The Time Course of Implicit Affective Picture Processing: An Eye Movement Study

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Abstract

Consistent with a negativity bias account, neuroscientific and behavioural evidence demonstrates modulation of even early sensory processes by unpleasant, potentially threat-relevant information. The aim of this research is to assess the extent to which pleasant and unpleasant visual stimuli presented extrafoveally capture attention and impact eye movement control. We report an experiment examining deviations in saccade metrics in the presence of emotional image distractors that are close to a non-emotional target. We additionally manipulate the saccade latency to test when the emotional distractor has its biggest impact on oculomotor control. The results demonstrate that saccade landing position was pulled towards unpleasant distractors, and that this pull was due to the quick saccade responses. Overall, these findings support a negativity bias account of early attentional control and call for the need to consider the time course of motivated attention when affect is implicit.

Keywords: eye movements, negativity bias, motivated attention, saccade control, time course

Introduction

The ability to efficiently locate and identify events that potentially bear relevance to the perceiver's wellbeing has clear evolutionary consequences. As such, it has been suggested that emotion-relevant information is given control precedence. Emotion-relevant cues attract attention quickly to prioritize further, detailed, processing and resources for potential action (Frijda, 1986; Öhman , Flykt & Esteves, 2001), even when cognitive resources are limited. It follows from this that effective peripheral processing (i.e., that which takes place outside of the fovea) of the emotional content of our environment is vital.

The recording of eye movements can shed light on the mechanisms of reflexive attention to emotion-relevant information. Studies that have examined the impact of emotional valence on eye movements have found results that support the primacy of emotion-relevant cues: Emotional images are more likely to be fixated first (Alpers, 2008; Calvo & Lang, 2004; Nummenmaa et al., 2006), even when instructed to look at the neutral image (Nummenmaa et al., 2006, Exp 2); voluntary and reflexive saccades show quicker response latencies to emotional images and more errors when a neutral image is cued (i.e., more erroneous saccades to an emotional image; Nummenmaa et al., 2009); and anti-saccade responses show more errors toward emotional images (Kissler & Keil, 2008). It is worth noting that the effects of emotional images on fixation and saccade patterns in most of these studies were reported for pleasant and unpleasant images equally (but see e.g. Nummenmaa et al., 2006 Exp 1, for a specific effect of pleasant images): These findings run counter to a dominant viewpoint suggesting prioritized processing of negative, particularly threat-related, information (e.g. Cacioppo, Gardner & Bernston, 1999; Öhman & Mineka, 2001, Vuilleumier, 2005). For instance, event-related potentials (ERP) demonstrate a specific effect of unpleasant images on short latency components (100-200 ms), even when pleasant and unpleasant stimuli are matched for affective arousal (see Oloffson et al., 2008, Feng et al., 2010).

With very few exceptions, the saccade target in studies where emotional stimuli were used either comprised of the emotional stimulus, or the emotional stimuli were presented foveally. A method to investigate the extent to which distracting emotional stimuli are inhibited while the task goal is to saccade to a non-emotional target would further shed light on the prioritization of emotion in attentional biasing. Using non-emotional stimuli, research has found that the presence of distracting stimuli changes the endpoint and trajectory of a target driven saccade (McSorley, Walker & Haggard, 2006; McSorley, Cruickshank & Inman, 2009). If the target and distractor are close together (<30 degree window centered on the target) both endpoint and trajectory will deviate toward the distractor. The direction of this deviation depends upon saccade latency, which is towards the distractor for short latency saccades and away for longer latency responses (McSorley, et al., 2009). Using emotional distractors but non-emotional targets, Nummenmaa et al. (2009) found that the landing position and trajectory of a target elicited saccade generally deviated *away* from a task-irrelevant emotional image, especially when the image was shown 150 ms prior to target onset. While this may have been due to inhibition of emotional image content, it is notable that the images were always presented in the same position (flanking the central fixation location) throughout the experiment. This fixed position may have allowed these images to be largely inhibited, leading to saccade deviation away from their position.

We report an experiment examining deviations in saccade metrics in the presence of emotional image distractors that flank a non-emotional target. A fixation cross disappears from the center of the screen and reappears either to the left or to the right on the horizontal meridian flanked by image distractors. The participant is instructed to saccade to the new position of the target cross as soon as it appears. In order to elicit a wide range of saccade latencies we employ a gap/overlap manipulation: fixation is either removed just before or just after target and distractor onset. This technique has been used successfully by McSorley et al. (2006, 2009). We predict that 1) the emotional distractors will pull the saccade towards them, resulting in a larger deviation away from the target and an endpoint closer to the emotional distractor, 2) if emotion-relevant information biases early perceptual processes which can be inhibited with increased processing time, the manipulation of saccade latency should demonstrate pull effects of emotional distractors, especially for the short latency saccades.

Method

Participants

Twenty participants took part (aged 19 to 21 years, 14 were females). All observers had normal, or corrected to normal, vision. Local ethical approval was obtained and all participants gave their informed consent prior to inclusion.

Apparatus

Eye movements were recorded using an Eyelink II eye-tracker with a sampling rate of 500Hz (SR Research), recording monocularly from observers' right eyes. Stimuli were presented in greyscale on a 21" colour monitor with a refresh rate of 75Hz (DiamondPro, Sony). Head movements were constrained with a chin-rest at a viewing distance of 1m. The eye-tracker was calibrated using a standard 9 point grid at the start of the experiment.

Materials

The images used were taken from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2005; see appendix for IAPS numbers): 128 images; 16 pleasant, 16 unpleasant, 16 neutral and 80 control images. The pleasant and unpleasant images were matched on arousal ($p > .1$). The pleasant, unpleasant and neutral images showed people in a number of different situations. The control images depicted everyday objects with no possible emotional content. These images were the same as those employed by Nummenmaa et al. (2006) who demonstrated that the images did not significantly differ in their low-level stimulus properties (i.e., luminance, contrast, RGB values) across categories.

Fixation and saccade targets were a cross ("+"), each line was 1º in length. Targets were shown 8º to the left or right of fixation on the horizontal meridian. Two images appeared above and below the saccade target, with their centers being 2.1º from the center of the target cross, and their nearest edges being 1º away (See Figure 1). The centers of these images were at an angle of 27.5º from the initial fixation point. All images were 2.2º by 2.93º in size.

Design and Procedure

The experimental display consisted of a target cross shown to the left or right of fixation accompanied by two images above and below its position. A neutral, pleasant or unpleasant image was paired with a random control image, and the remaining control images were then paired with each other to offer a baseline eye movement. The onset of the experimental display overlapped with the fixation screen by 150 or 75 ms or there was blank screen, i.e., a gap, between fixation and experimental display of 75 or 150 ms. It is important to note that the cue to make a saccadic response was the onset of the experimental display not the offset of the fixation cross. Thus, as both the images and the saccade target were onset simultaneously, there was no difference in the viewing times for each of the fixation gap and overlap conditions. Each image was shown once, giving 64 image pairings (16 Control-control; 16 Neutral-control; 16 Pleasant-control; 16 Unpleasant-control pairs) and these parings were repeated for each SOA giving 256 trials overall. Trials began with a central fixation cross presented for a random duration between 800 and 1300 ms. This was replaced by the onset of the experimental display, with fixation offset at a particular SOA. The experimental display was followed by a blank screen (500 ms) before the next trial.

Eye Tracking Measures

Saccade start and endpoints were identified using a 22°/s velocity and $8000°/s^2$ acceleration criteria. The main saccade metrics extracted were the landing position deviation (or angular deviation) and trajectory deviation of the first saccade in each trial.[1] Direction was defined as the angular deviation of saccade direction (°) taken from the initial fixation location to final endpoint in polar co-ordinates, with 0° being a horizontal saccade.

To examine the effect of image type we first determined the average landing position in the Control condition separately for each participant and the impact of the Neutral, Pleasant and Unpleasant images on landing position was subtracted from

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[1] Trajectory deviation was found not to significantly differ depending upon image type, $F(2, 38)=1.09$, $MSE=4.78$, $p=.346$, $\eta^2=.054$. This is different from that reported by Nummenmaa et al (2009); we suggest that this may be due to differences in experimental design (e.g., images flanking the target and not fixation, distance from target and/or fixation) which need to be explored further. However, as saccade trajectory was not found to depend upon image type it will not be considered further in this paper.

this. Positive values were assigned to endpoint deviations towards emotional or neutral images and negative values assigned when away.

Saccades were excluded from further analysis if saccade amplitude was more than two degrees from the target (19%), response latency was quicker than 70 ms (classified as an anticipatory saccade) or slower than 500 ms (in these cases the saccade is taken as having not been driven by the experimental display) (0.01%). Data collected from each target position (left and right) and from each of the four possible image locations was collapsed. Therefore, each overall average represents data from 64 trials.

Results

Angular deviation of the saccade landing position was found to generally change as a function of image type, $F(2, 38)=3.95$, $MSE=.846$, $p=.028$, $\eta^2=.172$ (see Figure 2a), with Unpleasant images resulting in a greater deviation in their direction relative to other image types, Neutral $t(19)=-2.115$ $p=.048$, $d=-.496$, Pleasant, $t(19)=-3.200$, $p=.005$, $d=-0.822$. Saccade angular deviation was not significantly different between Pleasant vs. Neutral images, $t(19)=.725$, $p=.477$, $d=.158$.[2]

The gap effect was employed to generate a wide range of saccade latencies in order to examine the time course of the processing of emotional image content. This manipulation was successful. An equivalent dependency across image type was found for saccade latency on SOA with faster responses as fixation is removed prior to

[2] Note that we obtained the same effect of image type on saccade landing position deviation in an independent experiment with 20 participants with a constant fixation-target display SOA (0 ms), $F(2, 38) = 6.23$, $MSE=3.15$, $p = .005$, $\eta^2=.247$ where unpleasant images resulted in a greater deviation relative to other image types ($t(19) = -2.49$, p =.02 vs Neutral, $t(19) = -3.75$, $p = .001$ vs Pleasant), Neutral vs Pleasant, $t < 1$, *n.s.*).

stimuli onset: quicker latencies were elicited for gap SOA's and slower ones for overlap SOA's (running from gap 150 to overlap 150: 238, 249, 253 and 302 ms), $F(3, 57)=48.862$, $MSE=1247.239$, $p<0.001$, $\eta^2=.720$. In order to examine the temporal impact of emotional content on saccade control the impact of the image distractors on the deviation of saccade landing positions for responses of different latencies was derived. We collapsed the saccade deviation data across gap and vincentized the distribution: For each participant the latencies were separated into six time bins and the average angular deviation was computed for each bin (note that due to rounding when dividing the number of trial by six the last bin has less trials than the preceding five). The effects across subjects are shown in Figure 2b for each image type. A two-way independent measures ANOVA showed the predicted effect of Image Type, $F(2,38)=3.175$, $MSE=6.545$, $p=.053$, $\eta^2=.143$, although it just missed the conventional $p < .05$ level the effect size is large. Corrected planned comparisons (simple main effects analysis) were carried out to examine the time course of the impact of each image type on saccade control. Only the early latencies show any differences with saccades in the Unpleasant image condition being significantly pulled toward it relative to both the Pleasant and Neutral conditions (Unpleasant versus Pleasant $p=.004$; Unpleasant versus Neutral $p=.014$). The apparent difference in the pattern for Pleasant images in the first time bin was not significant (Pleasant versus Neutral p=.165; note that repeated measures error bars are plotted). There was a trend for this pattern in the second time bin with Unpleasant and Neutral conditions (Unpleasant versus Neutral p=.063, all other *p*'s in all time bins >.165). Planned trend analyses for each image type showed no linear components but did show a strongly significant quadratic component for the Unpleasant condition, $F(1,19)=9.720$, $MSE=3.458$,

p=.006, η^2=.338, similarly supporting the previous analysis showing that early time bins result in larger deviations towards than the later time bins.

Discussion

In this experiment, task-irrelevant unpleasant, neutral and pleasant images, paired with control images, flanked a target towards which the participant was instructed to saccade. Saccade landing position was found to only deviate towards task-irrelevant images that were unpleasant (without impacting on trajectory deviation). This was replicated in an independent sample (see footnote 2). Furthermore, this pull of saccade deviations towards unpleasant images was found to be due to stronger deviations in the quick saccade responses suggesting fast, parafoveal decoding of negative information.

This finding is line with a large body of research that supports the view that negative information biases attention, especially during early stages of processing (e.g. Öhman & Mineka, 2001; Cacioppo et al., 1999; Vuilleumier, 2005, although this is debated e.g. Schupp et al., 2003; Brosch et al., 2008). Given the overall negativity bias effect in our results, and the likely coarse rapid coding of the unpleasant distractors driving the fast saccades, an early guiding of attentional processes is suggested to underlie this effect. Such an early effect follows on from the prevalent view that potentially threat-related information is prioritized to instantiate the preparation of adaptive behavioural responses.

However, this finding runs counter to other eye movement studies, where results suggest a prioritization of both pleasant and unpleasant – relative to neutral - information. It is important to note that in most of these prior studies, the emotional images were central to the task at hand (Alpers, 2008; Calvo & Lang, 2004;

Nummenmaa et al., 2006; Kissler & Keil, 2008) thus encouraging some level of coding. To our knowledge, only one extant eye movement study (Nummenmaa et al., 2009) presented emotional images as task-irrelevant. Here saccade landing position deviated *away* from emotional images rather than towards. As suggested in the introduction, this discrepancy may lie in the placement of the distracting images relative to the targets: Nummenmaa et al. (2009) showed distracting images as flanking fixation regardless of the location of the target, whereas our images always flanked the target. In Nummenmaa et al.'s design then it is possible to inhibit the distractor locations throughout the experiment that may lead to deviation away from the distractor location. In ours this is not possible and the lack of prior inhibition coupled with the distractors being much closer to the target location may give rise to deviations towards.

A second factor which may contribute to the mixed findings is that when unpleasant and pleasant information is moderately arousing – as was the case in the picture set that we used – unpleasant information may be preferentially biasing attention. This effect may diminish when both pleasant and unpleasant stimuli are highly arousing (see also Olofsson et al., 2008). Future studies should explicitly investigate the extent to which a negativity bias towards unpleasant information persists when high vs. low relevant (or arousing) information is task-irrelevant and potentially distracting from the saccade.

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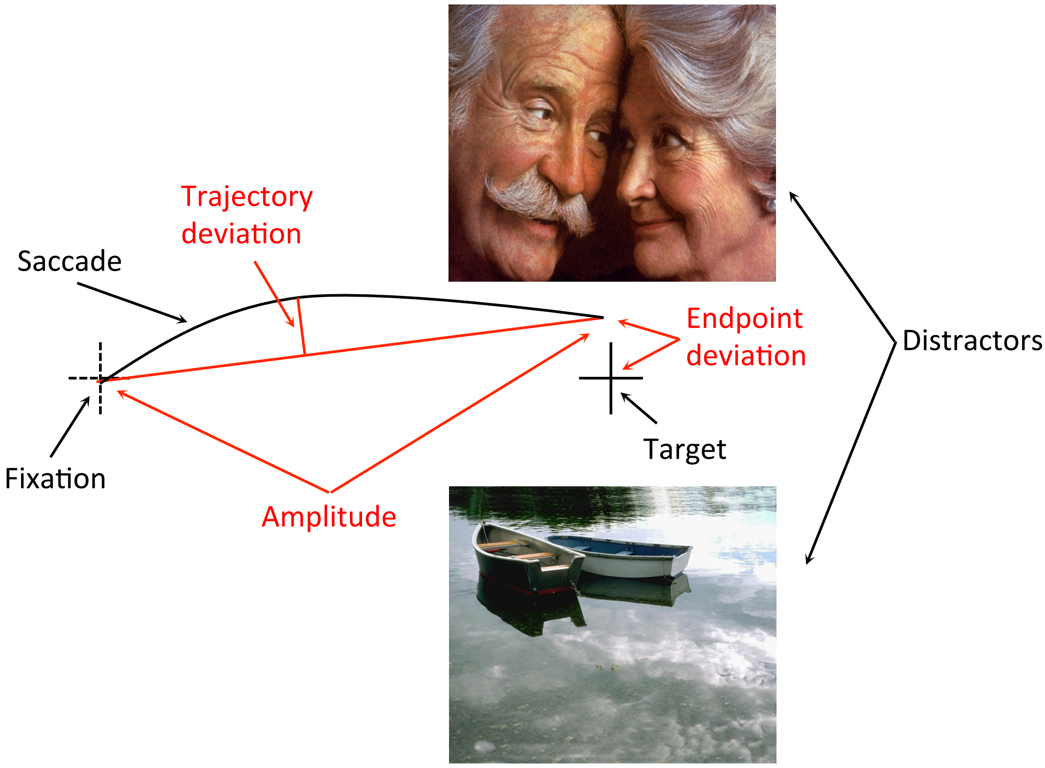

Figure 1. Display layout. A fixation cross was shown for 800-1300 ms before disappearing and immediately reappearing 8º to the left or right on the horizontal meridian. To illustrate this the fixation cross is shown as dashed lines to indicate that it has been offset and the right hand target cross is shown with solid lines. The cross was flanked by two images one of which was a Control image (no emotional content) and the other was a Control, Neutral, Pleasant or Unpleasant image (here Pleasant). This remained on for 1 second. Participants were instructed to saccade to the target cross and ignore the task-irrelevant image distractors. A schematic saccade is shown as a curved solid line from fixation toward the target. The saccade metrics (amplitude, trajectory deviation and endpoint deviation) are shown in red.

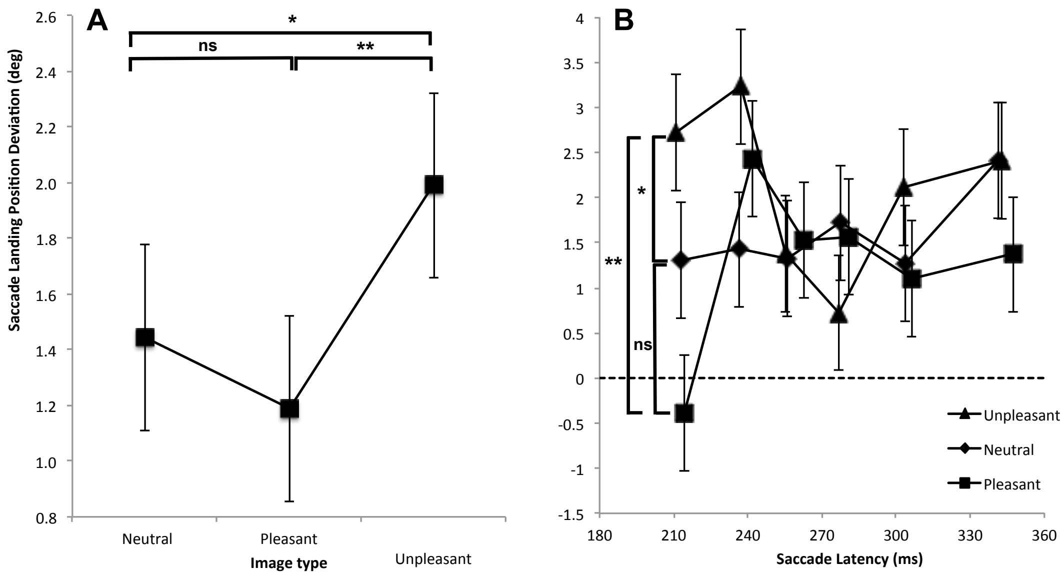

Figure 2. (A) Saccade landing position deviations as a function of image type relative to the control image condition. Positive values indicate deviations towards the content image (Neutral, Pleasant and Unpleasant) while negative values indicate deviations away. (B) Saccade landing position deviation as a for each image type as a function of saccade latency. Please note that error bars represent repeated measures confidence intervals (Loftus & Masson, 1994).

Appendix

IAPS Numbers for the Target and Control Picture Stimuli:

Unpleasant target pictures: 2095, 2375.10, 2750, 2800, 2900, 3015,3051, 3181, 3301, 3550, 6243, 6570, 6838, 9040, 9421, and 9435

Pleasant target pictures: 2040, 2050, 2057, 2070, 2091, 2165, 2209, 2216, 2340, 2352, 2550, 4608, 4641, 4653, 4700, and 8490

Neutral target pictures: 2190, 2191, 2215, 2235, 2393, 2487, 2516, 2745.1, 2840, 2850, 2870, 7493, 7496, 7550, 8311, and 9070

Neutral control pictures: 5130, 7031, 5390, 5395, 5661, 5900, 6000, 6150, 6610, 6900, 6930, 7000, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7034, 7035, 7036, 7037, 7038, 7039, 7040, 7041, 7050, 7060, 7080, 7090, 7095, 7096, 7100, 7110, 7130, 7140, 7150, 7160, 7161, 7170, 7175, 7179, 7182, 7183, 7184, 7185, 7186, 7187, 7180, 7190, 7205, 7207, 7211, 7217, 7224, 7233, 7234, 7235, 7236, 7237, 7490, 7491, 7495, 7500, 7504, 7510, 7560, 7590, 7595, 7600, 7705, 7710, 7950, 9110, 9360, 9390, 9401, and 9472