



Attentional disengagement is modulated by the offset of unpleasant pictures: a saccadic reaction time study

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ABSTRACT

We studied the influence of passively viewing a picture on saccade latencies to peripheral targets. Thirty-two volunteers were instructed to look at a central picture, wait for the onset of a peripheral target, and execute a saccade toward it as quickly as possible – saccadic reaction time (SRT). The central picture (neutral or unpleasant) could be turned off simultaneously with target onset (the no-gap condition) or 200 ms prior to target onset (the gap-200 condition). We found that saccade latencies were influenced by emotional valence and condition. In the no-gap condition, SRTs were longer after viewing unpleasant pictures. In the gap-200 condition, the pattern was reversed, and unpleasant pictures induced shorter SRTs in relation to neutral pictures. Furthermore, the influence of unpleasant pictures gradually decreased when images were re-exposed to the participants – affective habituation. The results are discussed in terms of attentional avoidance and disengagement from unpleasant emotional pictures.

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1. Introduction

The complex environment in which we live makes distinguishing relevant from irrelevant information necessary. Selective attention limits neural processing to items that are currently relevant to behavior. Controlled (or voluntary) attention is always selecting relevant information in the environment for a fast and accurate processing. However, despite our volitional efforts, some stimuli, due to their intrinsic “saliency” are able to draw automatically the attention, creating a tendency to direct our eyes to them. It occurs due to the strong link between the attentional and the eye movement systems (Rizzolatti et al., 1987; Sheliga et al., 1994; Corbetta et al., 1998). In this sense, a considerable number of studies have shown that emotional stimuli are prioritized in perception, and have investigated the mechanisms by which affective

information interferes on the deployment of attention (e.g., Erthal et al., 2005; Pereira et al., 2006, 2010). Behavioral and event-related potential studies have confirmed the link between emotion and attention, the so-called attentional bias of emotional stimuli (Carretié et al., 2001; Öhman et al., 2001; Smith et al., 2003; Calvo and Lang, 2004; Mogg and Bradley, 2006). These studies tested the capability of emotional stimuli to capture/engage attention and attentional dwell time (i.e., the ability to disengage attention from affective stimuli). Some authors found that interference is at least partially attributable to a facilitation of engagement/orienting by affective stimuli (Calvo and Lang, 2004; Mogg and Bradley, 2006; Nummenmaa et al., 2006). Other studies, however, have suggested that attentional bias to emotional stimuli is mainly caused by an increase in attentional dwell time or impaired disengagement from affective stimuli (Fox et al., 2001, 2002). Finally, some studies have found that both mechanisms occur and contribute to attentional bias, i.e., the vigilance-avoidance pattern (Koster et al., 2005, 2006; Pflugshaupt et al., 2005; Rinck and Becker, 2006; for a recent review, see Cisler and Koster, 2010).

Despite the strong link between attention and eye movement, only more recently some authors introduced eye movements as a tool to assess the relationship between attention and emotion. Calvo and Lang (2004) and Nummenmaa et al. (2006) showed that emotional pictures capture overt visual attention. Under free-viewing conditions, the probability of first saccades and gaze duration were higher for

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emotional stimuli, especially unpleasant ones, than for neutral stimuli. Interestingly, Nummenmaa et al. (2006) also showed that even under competing task instructions (“fixate the neutral picture of two exemplars first”) the emotional pictures were looked at first more frequently and for a longer period of time than the neutral pictures.

More recently, the gap paradigm was used to investigate the relationship between emotion and attention. In the gap paradigm, the fixation point is turned off 200 ms before target onset, reducing saccadic reaction time (SRT) — *i.e.*, the gap effect (Saslow, 1967). This reduction in SRTs was also accompanied by a new peak of saccades with very short latencies in the SRT distribution, the so-called “express saccades” (*e.g.*, Fischer and Weber, 1993). When the gap interval was varied, saccade latencies showed a U-shaped function with a minimum around gap durations of 200 ms: shorter or longer gap intervals did not produce the same amount of facilitation and reduced the occurrence of the express saccades (Braun and Breitmeyer, 1988; Mayfrank et al., 1986). This facilitatory influence has been mainly attributed to the disengagement of attention from the fixation point (for review, see Jin and Reeves, 2009). Thus, using the gap paradigm, Kissler and Keil (2008) instructed subjects to move their eyes directly to a target picture (pro-saccade) or the opposite side of the picture (anti-saccade) that appeared on either the left or right side of a fixation cross. Target pictures (emotional or neutral) could occur simultaneously with fixation offset (no-gap condition) or 200 ms after the fixation offset (gap condition). They found that for both saccades and anti-saccades, SRTs were globally reduced in the gap condition (approximately 16 ms) in relation to the no-gap condition. In the pro-saccade task, an interaction between picture content and visual hemifield was found: saccades toward pleasant pictures were faster in both hemifields in relation to neutral ones, while SRTs to unpleasant pictures were facilitated only in the left visual field. However, this pattern of results did not interact with the factor “gap/no-gap”. In the anti-saccade task more anti-saccade errors occurred toward emotional stimuli in relation to neutral pictures, but only in the gap condition. The increased anti-saccade errors observed for emotional stimuli and the faster pro-saccades toward emotional targets indicate a primacy for emotional pictures in attentional engagement.

West et al. (2011) also used the gap paradigm to study the relationship between emotion and attention. In their work, neutral or fearful faces were presented for 200 ms in the center of a computer screen. The peripheral target and a distracter stimulus then appeared while subjects were still looking at the central face (overlap task) or appeared 200 ms after the central face offset (gap task). They found that latencies did not differ after viewing neutral or fearful pictures in overlap tasks; however, in gap tasks, SRTs were shorter after fearful faces than after neutral faces. Thus, the offset of fearful faces was more effective in reducing SRTs than the offset of neutral faces. Their results were interpreted in terms of the influence of emotional display and amygdala activity on superior colliculus function and the saccade generation system.

The first goal of this study was to further explore the SRT findings obtained by West et al. (2011) using a somewhat different experimental procedure. In the present study, instead of faces, a complex central picture (neutral or unpleasant) was passively viewed by the volunteers and for a longer time (600 or 800 ms). We asked whether the emotional content of those pictures would also affect saccade latencies to targets under no-gap (*i.e.*, simultaneous picture offset and target onset) and gap-200 (*i.e.*, picture offset 200 ms before target onset) conditions, as observed by West et al. (2011), but in a somewhat different context. If attentional bias is really related to impaired disengagement from affective stimuli, we expect that the gap-200 condition would favor the attentional disengagement from unpleasant stimuli and so, reduce their SRTs in relation to neutral stimuli. Thus, we directly tested the participants' ability to disengage attention from central unpleasant and neutral pictures.

Our second goal was to test the influence of re-exposing the same pictures on SRTs. We asked if (and how) habituation would affect

saccadic responses and the ability to take the eyes off neutral and unpleasant pictures — the attentional disengagement. According to many authors, paying attention to novel stimulation is important for survival primarily because any new stimulus may be dangerous and so, stimulus “novelty” is a major factor that activates the motivational systems and favors the engagement of attention (*e.g.*, Bradley, 2009; Lang and Bradley, 2010). Moreover, since the classical studies of Sokolov (1963), it is clear that an unexpected (new) stimulus elicits orienting responses and that stimulus repetition promotes habituation in those responses. Using quite different protocols, many authors have studied how picture repetition (and reduced stimulus significance) modulates different components of the orienting response. Thus, habituation has been tested in physiological components such as heart rate (sustained cardiac deceleration), skin conductance, corrugator electromyographic responses, evoked startle reflex (eye-blink magnitude), some specific components of the event related potentials (late positive potential, for example) and manual reaction times (Bradley, 2009; Bradley et al., 1993; Codispoti et al., 2006, 2007; Pereira et al., 2006). In short, those studies concluded that different components of the orienting response are differentially modulated by picture repetition and so, orienting cannot be considered a unitary response. However, as far as we know, no previous study tested the impact of picture repetition on saccade latencies. In this study, as a second goal, we also tested the influence of picture repetition (neutral or unpleasant) on SRTs and tried to contextualize the saccadic responses amongst the other components of the orienting response above mentioned.

2. Material and methods

2.1. Participants

Thirty-two female psychology students (21.3 ± 1.57 years of age, 29 right-handed) at the University of Granada, Spain, received course credit to participate in the experiment. They were naive with respect to the goals of the study and had normal or corrected-to-normal vision. Procedures were approved by the local ethics committee, and written informed consent was obtained prior to the study.

2.2. Materials

One hundred four unpleasant pictures (mutilated bodies) and 104 neutral pictures (people in “normal life”) were selected from the International Affective Pictures System (IAPS; Lang et al., 2005), Internet, or photographs taken by the authors. Additional unpleasant pictures were selected apart from the IAPS because IAPS database was not large enough to provide all 104 mutilation pictures necessary to conduct this study. Also, some neutral pictures were added in an attempt to match unpleasant and neutral stimuli in terms of both color content and complexity (*e.g.*, number of faces and body parts, type of body parts, etc.). However, and very important, all the new images used in the present study had their valence and arousal assessed by a separate group of participants ($n = 20$), following the protocol developed by Bradley and Lang (1994), and were already used in a previous study (for details, see Pereira et al., 2010). In relation to the unpleasant pictures employed in this experiment, 36 were extracted from IAPS and 68 were new pictures; for the neutral pictures, 38 were from IAPS database and 66 were new. Unpleasant and neutral pictures, respectively, differed significantly with regard to valence (2.22 vs. 5.14) and arousal (6.56 vs. 3.36; $p < 0.001$ for both comparisons). It is important to mention that only colored pictures were used in this experiment.

2.3. Apparatus

The experiment occurred in a sound-attenuated room under dim ambient light. Subjects sat in front of a computer monitor, with their head positioned by means of a chin-rest approximately 57 cm from

the display. A computer ran customized software (E-Prime, Psychology Software Tools) that timed the stimulus presentation. Saccades were collected by horizontal electrooculograms (EOGs) recorded with AgCl skin electrodes placed at the outer canthi of the two eyes, with a sampling rate of 1000 Hz, using the electroencephalogram “Cz” channel as a reference. Electroencephalographic data were collected but not used in the present study. Custom analysis software (Matlab language) was used to calculate saccade latency off-line using a velocity criterion. The beginning of a saccade was defined to be the first point following the target onset, at which the eye movement abandoned the fixation, attained a velocity of 30 deg/s and maintained this velocity for at least five consecutive samples. This point (saccade onset) was automatically marked and then it was visually confirmed off-line by the experimenter. Similar criteria have been used by others (Sheliga et al., 1994; Kissler and Keil, 2008) and permitted to separate true saccades from other slower drifts in the eye position. Trials with eye movements in the wrong direction and blinks within the time-window between fixation-point appearance and saccade onset were excluded.

2.4. Procedure

Fig. 1 illustrates the time sequence and the design of the experiment. Each trial began with a central fixation-point (FP). After approximately 700 ± 100 ms, a neutral or unpleasant picture (9° height \times 12° width) was presented centrally while FP remained on. Two different conditions were used. In the no-gap condition, the picture remained on for 800 ms, and a peripheral target (an asterisk; 1° visual angle) appeared 9° on the right or left side simultaneously with the offset of the picture. In the gap-200 condition, the picture remained on for 600 ms. After a blank interval of 200 ms, the target appeared. Participants were instructed

to look at the target as soon as possible. The SRT was defined as the interval between target onset and saccade onset. After an intertrial interval (1100–1600 ms), FP blinked for 50 ms, indicating the beginning of the next trial.

The entire experiment lasted approximately 60 min. Three experimental sessions were run sequentially in a same day. Each session was subdivided into two blocks of 106 trials each, with 2 or 3 min of rest between blocks. The first two trials in each block were “warm-up trials” that used household objects and were not considered in the analysis. The other 104 pictures (52 neutral pictures and 52 unpleasant pictures) used in the first block differed from those used in the second block. However, in the second and third sessions, participants were re-exposed to the same pictures, but in a different counterbalanced order. Arousal and valence mean scores for unpleasant and neutral pictures did not differ between blocks and conditions. Pictures (neutral or unpleasant), conditions (no-gap or gap-200), and hemifields (left or right) were balanced in each block but occurred in a pseudorandom order. No more than three consecutive trials with the same valence, condition, or hemifield were allowed. Finally, to avoid an anticipatory tendency by the participants, each block contained 16 catch-trials (15% – trials in which no targets were presented). Catch-trials were equally distributed among the factors. In “no-gap/catch trials”, the picture remained on for 800 ms and after its offset, no target appeared; in “gap-200/catch trials” the picture remained on for 600 ms and after its offset, no target appeared. Participants were explicitly informed about those trials and instructed not to move their eyes from the FP under those conditions.

Before each session, a short practice block of 20 trials using household objects was run. Participants were instructed to avoid blinks within the critical time-window between FP appearance and saccade onset,

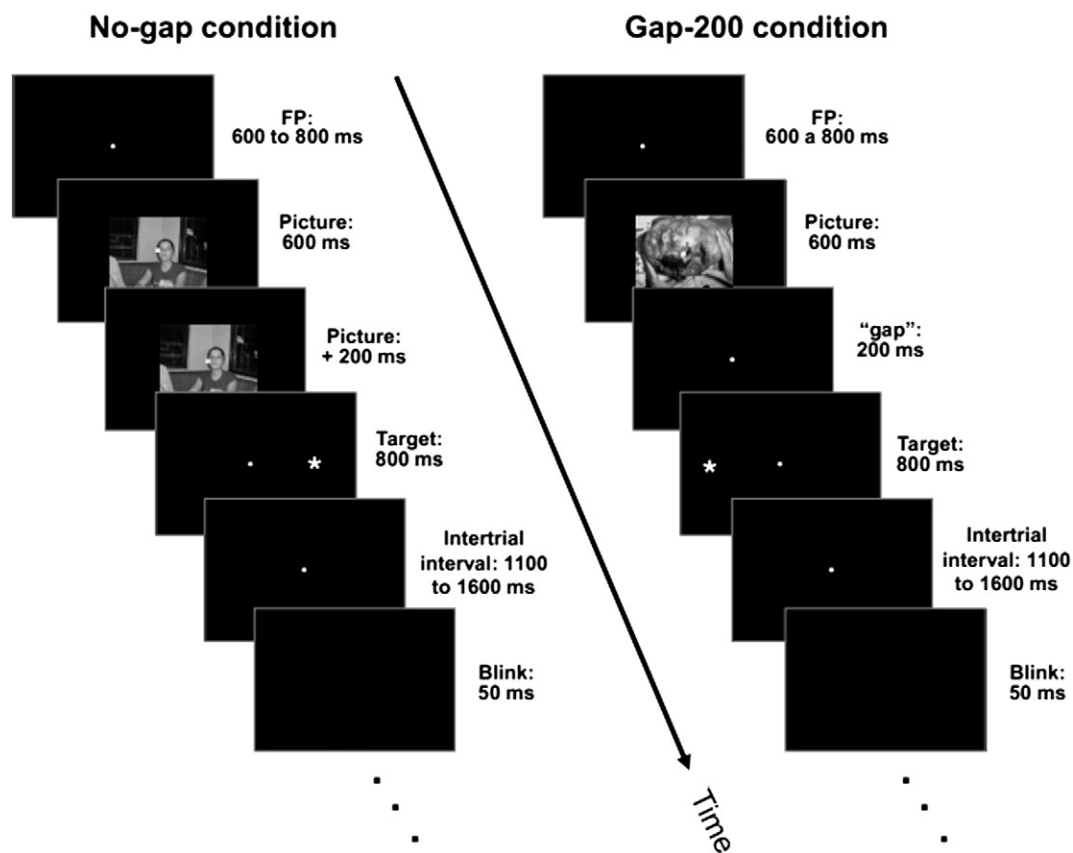


Fig. 1. Time sequence and experimental design. Initially, the fixation point (FP) was presented for 600 to 800 ms and remained on throughout the trial. Then, a picture (neutral or unpleasant) was centrally presented. In no-gap trials (left side), it remained on for 800 ms and the peripheral target appeared simultaneously with the offset of the picture. In gap-200 trials (right side), the picture remained on for 600 ms and after a blank interval of 200 ms, the target appeared. After an intertrial interval (1100–1600 ms), FP blinked for 50 ms, indicating the beginning of the next trial. Participants were instructed to look at the target as soon as possible.

and this instruction was particularly stressed during the practice block. It was also emphasized that the best moment to blink the eyes was just after the saccade reaches the target and while the eyes were returning to fixation. Data analysis revealed that volunteers followed our suggestion and eye blinks were very rare in this critical period of time. The practice blocks were important in our procedures because it was the moment when we verified if participants were actually following the instructions related to the eye blinks, before data collection. That is the reason why the practice blocks were always used before the sessions 1, 2 and 3. During the experiment, no feedback about performance was given. Trials with blinks within the critical time-window, anticipatory responses (*i.e.*, SRT < 80 ms or making a saccade in a catch-trial), slow responses (*i.e.*, SRT > 1000 ms), and saccades to the wrong hemifield were excluded from further analyses.

Saccadic reaction times were analyzed using a Session (1, 2, or 3) × Valence (neutral or unpleasant) × Condition (no-gap or gap-200) × Target Hemifield (left or right) repeated-measures analysis of variance (ANOVA), with the median SRT of correct trials as the dependent variable. When appropriate, the Newman–Keuls *post hoc* test was performed, and a Greenhouse–Geisser ϵ correction for non-sphericity was applied. The alpha level was $p = 0.05$.

3. Results

The overall mean percentage of errors was 1.17%. Because no variance was found in some conditions, we could not apply conventional statistical analyses, and *t*-tests were used to analyze the errors. Anticipations (false-alarms) were more frequent in no-gap than in gap-200 trials (50 vs. 10, $p < 0.001$). Erroneous saccades were more frequent for unpleasant than for neutral pictures (66 vs. 37, $p = 0.024$). No other difference reached significance, and no difference was found among sessions.

The ANOVA of SRTs revealed main effects of Session ($F_{2,62} = 19.57$, $p < 0.001$, $\epsilon = 0.839$) and Condition ($F_{1,31} = 341.00$, $p < 0.001$, $\epsilon = 1.000$). The Session × Condition ($F_{2,62} = 4.77$, $p = 0.018$, $\epsilon = 0.811$), Valence × Condition ($F_{1,31} = 48.99$, $p < 0.001$, $\epsilon = 1.000$), and Session × Valence × Condition ($F_{2,62} = 12.63$, $p < 0.001$, $\epsilon = 0.748$) interactions were also significant. Target hemifield was not significant and did not interact with any other factor. The most relevant results were the following. The Valence × Condition interaction revealed that SRTs in the no-gap condition were longer after unpleasant pictures (208 vs. 201 ms, $p = 0.001$), but this pattern was reversed in the gap-200 condition, in which SRTs were shorter after unpleasant pictures than after neutral pictures (275 vs. 287 ms, $p < 0.001$). Table 1 shows the triple interaction among Session, Valence, and Condition. The SRTs for unpleasant (unpl) and neutral (neu) pictures and difference between them (unpl-neu) are shown for each session. In the no-gap condition, SRTs were longer after unpleasant pictures, reflecting emotional interference, but they were significant only in the first session

(14 ms, $p < 0.001$; 2 ms, $p = 0.263$; 3 ms, $p = 0.139$). In the gap-200 condition, SRTs were significantly shorter after unpleasant pictures in all of the sessions, but this difference gradually decreased (−18 ms, $p < 0.001$; −11 ms, $p < 0.001$; −8 ms, $p = 0.016$). Paired *t*-tests confirmed that in the no-gap condition the emotional interference observed in the first session differed significantly from those obtained in sessions 2 and 3 ($p = 0.012$ and $p = 0.002$, respectively, corrected for multiple comparisons). In the gap-200 condition, the facilitation obtained for unpleasant pictures in the first session differed from that observed in session 3 ($p = 0.017$, corrected for multiple comparisons) and showed a tendency to be significant in relation to session 2 ($p = 0.060$, corrected for multiple comparisons).

In short, our results showed that viewing unpleasant pictures in the no-gap condition produced SRT interference; but in the gap-200 condition, unpleasant picture offset produced saccade facilitation compared with the neutral pictures. In relation to habituation, a clear tendency to reduce the influence of unpleasant pictures in relation to neutral pictures after the first session was noted for both conditions. The emotional interference observed in the gap-0 condition was significant only in the first session, and the saccade facilitation obtained for unpleasant pictures in the gap-200 condition gradually decreased from the first to the third sessions.

4. Discussion

Our main results can be shortly presented as follow: (i) emotional interference was observed when target onset and picture offset were simultaneous; (ii) emotional interference was replaced by facilitation in relation to neutral pictures when the gap-200 condition was used; and (iii) re-exposition of the same pictures induced affective habituation in the SRTs. It indicated that unpleasant pictures offset 200 ms before target onset, in fact affected attentional mechanisms and changed the influence of those pictures in SRTs. Also, this affective modulatory influence was susceptible to habituation. These main findings will be sequentially discussed hereafter.

Our data revealed a clear interaction between the emotional picture content and temporal gap condition. In the no-gap condition, latencies were longer for unpleasant pictures, and in the gap-200 condition, the pattern was reversed. The longer SRTs obtained when participants were looking at unpleasant pictures in the no-gap condition is a typical interference effect described by many authors – the attentional bias elicited by emotional pictures (*e.g.*, Carretié et al., 2001; Calvo and Lang, 2004; Erthal et al., 2005; Nummenmaa et al., 2006). Attention is automatically attracted to unpleasant pictures and as long as attention is engaged in threatening information, the processing of other stimuli and motor responses are impaired. Thus, the interference observed in SRT when unpleasant pictures were viewed denotes the involvement of attention with threatening processing. The reasoning is that prioritizing unpleasant items diverts resources away from processing other items, which slows reaction times to the main task (Pereira et al., 2006).

In the gap-200 condition, SRTs were shorter after the offset of unpleasant pictures compared with neutral ones. Therefore, unpleasant picture offset 200 ms before the target onset affected attentional mechanisms and facilitated the disengagement from emotional stimuli. Our data partially replicate those obtained by West et al. (2011). In their study, the affective faces used to induce emotional drive were presented for 200 ms. In the present study, emotional drive was induced by more complex pictures, which were presented for a longer time (600 or 800 ms). Despite these differences, a similar effect was found: a clear modulation of the so-called attentional dwell time by the offset of unpleasant pictures compared with neutral ones. The reason why attentional disengagement is effective for unpleasant pictures may be attributable to a mechanism called attentional avoidance. According to Mogg and Bradley (2006), the initial automatic capture of attention by fear-relevant stimuli can be followed by avoidance strategies – the “vigilant-avoidant” pattern of attentional bias. Thus, following initial

Table 1
Main results of the experiment. Saccadic reaction times (in milliseconds) for unpleasant (unpl) and neutral (neu) pictures and the difference between them (unpl-neu, in bold) obtained in the no-gap and gap-200 conditions in the three experimental sessions.

Valence:	Session 1		Session 2		Session 3	
	unpl	neu	unpl	neu	unpl	neu
No-Gap condition						
►Reaction time (ms)	225	211	202	200	198	195
►Difference (unpl-neu)	14*		2		3	
Gap-200 condition						
►Reaction time (ms)	280	298	277	288	268	276
►Difference (unpl-neu)	−18*		−11*		−8*	

* statistically significant differences between unpleasant and neutral pictures ($P < 0.05$).

attentional capture, volunteers may exhibit avoidance of feared stimuli. For example, in a time-course study, Koster et al. (2005) presented mixed pairs of neutral (e.g., household objects), mild-threatening (e.g., man with knife) and high-threatening (e.g., mutilation) pictures to high and low trait anxiety students for 100, 500, or 1250 ms. Immediately after the picture offset, a small dot-probe appeared at the spatial location of one of the pictures. Participants had to press one of two keys to indicate the probe position. The results indicated attentional bias to high-threatening pictures for all volunteers at 100 and 500 ms, and high trait anxious also showed attentional bias for mild-threatening images at 500 ms. At 1250 ms, all volunteers attended away from high-threatening pictures and high trait anxious also attended away from mild threat pictures. According to the authors, the results obtained at 100 ms indicate that the rapid prioritizing of threat represents an adaptive and helpful mechanism. However, selective attention to threat at 500 ms does not reflect attentional capture by threat; rather, it is caused by problems disengaging attention from threat. At the viewing time of 1250 ms, all individuals showed avoidance of high-threatening pictures, suggesting that attention was finally disengaged from the spatial location where unpleasant pictures had been presented. Because attentional avoidance occurred only in trials that contained threatening pictures, they proposed that attentional avoidance does not represent a general strategy of reduced attention to cues but was instigated by the “aversiveness” of the image.

Following the same interpretation of Koster et al. (2005, 2006), many authors agree that (i) the mechanisms that direct attention to threatening stimuli are automatic (Fox et al., 2001; Pflugshaupt et al., 2005), (ii) attentional disengagement may be influenced by higher-level variables, such as meaning and valence (Fox et al., 2001), and (iii) controlled avoidance of emotional content becomes possible with additional time because avoidance strategies need sufficient time to replace the initial orienting to threat (Pflugshaupt et al., 2005; Nummenmaa et al., 2006; for review, see Cisler and Koster, 2010). Our data support the interpretation related to attentional disengagement and avoidance, and indicate that both mechanisms were modulated by picture offset and valence. The offset of pictures after passively viewing them for 600 ms facilitated saccades from aversive pictures compared with neutral ones. Such picture offset appeared to be essential in our protocol because disengagement was not evident when the temporal gap was absent and the unpleasant picture was viewed for 800 ms (the no-gap condition). Finally, in the study of Koster et al. (2005), highly threatening stimuli caused attentional avoidance, overriding disengagement difficulties, only when it was viewed by a relatively long period of time (1250 ms). Our results and those obtained by West et al. (2011) extend this finding by showing that attentional avoidance for unpleasant pictures can be apparent, even in shorter viewing times, but only if the “aversive” picture was turned off 200 ms before the onset of a visual target, probably due to a modulation in attentional disengagement mechanisms.

An additional finding of the present study was that for both conditions the effects of unpleasant pictures were affected by re-exposing volunteers to the same stimuli. As mentioned, different physiological systems have been used to test the effects of picture repetition and reduced stimulus significance on distinct components of the orienting response. Using different protocols, those studies concluded that the rates of habituation vary according to the physiological component tested. In a typical experimental protocol, affective (pleasant or unpleasant) or neutral stimuli were presented in a first block of trials, whilst a physiological response was being registered. In the following blocks, pictures were re-exposed to the participants and the new response was then compared to that observed in the first presentation. Using such protocols, authors have found that the cardiac deceleration observed in the first three seconds after viewing a novel stimulus, and that was especially strong for unpleasant pictures, rapidly disappeared when stimuli were re-exposed in other blocks (Bradley et al., 1993; Bradley, 2009; Codispoti et al., 2006). Similarly, the skin conductance

response (Bradley et al., 1993; Codispoti et al., 2006) and the corrugator electromyographic response (Bradley et al., 1993) evidence rapid affective habituation across blocks, just as was found for the heart rate changes. On the other hand, the magnitude of eye-blink response observed in the evoked startle reflex clearly decreased across the blocks, but the emotional content of pictures continued to exert its modulatory influence throughout the habituation (Bradley et al., 1993). A similar pattern was found for the late positive potential (LPP) component of the event related potentials: its magnitude decreased, but affective modulation was maintained across blocks (Codispoti et al., 2006; Bradley, 2009).

In this study, we found that the influence of unpleasant pictures on SRTs to peripheral targets decreased across blocks, for both no-gap and gap-200 conditions. In the no-gap condition affective modulation disappeared after the first session, and in the gap-200 condition modulation gradually decreased across the three sessions. In a previous study of our group, Pereira et al. (2006) showed that the interference of unpleasant pictures on manual reaction times disappeared when pictures were re-exposed. In their study, affective or neutral pictures were centrally presented for 2000 ms and 500 to 700 ms after its offset twelve visual targets were sequentially presented. Participants had to press a key for each one of the twelve targets presented centrally. The significant interference of unpleasant pictures in relation to neutral or pleasant pictures obtained in the first block (approximately 16 ms) disappeared when the same set of 24 unpleasant pictures were re-exposed 24–48 h later. Therefore, the rate of habituation for manual responses and that observed in our SRT study were similar to those obtained for heart rate changes, skin conductance and corrugator responses, despite the differences in the experimental protocols among different studies. These physiological responses, contrary to the eye-blink responses and LPP magnitude, where affective modulation was persistent, showed a relatively fast affective habituation. Bradley et al. (1993) and Codispoti et al. (2006) have already pointed out that the differences in the rate of habituation observed for distinct physiological responses reflect different functional processes. Autonomic responses would reflect mechanisms of initial orienting responses such as sensory intake and preparation for action. Conversely, LPP would reflect mandatory processes related to stimulus detection and categorization, which in turn should not be susceptible to habituation, and should persist whenever a stimulus is presented, despite the number of repetition. According to this hypothesis and to our data, SRTs should be viewed as a component of the initial orienting response and so, it would be susceptible to habituation. This view is coherent with the ecological function of eye movements and selective attention in searching novel aspects in the environment to prioritize processing.

It is important to remember that in the present study, a non-selected sample of participants was used. Thus, our study is consistent with others (Mogg and Bradley, 1998; Öhman et al., 2001; Koster et al., 2006) and supports the hypothesis that directing attention to high-threatening information is helpful and adaptive, and threat also modulates attentional engagement and disengagement in “healthy” individuals. However, there is also wealth of evidence that biased attentive processing to threatening stimuli is enhanced in clinical and sub-clinical (high trait anxious) populations, in relation to low trait anxious and non-anxious individuals (Mogg and Bradley, 1998; Koster et al., 2006; Cisler and Koster, 2010). In short, there is empirical evidence that processing preference for threat is normally helpful and functional and that this general feature is only strengthened in anxiety disorders. In this sense, many previous studies have used eye movements to evaluate the attentional bias in clinical and non-clinical samples (Nummenmaa et al., 2006; Calvo and Lang, 2004; Tolin et al., 1999; Pflugshaupt et al., 2005; Rinck and Becker, 2006). These studies, though, were interested in parameters such as the probability of first fixation in neutral or affective pictures and the total viewing time in each picture. Instead, we directly assessed the time necessary to take the eyes off unpleasant versus neutral pictures, and the effect of stimulus

repetition on SRTs – affective habituation. Our results, obtained in a non-clinical sample of volunteers, indicate that the “gap/no-gap” SRT protocol can also be used to estimate the impact of specific pictures (or specific emotional contents) in clinical or sub-clinical populations, as another index of orienting responses. The rate of habituation observed for SRTs suggests that saccadic responses should be viewed as a component of the orienting response involved mainly in sensory intake and/or preparation for action, and consequently were susceptible to fast habituation. We wonder if the same pattern of results would also be found in high trait anxious and in phobic patients, due to their enhanced preference for threatening stimuli. Would the magnitude of the unpleasant interference observed in the no-gap condition be greater for anxious disorders? Would the gap-200 protocol facilitate the attentional disengagement from unpleasant pictures in those populations? Would the rate of habituation be the same, or it would be slower? The answers to these questions would indicate whether, in fact, our protocols have the potential to be used in clinical evaluation.

At this point, mentioning why SRTs were globally slower in the gap-200 condition than in no-gap condition is important. In our study, in contrast to Kissler and Keil (2008) and West et al. (2011), catch-trials were included to avoid anticipatory tendencies by the participants. In no-gap trials, picture offset occurred simultaneously with target onset. In gap-200 trials, a blank period always occurred between picture offset and the target. Thus, cases in which pictures were turned off and not immediately replaced by the target (as in the gap-200 condition) may indicate a catch-trial occurrence, and cases in which targets occurred simultaneously to the picture offset (the no-gap condition) would not be under the catch-trial influence. In this sense, it was as if catch-trials were occurring only in the gap-200 condition. According to our view, catch-trials would act as a no-go signal (*i.e.*, response not required), decreasing response readiness only in the gap-200 condition. We hypothesize that under such target uncertainty, top-down inhibitory control is necessary to prevent undesired responses (false-alarms). Response inhibition mechanisms clearly increase reaction time and have already been demonstrated in no-go and stop-signal protocols (Falkenstein et al., 1999; van den Wildenberg et al., 2002). The frontal N2 wave possibly reflects such inhibitory control. No-go N2 is stronger and occurs earlier in volunteers with low false-alarm rates than in volunteers with high false-alarm rates (Falkenstein et al., 1999). In the present study, confirming this prediction, false-alarms were significantly lower in the gap-200 condition, suggesting the imposition of inhibitory mechanisms caused by target uncertainty. In short, we believe that the present catch-trial procedure implicitly created an inhibitory bias in the gap-200 condition, increasing SRTs for both pictures in this condition. The influence of catch-trials to increase saccadic responses has already been demonstrated by others (e.g., Jüttner and Wolf, 1991). Thus, despite this undesirable effect in the gap-200 condition (the global elevation of SRTs), it was not able to mask the most relevant result: the strong interaction between gap-condition and picture valence.

Finally, in relation to the neurophysiological aspects, electrophysiological and pharmacological studies have shown that the gap effect is mediated by disinhibition of the fixations neurons in the rostral pole of the superior colliculus (Dorris and Munoz, 1995; Munoz and Wurtz, 1993a, 1993b). These fixation neurons exert a tonic inhibition on the saccade generation system of the brain stem, and saccade latencies reduction would occur after the removal of this inhibition. Our results indicate that the activity of the fixation neurons can be modulated by the offset of unpleasant pictures in relation to the neutral pictures. These affective modulatory signals probably have its origin in the amygdala, and reach the superior colliculus via pulvinar, as already proposed (LeDoux, 2000; West et al., 2011). Thus, eye movements and saccade latencies represent, in fact, a good way to study the interaction between attentional and emotional systems. As already mentioned, our protocol has the potential to be used also in clinical or subclinical populations providing a direct estimation of two important mechanisms related to

attention and emotion: the attentional disengagement from affective pictures and the affective habituation. Our results and others corroborate the use of eye movements as an important tool to study the relationship between emotion and attention. The fact that the anatomy of the eye movement system is very well described represents an advantage to understand the pathways by which attention and emotion interact to select targets in the environment and to organize the behavior.

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References

- Bradley, M.M., 2009. Natural selective attention: orienting and emotion. *Psychophysiology* 46, 1–11.
- Bradley, M.M., Lang, P.J., 1994. Measuring emotion: the Self-Assessment Manikin and the Semantic Differential. *J. Behav. Ther. Exp. Psychiatry* 25, 49–59.
- Bradley, M.M., Lang, P.J., Cuthbert, B.N., 1993. Emotion, novelty, and the startle reflex: habituation in humans. *Behav. Neurosci.* 107, 970–980.
- Braun, D., Breitmeyer, B.G., 1988. Relationship between directed visual attention and saccadic reaction times. *Exp. Brain Res.* 73, 546–552.
- Calvo, M.G., Lang, P.J., 2004. Gaze patterns when looking at emotional pictures: motivationally biased attention. *Motiv. Emot.* 28, 221–243.
- Carretié, L., Mercado, F., Tapia, M., Hinojosa, J.A., 2001. Emotion, attention, and the 'negativity bias', studied through event-related potentials. *Int. J. Psychophysiol.* 41, 75–85.
- Cisler, J.M., Koster, E.H.W., 2010. Mechanisms of attentional biases towards threat in anxiety disorders: an integrative review. *Clin. Psychol. Rev.* 30, 203–216.
- Codispoti, M., Ferrari, V., Bradley, M.M., 2006. Repetitive picture processing: autonomic and cortical correlates. *Brain Res.* 1068, 213–220.
- Codispoti, M., Ferrari, V., Bradley, M.M., 2007. Repetition and event related potentials: distinguishing early and late processes in affective picture perception. *J. Cogn. Neurosci.* 19, 577–586.
- Corbetta, M., Akbudak, E., Conturo, T.E., Snyder, A.Z., Ollinger, J.M., Drury, H.A., Linenweber, M.R., Petersen, S.E., Raichle, M.E., Van Essen, D.C., Shulman, G.L., 1998. A common network of functional areas for attention and eye movements. *Neuron* 21, 761–773.
- Dorris, M.C., Munoz, D.P., 1995. A neural correlate for the gap effect on saccadic reaction times in monkey. *J. Neurophysiol.* 73, 2558–2562.
- Erthal, F.S., Oliveira, L., Mocaiber, I., Pereira, M.G., Machado-Pinheiro, W., Volchan, E., Pessoa, L., 2005. Load-dependent modulation of affective picture processing. *Cogn. Affect. Behav. Neurosci.* 5, 388–395.
- Falkenstein, M., Hoormann, J., Hohnsbein, J., 1999. ERP components in Go/Nogo tasks and their relation to inhibition. *Acta Psychol.* 101, 267–291.
- Fischer, B., Weber, H., 1993. Express saccades and visual attention. *Behav. Brain Sci.* 16, 553–610.
- Fox, E., Russo, R., Bowles, R., Dutton, K., 2001. Do threatening stimuli draw or hold visual attention in subclinical anxiety? *J. Exp. Psychol. Gen.* 130, 681–700.
- Fox, E., Russo, R., Dutton, K., 2002. Attentional bias for threat: evidence for delayed disengagement from emotional faces. *Cogn. Emot.* 16, 355–379.
- Jin, Z., Reeves, A., 2009. Attentional release in the saccadic gap effect. *Vision Res.* 49, 2045–2055.
- Jüttner, M., Wolf, W., 1991. Human express saccades: catch trials influence the probability of their occurrence. In: Schmid, R., Zambbarbieri, D. (Eds.), *Oculomotor Control and Cognitive Processes*. Elsevier, Amsterdam, pp. 163–175.
- Kissler, J., Keil, A., 2008. Look-don't look! How emotional pictures affect pro- and anti-saccades. *Exp. Brain Res.* 188, 215–222.
- Koster, E.H.W., Verschuere, B., Crombez, G., Van Damme, S., 2005. Time-course of attention for threatening pictures in high and low trait anxiety. *Behav. Res. Ther.* 43, 1087–1098.
- Koster, E.H.W., Crombez, G., Verschuere, B., Van Damme, S., Wiersema, J.R., 2006. Components of attentional bias to threat in high trait anxiety: facilitated engagement, impaired disengagement, and attentional avoidance. *Behav. Res. Ther.* 44, 1757–1771.
- Lang, P.J., Bradley, M.M., 2010. Emotion and the motivational brain. *Biol. Psychol.* 84, 437–450.
- Lang, P.J., Bradley, M.M., Cuthbert, B.N., 2005. International affective picture system (IAPS): affective ratings of pictures and instruction manual. Technical Report A-6. Center for the Study of Emotion and Attention, Gainesville.
- LeDoux, J.E., 2000. Emotion circuits in the brain. *Annu. Rev. Neurosci.* 23, 155–184.
- Mayfrank, L., Mobashery, M., Kimming, H., Fischer, B., 1986. The role of fixation and visual attention in the occurrence of express saccades in man. *Eur. Arch. Psychiatry Neurol. Sci.* 235, 269–275.
- Mogg, K., Bradley, B.P., 1998. A cognitive-motivational analysis of anxiety. *Behav. Res. Ther.* 36, 809–848.
- Mogg, K., Bradley, B.P., 2006. Time course of attentional bias for fear-relevant pictures in spider-fearful individuals. *Behav. Res. Ther.* 44, 1241–1250.
- Munoz, D.P., Wurtz, R.H., 1993a. Fixation cells in monkey superior colliculus. I. Characteristics of cell discharge. *J. Neurophysiol.* 70, 559–575.

- Munoz, D.P., Wurtz, R.H., 1993b. Fixation cells in monkey superior colliculus. II. Reversible activation and deactivation. *J. Neurophysiol.* 70, 576–589.
- Nummenmaa, L., Hyona, J., Calvo, M.G., 2006. Eye movement assessment of selective attentional capture by emotional pictures. *Emotion* 6, 257–268.
- Öhman, A., Flykt, A., Esteves, F., 2001. Emotion drives attention: detecting the snake in the grass. *J. Exp. Psychol. Gen.* 130, 466–478.
- Pereira, M.G., Volchan, E., Souza, G.G., Oliveira, L., Campagnoli, R.R., Machado-Pinheiro, W., Pessoa, L., 2006. Sustained and transient modulation of performance induced by emotional picture viewing. *Emotion* 6, 622–634.
- Pereira, M.G., Oliveira, L., Erthal, F.S., Joffily, M., Mocaiber, I.F., Volchan, E., Pessoa, L., 2010. Emotion affects action: midcingulate cortex as a pivotal node of interaction between negative emotion and motor signals. *Cogn. Affect. Behav. Neurosci.* 10, 94–106.
- Pflugshaupt, T., Mosimann, U.P., von Wartburg, R., Schmitt, W., Nyffeler, T., Muri, R.M., 2005. Hypervigilance-avoidance pattern in spider phobia. *J. Anxiety Disord.* 19, 105–116.
- Rinck, M., Becker, E.S., 2006. Spider fearful individuals attend to threat, then quickly avoid it: evidence from eye movements. *J. Abnorm. Psychol.* 115, 231–238.
- Rizzolatti, G., Riggio, L., Dascola, I., Umiltà, C., 1987. Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. *Neuropsychologia* 25, 31–40.
- Saslow, M.G., 1967. Effects of components of displacement-step stimuli upon latency of saccadic eye movements. *J. Opt. Soc. Am.* 57, 1024–1029.
- Sheliga, B., Riggio, L., Rizzolatti, G., 1994. Orienting of attention and eye movements. *Exp. Brain Res.* 98, 507–522.
- Smith, N.K., Cacioppo, J.T., Larsen, J.T., Chartrand, T.L., 2003. May I have your attention, please: electrocortical responses to positive and negative stimuli. *Neuropsychologia* 41, 171–183.
- Sokolov, E.N., 1963. A neuronal model of the stimulus and the orienting reflex. In: Worters, R., Clarke, A.D.B. (Eds.), *Perception and the Conditioned Reflex*. The Macmillan Company, New York, pp. 282–294.
- Tolin, D.F., Lohr, J.M., Lee, T.C., Sawchuk, C.N., 1999. Visual avoidance in specific phobia. *Behav. Res. Ther.* 37, 63–70.
- van den Wildenberg, W.P.M., van der Molen, M.W., Logan, G.D., 2002. Reduced response readiness delays stop signal inhibition. *Acta Psychol.* 111, 155–169.
- West, G.L., Al-Aidroos, N., Susskind, J., Pratt, J., 2011. Emotion and action: the effect of fear on saccadic performance. *Exp. Brain Res.* 209, 153–158.