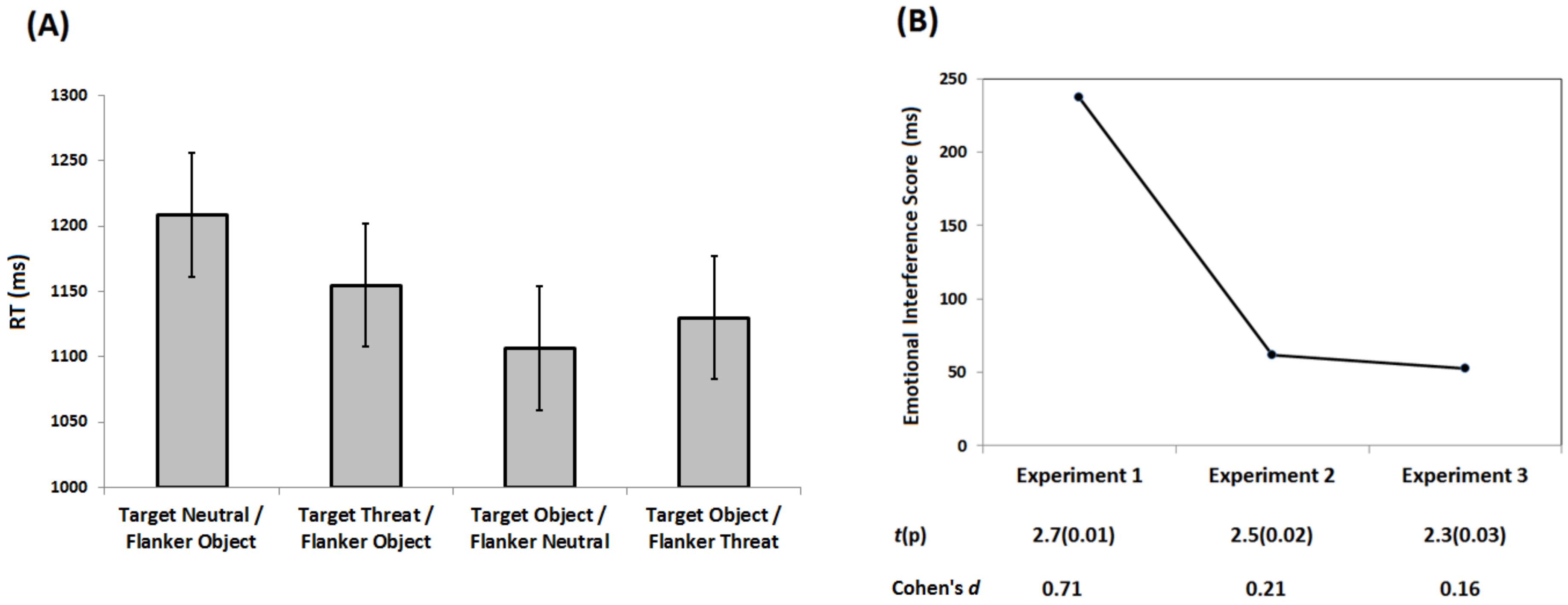

750
700
650
600
550
500
RT (ms)
Target Neutral / Flanker Neutral
Target Threat / Flanker Threat
Target Neutral / Flanker Threat
Target Threat / Flanker Neutral

Figure 4.


(A)
1300
1250
1200
1150
1100
1050
1000
RT (ms)
Target Neutral / Flanker Object
Target Threat / Flanker Object
Target Object / Flanker Neutral
Target Object / Flanker Threat
(B)
250
200
150
100
50
0
Emotional Interference Score (ms)
Experiment 1
Experiment 2
Experiment 3
t(p)
2.7(0.01)
2.5(0.02)
2.3(0.03)
Cohen's d
0.71
0.21
0.16

Supplementary Material 1

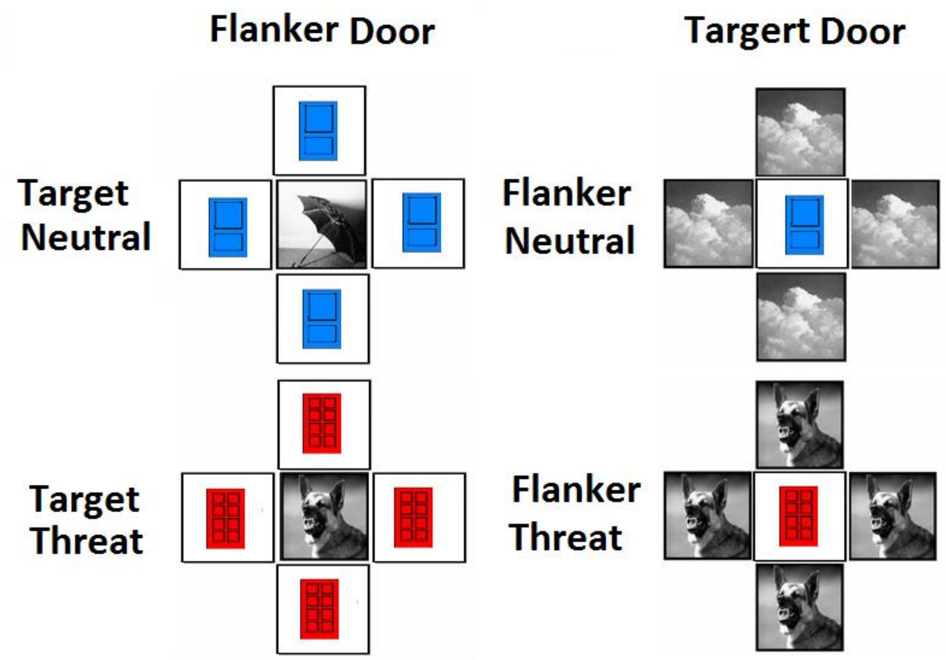
Pilot study using coloured doors as stimuli competing for attention

Participants

Twenty six healthy young volunteers with mean age of 24 (SD = 8) and average education of 14 (SD = 2) took part in a pilot study. Participants were college students who took part in the study on volunteer basis. None of them reported psychiatric or neurological problems, or symptoms of anxiety. They all signed a consent form prior participations.

Task

The structure of the task used in this pilot study is the same to that described in Experiment 1 of the manuscript. The affective pictures were presented together with drawing of different doors which were either blue or red. This led to four different combinations of pictures: Target Neutral/Flanker Door; Target Threat/ Flanker Door; Target Door/Flanker Threat; and Target Door/ Flanker Neutral. Participants were instructed to respond to the central images. If these were doors, they had to decide whether they were red or blue and press one of two keys of the keyboard (with colour stickers). If the central stimuli were pictures, participants had to decide whether they show Threatening or Neutral images. The colour stickers were labelled as to match the responses to the affective picture (“T” or “N”). Participants were instructed to response as quickly as possible and with accuracy. For the analysis of the RT data, a two-way repeated measure ANOVA with the factors Position (Target vs. Flanker: Neutral as Target and Flanker-> Target Neutral/Flanker Doors and Target Doors/Flanker Neutral vs. Threat as Target and Flanker -> Target Threat/Flanker Doors and Target Doors/Flanker Threat). The second repeated measure was Emotion (Neutral vs Threat: Emotion as Target -> Target Neutral/Flanker Doors and Target Threat/Flanker Doors vs. Emotion as Flanker -> Target Doors/Flanker Neutral and Target Doors/Flanker Threat).

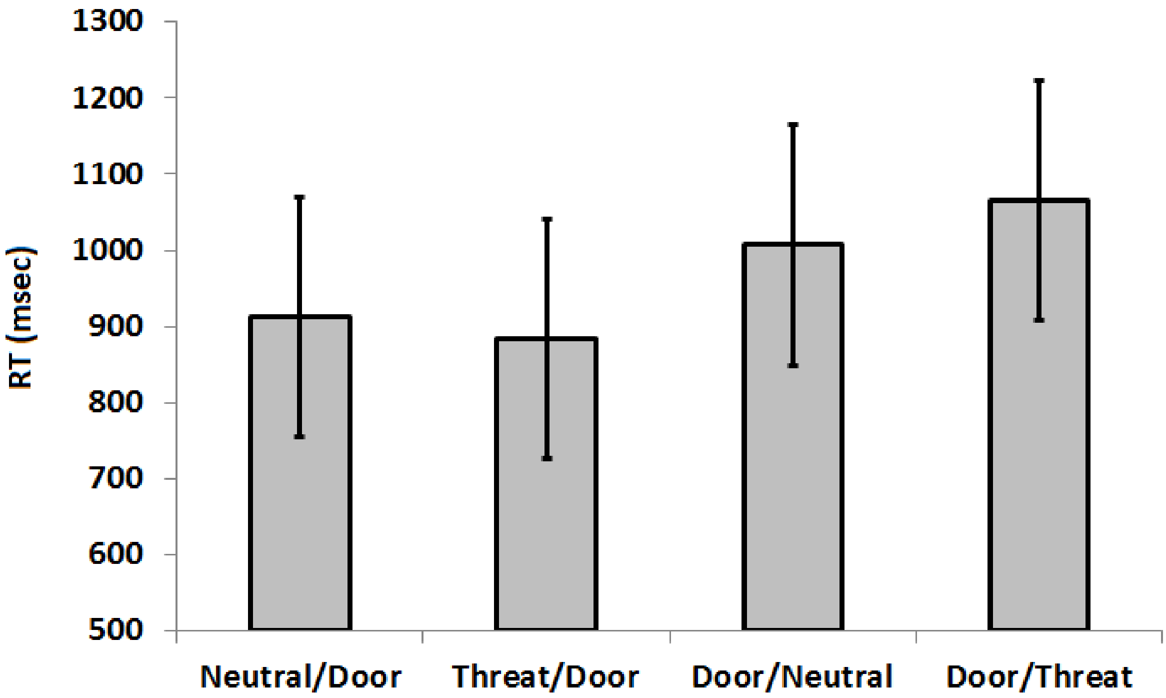


Supplementary Figure 1. Example of the Emotional Flanker Task using doors.

Results

Mean RT data is shown in Supplementary Figure 2, left panel. There was an effect of Position [$F(1,25) = 66.59$, $p<0.001$; $\eta^2=0.73$, $\beta=1.0$]. Emotion was non-significant [$F(1,25)$

= 1.32, p=0.262; η^2=0.05, β=0.19]. The Position x Emotion interaction was significant [F(1,25) = 18.28, p<0.001; η^2=0.425, β=0.98]. Paired-sample t-tests demonstrated that Target Door/Flanker Threat were reacted to slower than Target Door/ Flanker Neutral (t(25) =2.73, p=0.013; d=0.20). Target Neutral/Flanker Door trials attracted slower responses than Target Threat/ Flanker Door (t(25) = 2.95, p=0.007; d=0.13).



Supplementary Figure 2. Mean RT data from the Pilot Experiment.

Comments on the pilot data

These results revealed the effect that was further investigated in the series of experiments presented in the manuscript. In the context of this supplementary information it is used to support the view that interference between competing information should not be the mechanism underlying the threat-related attentional bias observed in our experimental series nor could it be attributed to mapping responses to specific keys. When the threat-related stimuli presented as flankers competed with drawing of coloured doors, the threat-related attentional bias further explored in this series of experiments was observed. However, due to the high frequency of presentation of the stimuli within the colour category, this pilot data alone cannot entirely rule out some form of categorical association between colour-emotion. This possibility was further investigated in Experiment 3.

Supplementary Material 2

Assessing task demands across stimulus categories (Doors vs IAPS Images / Objects vs IAPS Images)

Doors vs IAPS Images (Pilot Experiment)

To investigate whether the two tasks (door-based decisions and IAPS images -based decisions) differ in their cognitive demands we compared accuracy data from trials Target Door/Flanker Threat vs Target Threat/ Flanker Door and Target Door/ Flanker Neutral vs. Target Neutral/Flanker Door. None of these contrasts proved significant ($t(25) = 1.87$, p=0.072; d=0.31 and $t(25) = 0.0$, p=1.00; d=0.00, respectively).

Objects vs IAPS Images (Experiment 3 of the manuscript)

As for doors, we also subjected line drawings of objects to the same query. We compared accuracy data from trials Target Object/Flanker Threat vs Target Threat/Flanker Object and Target Object/Flanker Neutral vs. Target Neutral/Flanker Object. Target Object/Flanker Threat vs Target Threat/Flanker Object yielded no significant differences ($t(25) = 0.915=4$, $p=0.368$; $d=0.17$). Target Object/Flanker Neutral vs. Target Neutral/Flanker Object showed significant differences ($t(25) = 4.96$, $p<0.001$; $d=0.70$). To investigate if this was solely due a greater difficulty to evaluate neutral images relative to line drawings of objects we also contrasted trials Target Neutral/Flanker Object vs. Target Threat/Flanker Object. This contrast showed a significant difference ($t(25) = 4.46$, $p<0.001$; $d=0.82$). Neutral images attracted less accurate responses.

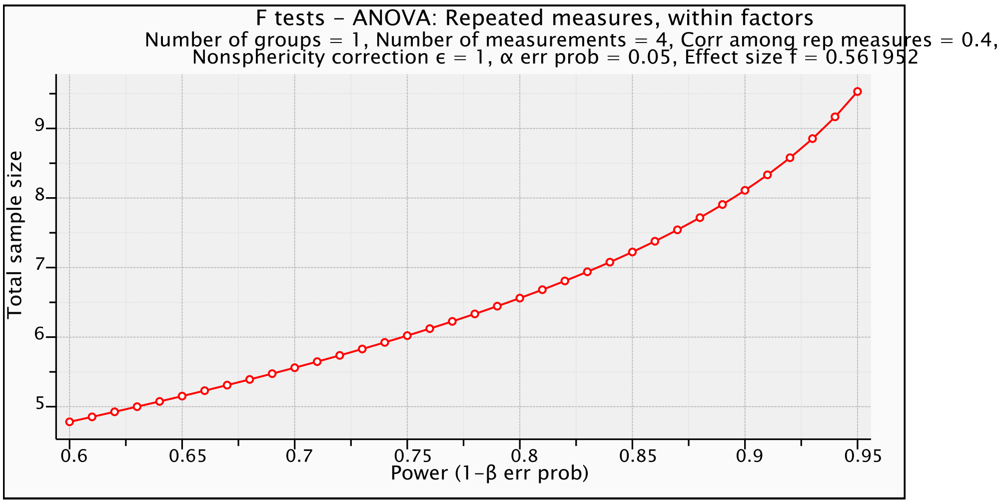
Comments

This pattern of performance based on accuracy data suggests that different levels of cognitive demands as informed by Object/Door based decision relative to IAPS images based decisions would unlikely explain the relevant interactions described in the series of experiments reported in our manuscript. It is worth remembering that the patterns of interaction reported in these experiments were driven by response time not by accuracy.

Supplementary Material 3

Power and Sample Size Calculation

We used the data collected in the pilot study to estimate the sample size that would be needed to further investigate the interaction described above (Supplementary Material 1) aiming at 80% power, medium effect size (η^2=0.24), a modest correlation (r=0.4), and α = 0.05.



The results indicate that with around 10 subjects we would achieve above 95% Power. The calculated critical *F* for the interaction was 3.16. As our analysis across the series of experiments showed, this value was always outreached.