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Upper–lower visual field asymmetries in oculomotor inhibition of emotional distractors

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ABSTRACT

The present study investigated oculomotor inhibition of emotional faces as indicated by saccade curvatures. In Experiment 1, participants saccaded towards a target that appeared above or below fixation while single facial distractors depicting neutral, happy, and angry expressions appeared in one of the four quadrants of the screen. In Experiment 2, participants selected between two objects on the screen by saccading towards a predefined target, while again single facial emotional distractors were presented in one of the four screen quadrants. In both experiments, saccade trajectories curved most strongly away from angry distractors indicating enhanced attentional capture by angry faces. This effect occurred with upright faces but not with inverted faces. The emotion effect was restricted to targets at the lower vertical meridian. The lower visual field has been argued to be specialized for action in peripersonal space and near vision. The modulation by target location might be attributed to activation of near space representation by saccades toward a lower target, inducing increased vigilance for stimuli of action relevance to protect the peripersonal space from interference.

1. Introduction

Our eyes are continuously “bombarded” with a multitude of visual stimuli, each of which can serve as the target of our next eye movement. In order to direct our gaze to a target object from our visual environment, we therefore need to suppress eye movements to the objects that interfere with our goal. Direct evidence for this oculomotor inhibition process has come from a vast number of studies on saccade trajectories showing that saccade trajectories curve away from the location of a competing visual distractor (e.g., Doyle & Walker, 2001; Godijn & Theeuwes, 2002; McSorley, Haggard, & Walker, 2004; Tipper, Howard, & Houghton, 2000).

This modulation of saccade trajectories has been assumed to be the result of competitive interactions between the representations of potential targets within a common motor map (e.g., McSorley, Haggard, & Walker, 2004; Tipper, Howard, & Houghton, 2000). According to these models, the direction of an eye movement is coded by a population of neurons. The simultaneous presentation of both target and distractor activates two neuron populations – one coding for the movement towards the target and one coding for the movement towards the distractor. The competition between the two populations is assumed to be resolved by inhibiting the population that codes for the movement to the distractor. Since the population code is distributed in nature and thus the two neuron populations can overlap (i.e., some neurons are activated by the presence of both objects), inhibiting the population coding for the movement towards the distractor will inhibit a subset of the population coding for the movement towards the target. As a result, the saccade trajectory curves away from the inhibited distractor side.

The modulation of saccade trajectories by distractors has been shown to be a measure of attentional allocation in space. In a seminal study, Sheliga et al. (1994) showed that saccade trajectories deviated away from the location of the cue that signaled the participants to make a saccade towards a target. This finding was extended in a study by Van der Stigchel and Theeuwes (2007), who demonstrated that the strength of saccade deviation was a measure of the amount of attention allocated to any particular location.

A great body of research has recently looked at the factors that modulate the trajectory deviation effect (for a review, see Van der Stigchel, 2010; Van der Stigchel, Meeter, & Theeuwes, 2006). However, while this research has focused on the low-level factors that modulate saccade trajectories, little is known about the extent to which the process underlying this deviation effect is cognitively penetrable by high-level factors such as the emotional content of the distractors. Were an observer to focus solely on task-relevant information, ignoring everything else, they would miss potential dangers or chances. An effective behavior regulation mechanism should therefore enable the selection of goal-relevant information

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and the inhibition of goal-irrelevant information without missing information of superior relevance. It is therefore reasonable to assume that distractor information of superior action relevance (although task-irrelevant) should also modulate the trajectory deviation effect. One factor frequently conveying superior action relevance is emotional connotation of stimuli. For example, facial emotional expressions (in particular angry faces) have been regarded as indicating states of action readiness that are likely to lead to an action that interferes with observer's ongoing actions (e.g., Frijda, 2007). In fact, crude emotional information has been proposed to reach the amygdala through a fast subcortical route from magnocellular visual input through the superior colliculus, a structure playing a crucial role in the control of saccade eye movements (e.g., Vuilleumier, 2005). Thus, our main goal in the present study was to test for the effect of emotional distractors on saccade trajectories.

The interest in the effects of emotional stimuli on eye movements has grown in recent years. Several paradigms and measures of oculomotor competition have been employed to study them. For example, Calvo, Avero, and Lundqvist (2006) found in a visual search task that discrepant angry faces were looked at less than other faces and were more accurately detected than other faces when presented for 150 ms, but the authors found no higher probability of first fixation on angry faces. Nummenmaa, Hyönä, and Calvo (2006) found that emotional pictures received the first fixation with a greater probability than the neutral pictures. In this study, pairs of emotional and neutral pictures were presented laterally from fixation point and participants were asked to compare the pleasantness of the pictures (Experiment 1), and to look towards the emotional or neutral picture (Experiment 2). Nummenmaa, Hyönä, and Calvo (2009) found faster saccadic reaction times with emotional pictures than neutral pictures when both an endogenous and exogenous cue signaled which picture was the saccade target (Experiments 1 and 2). In the subclinical domain, Derakshan et al. (2009) found that high-anxious participants took longer time than low-anxious participants to make a saccade away from a laterally presented angry face.

The measures of oculomotor competition used in those studies did indeed provide a temporally more fine-grained information about the competition process between target and distractor than manual reaction times. However, saccade trajectories might tell us even more about this competition process. Saccade trajectories have been repeatedly shown to be sensitive to briefly active representations that might never elicit overt response. Importantly, such effects on saccade trajectories have been repeatedly observed in the absence of saccade latency differences, suggesting that saccade trajectories are a more sensitive measure of oculomotor competition than saccade latencies. Moreover, in contrast to the emotional stimuli in the above-mentioned paradigms, the distractors in the trajectory deviation paradigm are completely task-irrelevant. Therefore, the trajectory deviation paradigm is perfectly suited to explore and provide deeper insight into the fast and involuntary effects of emotional distractors on attention. Thus, given that saccade trajectories measure the amount of spatial attention one might validly argue that the distractor effect found on saccade trajectories in this paradigm reflects attentional capture by the distractor.

Surprisingly, there is only one study to date that has investigated the effect of emotional stimuli on saccade trajectories (Nummenmaa, Hyönä, & Calvo, 2009, Experiment 3). In this study, pairs of pictures depicting complex neutral and emotional scenes were presented laterally from fixation while participants executed vertical saccades. The authors found that saccade *endpoint* deviated away from the emotional stimulus, both with simultaneous presentation of target and distractors and when the distractors preceded the target with a stimulus onset asynchrony (SOA) of 150 ms. Saccade *curvatures*, however, were found to deviate away from the emotional stimulus with the 150 ms SOA only. No difference between pleasant and unpleasant distractors was found.

Saccade curvatures have been shown to reflect activity at saccade initiation, while saccade endpoint deviations have been shown to reflect activity at saccade end (McSorley, Cruickshank, & Inman, 2009). Therefore, in the current study we were particularly interested in whether the emotional content of the distractors influences saccade *curvatures* with *simultaneous* presentation of target and distractor. To this end, we used emotional facial expressions instead of complex scenes. There is a vast amount of literature which shows that emotional faces are processed in a fast and involuntary manner (for a review, see Frischen, Eastwood, & Smilek, 2008; Palermo & Rhodes, 2007). In addition, compared to the distractors typically used in the research on trajectories (e.g., simple shapes) on the one hand, and the complex emotional scenes (as used by Nummenmaa, Hyönä, & Calvo, 2009) on the other hand, facial stimuli are of intermediate complexity. Thus, finding a modulation of saccadic curvature by the emotional content of faces would lend evidence that saccadic processing is influenced by top-down conceptual information and therefore is not completely encapsulated (i.e., influenced merely by bottom-up sensory information). Since emotional faces are less complex than emotional scenes, it is *a priori* more probable to find an effect of emotion on saccade curvatures even with simultaneous presentation of target and distractor. Importantly, given that faces are processed very fast and involuntary, one might even expect a more differentiated emotional specificity in the effect of emotional stimuli on saccade trajectories. Thus, our primary focus was on the emotion-specific contrast between angry and happy faces. Our hypothesis was that due to their particular action and biological relevance, angry faces should be more strongly activated than happy faces and therefore should be more strongly inhibited, which should result in greater saccade curvature away (anger-superiority effect). However, to keep our study comparable with the study by Nummenmaa et al., who found a valence-unspecific effect on saccade trajectories, we also included neutral faces.

In addition, we aimed at investigating possible visual field asymmetries in the effect of emotion on saccade trajectories. This aim was partly motivated by a pilot experiment showing that the emotional content of the distractors modulated saccade trajectories only when the target appeared at the lower vertical meridian. A great body of literature has demonstrated upper–lower visual field asymmetries across various tasks (see Danckert and Goodale (2003) for a review). For example, lower visual field advantage has been observed with directing visually guided actions (e.g., Brown, Halpert, & Goodale, 2005; Danckert & Goodale, 2001; Khan & Lawrence, 2005; Krigolson & Heath, 2006), visual attention towards graspable objects (Handy et al., 2003), coordinate spatial judgements requiring visuomotor coordination (Niebauer & Christman, 1998), segmentation of an image into figures and background (Rubin, Nakayama, & Shapley, 1996). In addition, a great body of research has shown better visual performance at the lower vertical meridian than in the upper vertical meridian (i.e., vertical meridian asymmetry) in motion processing (e.g., Amenedo, Pazo-Alverez, & Cadaveira, 2007), contrast sensitivity and spatial resolution (e.g., Abrams, Nizam, & Carrasco, 2012; Cameron, Tai, & Carrasco, 2002; Carrasco, Talgar, & Cameron, 2001; Silva et al., 2008; Talgar & Carrasco, 2002). A vertical meridian asymmetry has been also observed with subjective measures, with the perceived contrast being higher along the lower vertical meridian (e.g., Fuller, Rodriguez, & Carrasco, 2008).

One possible explanation for these asymmetries might be the anatomical properties of the visual system. For example, the density of ganglion and cone cells is greater in the superior hemiretina (which receives input from the lower visual field) than the inferior hemiretina (which receives input from the upper visual field; Curcio & Allen, 1990; Drasdo et al., 2007; Perry & Cowey, 1985). At the level of LGN, more area in the parvocellular layers has been found to be dedicated to the lower visual field compared to the upper visual field (Connolly & Van Essen, 1984). The overrepresentation of the lower visual field as compared to the upper visual field has been also observed to extend in the visual cortex, particularly in the V1 and MT (Maunsell & Van Essen, 1987; Tootell et al., 1988; Van Essen, Newsome, & Maunsell, 1984) as well as in the posterior parietal cortex, which plays a dominant role in the action control (Galletti et al., 1999).

The upper–lower visual field asymmetries have been also interpreted in ecological terms. According to Previc (1990, 1998) the upper and lower visual fields serve different ecological functions. In particular, Previc argued that the lower visual field is almost exclusively involved in performing actions in peripersonal space. Therefore, according to Previc the lower visual field is functionally specialized for near vision and action control, such that visual information is more efficiently processed in the lower visual field than the upper visual field and action control is better in the lower visual field than the upper visual field. In contrast, the upper visual field has been assumed to be mainly involved in visual search and scene scanning in extrapersonal space. Therefore, the upper visual field has been assumed to be functionally specialized for far vision and visual search/perception. Evidence for the association of the lower visual field with near space and the association of the upper visual field with far space came from studies with neglect patients. For example, Rapcsak, Cimino, and Heilman (1988) reported a neglect patient with bilateral lesions including the posterior parietal cortex, who placed the perceived midpoint of vertical lines above the true midpoint and who showed extinction to stimuli in the lower visual field (i.e., neglect of the lower visual field). The same patient has been also reported to bisect lines extending away from the body beyond the true midpoint (i.e., neglect of near space; Mennemeier, Wertman, & Heilman, 1992). In contrast, Shelton, Bowers, and Heilman (1990) reported a patient with bilateral lesions including the temporo-occipital cortex who marked the perceived midpoint of a vertical line below the true midpoint (i.e., neglect of the upper visual field) and bisected lines extending away from the body closer to the body (i.e., neglect of far space). It should be noted, however, that the support for the upper visual field specialization for visual search and scanning is rather scarce. Only few studies reported upper visual field advantage in visual search and categorical judgments (e.g., Fecteau, Enns, & Kingstone, 2000; Niebauer & Christman, 1998; Previc & Blume, 1993; Previc & Naegele, 2001). Thus, as argued by Danckert and Goodale (2003) a one-to-one mapping of the lower and upper visual fields onto the dorsal "action" pathway and the ventral "perception" pathway might be too simplistic because the ventral "perception" pathway is mainly biased toward the central visual field, and therefore, upper visual field biases should not be observed far in the periphery.

Given this background, one might expect the vertical location of distractor and/or target to modulate the effect of emotional faces on saccade trajectory. In particular, goal interference may depend on the visual field in which the distractors appear. Given that stimuli in the lower visual field are represented in near space, an emotional distractor presented in this hemifield might be assumed to be represented as being in near space, and therefore relevant for action, leading to a stronger goal interference as compared to a distractor presented in the upper field. In this case, an interaction of distractor location and distractor emotion should be observed, with distractor emotion modulating saccade curvature only when distractors appear in the lower visual field. Alternatively, target location may drive the effect of emotional faces on saccade curvature (and this was actually found in our pilot experiment). A saccade towards a lower target might invoke representations of near space and therefore induce increased vigilance for stimuli of unspecific action relevance to protect the peripersonal action space from interference (regardless of the distractor location). In this case, an interaction of target location and distractor emotion should be observed, with distractor emotion modulating saccade curvature only when downward saccades are required. Finally, goal interference might depend on both target and distractor location. In this case, a three-way interaction should be observed, with distractor emotion modulating saccade curvature when both target and distractor appear in the lower visual field.

2. Experiment 1

Effects of emotional stimuli on attentional processes have been often attributed to differences in perceptual processing (e.g., Purcell, Stewart, & Skov, 1996). To tease apart the effects of emotional and perceptual processing we employed the standard procedure of using upright and inverted facial photographs (e.g., Fox et al., 2000). The reasoning is that inversion impairs holistic processing of faces, including emotion processing, whereas the perceptual processing of components remains intact. Thus, if the effect of, for example, angry vs. happy faces on saccade curvature is due to processing of the emotional content rather than the low-level perceptual features of the images, then it should be observed with upright faces but not with inverted faces. Thus, if face orientation (i.e., upright vs. inverted) moderates the effect, we can plausibly infer that the emotional connotation is the underlying influence. In addition, to enhance participants' engagement in the task and emphasize the action-like nature of saccading we presented participants with gaze-contingent feedback upon target fixation.

2.1. Method

2.1.1. Participants

Twenty-three non-psychology students of Saarland University participated in the experiment (14 female). Their median age was 25 years (ranging from 20 to 29 years). All reported having normal or corrected-to-normal vision. Participants were paid 7.50 € for their participation. They gave their informed consent prior to the experiment session. One further participant had to be excluded due to poor eye-tracking quality.

2.1.2. Apparatus and material

Eye movements were recorded using a video-based column eye tracker (SensoMotoric Instruments) with a temporal resolution of 500 Hz and a spatial resolution of 0.01°. Data were recorded from the dominant eye. A chin rest was used to minimize head movements and to maintain the viewing distance at 64 cm. A forehead rest was used to enable participants to keep their head parallel to the display. This ensured that the stimuli subtended the same visual angle independent of the visual hemifield in which they appeared. The stimuli were presented on a black background. The fixation cross was a white cross subtending a visual angle of $1.79^\circ \times 1.79^\circ$. The target was a gray diamond subtending a visual angle of $2.24^\circ \times 2.24^\circ$, which appeared 10.27° above or below fixation. Distractors were the neutral, angry, and happy face photographs of 10 individuals (5 female) from the Karolinska Directed Emotional Faces Set (Lundqvist, Flykt, & Öhman, 1998). Non-facial features were cropped by applying an oval shape that retained the eyebrows, eyes, nose, and mouth in each image. The distractors subtended a visual angle of $3.58^\circ \times 4.92^\circ$ and appeared in the upper-left, upper-right, lower-left, and lower-right part of the screen (at a vertical distance of 2.24° between the fixation cross and the innermost edge of the face photograph and a horizontal distance of 5.37° between the fixation cross and the innermost edge of the face photograph, at one of four polar angles relative to the horizontal meridian 22.62°, 157.38°, 202.62°, and 337.38°, where 0° corresponds to East, 90° to North, 180° to West, and 270° to South). The mean luminance of the face photographs was assessed using Adobe Photoshop CS4. The distractor photographs did not differ in mean luminance, $F(2,27) = 2.15$, $p = .14$. In particular, there was no significant difference in mean luminance between angry and happy faces, $t(18) = 0.08$, n.s. The stimuli were presented on a 21-in linearized flat color monitor with a refresh rate of 75 Hz and a resolution of 1024 × 768 pixels.

2.1.3. Design

The design comprised one between-subject factor (distractor orientation: upright vs. inverted) and four within-subject factors, namely distractor emotion (angry vs. happy vs. neutral), target location (upper vs. lower), vertical distractor location (upper vs. lower), and horizontal distractor location (left vs. right). In addition, two no-distractor conditions (target upper vs. target lower) were included, which served as a baseline. Each participant completed a total of 540 trials (20 trials per distractor condition and 30 trials per no-distractor condition).

2.1.4. Procedure

Participants first provided informed consent. Individual eye-tracker adjustments were performed followed by a 13-point-calibration. Subsequently, the instructions were given on the display. There were eight practice trials. Participants could take an unlimited number of breaks.

Each trial began with a central fixation cross, which participants were asked to look at (see Fig. 1 for an illustration of the trial sequence). The experimenter carried the trial on, if participants fixated the fixation cross. If participants' gaze did not land on the fixation cross due to impairment in tracking accuracy, a recalibration was performed. Subsequently, the target rhombus and distractor face appeared simultaneously and remained on the screen for 1500 ms. The target display was followed by an inter-stimulus interval of 500 ms, after which the next trial started. Participants were instructed to look at the target as quickly and accurately as possible and to maintain their gaze on the target as long as it remained on the display. To provide participants with feedback on task compliance, the target color changed to green as soon as participants fixated it. Participants were told that in most trials, a face would appear at one of the intercardinal points of the display, simultaneously with the target. Participants were told that these faces were totally irrelevant for their task and therefore were to be ignored.

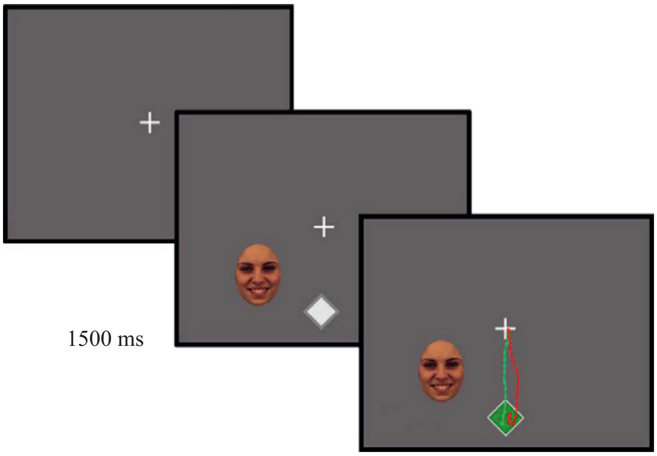

Fig. 1. An illustration of the trial sequence in Experiment 1. The target (grey rhombus) appeared above or below the fixation cross; the distractor face appeared in the upper-left, upper-right, lower-left, or lower-right quadrant of the display. The target's color changed to green as soon as the participant fixated the target. Depicted are also two sample saccade trajectories from the distractor condition (red line) and the corresponding no-distractor baseline condition (green line).

2.1.5. Data analysis

The SMI software BeGaze identified saccade start and end points using a 40°/s velocity criterion. Saccade latency, direction, and amplitude were derived from the eye movement records for the first saccade in each trial. Saccades were excluded from further analysis if (1) the gaze deviated more than 1.93° from the display center at the time of target onset, (2) the latency was less than 80 ms, (3) the saccade was not directed to the correct target location, or (4) the amplitude was less than 6° or greater than 16°. After saccades had been identified, the curvature was computed. The quadratic coefficient of the second-order polynomial that was fitted to the normalized saccade was used as a measure of curvature (see Ludwig and Gilchrist (2002) for a detailed description and comparison of curvature measures). Since saccade trajectories are never completely straight, *curvature scores* were calculated by subtracting the quadratic curvature observed in the no-distractor conditions from those observed in the distractor conditions. The baseline curvature for each participant was calculated and subtracted for each target location separately. Thus, the effect of distractor on trajectory reported here reflects the difference in curvature between the distractor and the corresponding no-distractor conditions. Trajectories curving towards the distractor were assigned positive values, whereas trajectories curving away from the distractor were assigned negative values. The trajectory curvatures are reported in degrees of visual angle.

2.2. Results

The exclusion criteria led to a mean loss of 13.31% of the trials.

2.2.1. Saccade curvature

Preliminary analyses showed that the horizontal distractor location did not significantly modulate any emotion effect, all $Fs < 2.53$. Therefore, to reduce the complexity of the analyses we collapsed across the horizontal distractor location. Curvature scores were submitted to a mixed 2 (distractor orientation: upright vs. inverted) × 3 (distractor emotion: angry vs. happy vs. neutral) × 2 (distractor location: upper vs. lower) × 2 (target location: upper vs. lower) MANOVA. Since we use the multivariate approach to repeated measures, the tripartite factor of emotion is – as part of the procedure – transformed into a vector of two orthogonal contrast variables (see, e.g., Dien & Santuzzi, 2005). We *a priori* chose the contrasts in a way that they represent the specific hypotheses outlined above. That is, the first contrast is the contrast between angry and happy faces, representing our hypothesis of larger curvature for angry compared to happy faces. For the second contrast, scores are averaged across angry and happy faces and contrasted with the neutral stimuli. This contrast represents the hypothesis that emotional stimuli (in general) produce larger curvature compared to neutral stimuli, as found by Nummenmaa, Hyönä, and Calvo (2009). For the sake of completeness, we also report the individual contrasts between angry and neutral distractors and between happy and neutral distractors.

The main effect of target location was significant, $F(1,21) = 6.49$, $p < .05$, $\eta_p^2 = .24$, indicating that downwards saccades curved away from the distractor more strongly than upwards saccades ($M = -0.14$, $SD = 0.12$ vs. $M = -0.08$, $SD = 0.11$). The interaction of distractor emotion and distractor location was marginally significant, $F(2,20) = 3.44$, $p = .05$, $\eta_p^2 = .26$ ($F(1,21) < 1$, for angry vs.

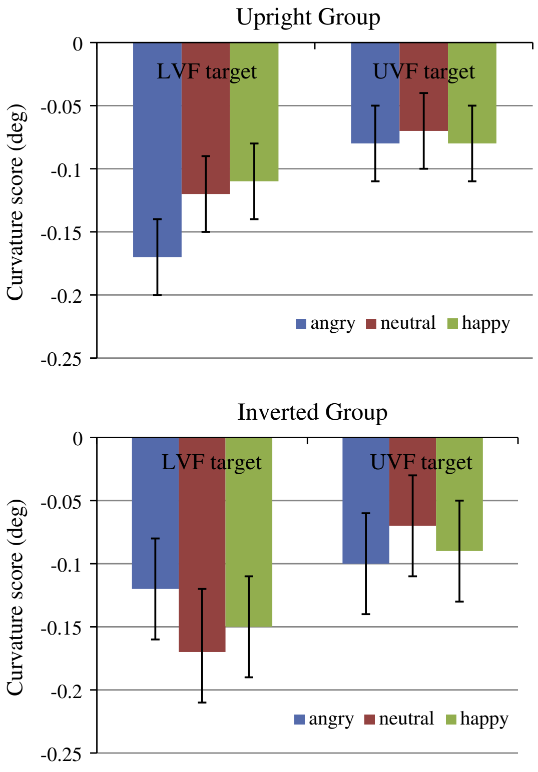

Fig. 2. Mean curvature scores (i.e., difference in curvature relative to the corresponding no-distractor baseline condition) in Experiment 1 (in degrees; error bars represent the standard error of the mean); positive values indicate curvature towards the distractor, negative values indicate curvature away from the distractor; UVF (upper visual field), LVF (lower visual field).

happy; $F(1,21) = 4.23$, $p = .05$, $\eta_p^2 = .17$, for neutral vs. emotional). In the upper visual field, mean curvature scores were numerically (but not significantly) greater for neutral compared to emotional distractors ($M = -0.11$, -0.10, -0.12 for angry, happy, neutral, respectively; $F(2,21) = 2.19$, $p = .14$, $\eta_p^2 = .17$; $F(1,22) = 1.87$, $p = .19$, $\eta_p^2 = .08$, for emotional vs. neutral); in the lower visual field, it was the other way round ($M = -0.12$, -0.11, -0.09 for angry, happy, neutral, respectively; $F(2,21) = 1.44$, $p = .26$, $\eta_p^2 = .12$; $F(1,22) = 2.87$, $p = .10$, $\eta_p^2 = .12$, for emotional vs. neutral). Note that this interaction was *not* qualified by distractor orientation (i.e., upright vs. inverted), $F(2,20) < 1$. Thus according to our rationale it had presumably nothing to do with emotional processing.

Most importantly, the interaction of distractor orientation, distractor emotion, and target location was significant, $F(2,20) = 5.58$, $p = .01$, $\eta_p^2 = .36$, suggesting that face inversion (i.e., whether a face directly signals an emotion or not) modulated the two-way-interaction of emotional face type and target location (see Fig. 2). This interaction was due to a significant contrast between the angry and happy distractors, $F(1,21) = 10.58$, $p < .01$, $\eta_p^2 = .34$, but not due to the contrast between the emotional (i.e., angry and happy stimuli collapsed) distractors and the neutral distractors, $F(1,21) = 2.44$, $p = .13$, $\eta_p^2 = .10$ ($F(1,21) = 6.82$, $p = .02$, $\eta_p^2 = .25$, for angry vs. neutral; $F(1,21) < 1$, for happy vs. neutral). There were no other significant effects or interactions (all $Fs < 2.59$). To further examine the interaction of distractor orientation, distractor emotion, and target location we conducted separate analyses for each distractor orientation group.

2.2.1.1. Analysis of upright faces: the effect of emotion. For the upright distractor orientation group, a significant interaction of distractor emotion and target location emerged, $F(2,10) = 4.41$, $p < .05$, $\eta_p^2 = .47$. Again, this result was due to a significant difference between the happy and angry distractors, $F(1,11) = 9.63$, $p = .01$, $\eta_p^2 = .47$ ($F(1,11) < 1$, for emotional vs. neutral; $F(1,11) = 1.34$, $p = .27$, $\eta_p^2 = .11$, for angry vs. neutral; $F(1,11) < 1$, for happy vs. neutral). We analyzed the curvature scores for each target location separately. For the upper target location the main effect of distractor emotion was not significant, $F(2,10) < 1$, n.s. For the lower target location, however, the main effect of distractor emotion was significant, $F(2,10) = 4.39$, $p < .05$, $\eta_p^2 = .47$. It was again almost exclusively due to the significant difference between the angry and happy distractors, $F(1,11) = 9.66$, $p = .01$, $\eta_p^2 = .47$ ($F(1,11) < 1$ for the contrast emotional vs. neutral; $F(1,11) = 3.72$, $p = .08$, $\eta_p^2 = .25$, for the contrast angry vs. neutral; $F(1,11) < 1$, for the contrast happy vs. neutral).

2.2.1.2. Analysis of inverted faces: controlling for perceptual features. As can be seen from Fig. 2, the numerical pattern of curvature scores was different for inverted faces compared to upright faces. The interaction of distractor emotion and target location missed the conventional level of significance, $F(2,9) = 3.15$, $p = .09$, $\eta_p^2 = .41$. Even more important, the contrast angry vs. happy (i.e., the essential difference for upright faces) was clearly non-significant for inverted faces, $F(1,10) = 2.74$, $p = .13$, $\eta_p^2 = .22$ ($F(1,10) = 5.53$, $p = .04$, $\eta_p^2 = .36$, for emotional vs. neutral; $F(1,10) = 6.99$, $p = .03$, $\eta_p^2 = .41$, for angry vs. neutral; $F(1,10) = 1.75$, $p = .22$, $\eta_p^2 = .15$, for happy vs. neutral). Although the interaction missed the conventional level of significance, we analyzed the curvature scores for each target location separately corresponding to the upright group analysis. Importantly, the main effect of emotion was not significant with either target location, $F(2,9) < 1$, n.s., for the upper target location, $F(2,9) = 2.59$, $p = .13$, $\eta_p^2 = .37$, for the lower target location ($F(1,10) = 3.97$, $p = .07$, $\eta_p^2 = .28$, for angry vs. happy; $F(1,10) = 4.44$, $p = .06$, $\eta_p^2 = .31$, for angry vs. neutral; $F(1,10) < 1$, for happy vs. neutral; $F(1,10) = 2.59$, $p = .14$, $\eta_p^2 = .21$, for emotional vs. neutral).

2.2.2. Saccade latency

Since the magnitude of saccade curvature depends on saccade latency (McSorley, Haggard, & Walker, 2006), we submitted saccade latencies to a mixed 2 (distractor orientation: upright vs. inverted) × 3 (distractor emotion: angry vs. happy vs. neutral) × 2 (distractor location: upper vs. lower) × 2 (target location: upper vs. lower) MANOVA. In line with previous studies (Honda & Findlay, 1992), the main effect of target location was significant, $F(1,21) = 89.41$, $p < .001$, $\eta_p^2 = .81$, indicating that upwards saccades were faster than downwards saccades ($M = 230$ ms, $SD = 32$ ms vs. $M = 258$ ms, $SD = 36$ ms). The interaction of target location and vertical distractor location was significant, $F(1,21) = 80.86$, $p < .001$, $\eta_p^2 = .79$, indicating that saccades were faster if target and distractor appeared in the same visual hemifield. Importantly, the interaction of distractor orientation, distractor emotion, and target location was not significant, $F(2,20) = 1.08$, $p = .36$, $\eta_p^2 = .10$. No other significant main effects or interactions emerged, all $Fs < 2.08$.

To investigate whether the effect of angry vs. happy faces found in the upright group with downwards saccades was due to the latencies being slower in the lower visual field compared to the upper visual field, we used a multiple regression approach for repeated measures (Lorch & Myers, 1990). The procedure can be best understood by assuming that curvature scores are regressed on distractor emotion (angry vs. happy), target location, and saccade latency, as well as on the interaction terms distractor emotion × target location and distractor emotion × saccade latency for each participant of the upright sample separately (using trials as cases). Means of regression coefficients across the sample are then tested on whether they significantly deviate from zero. If the test for distractor emotion × target location is significant, whereas it is not significant for distractor emotion × saccade latency, we can legitimately claim that location and not latency is the decisive factor. Actually, we used an equivalent procedure to the one just described (suggested by Lorch and Myers (1990)) that delivers the same result in a single analysis of the participants × trials data set (see also Van den Noortgate & Onghena, 2006). Using this procedure, we found the interaction of target location and distractor emotion (angry vs. happy) to be significant, $F(1,11) = 5.36$, $p < .05$, whereas the interaction of latency and distractor emotion was not significant, $F(1,11) < 1$.

2.3. Discussion

Experiment 1 aimed at investigating whether emotional face distractors modulate saccade curvature with simultaneous presentation of target and distractor and whether this effect is due to processing of the emotional content of the distractors or their perceptual low-level features. In addition, Experiment 1 aimed at investigating possible visual field asymmetries. To this end, single facial distractors displaying angry, happy, and neutral expressions were presented at intercardinal screen positions while participants executed exogenous saccades to a target onset above and below fixation. Target and distractor appeared simultaneously on the screen. To tease apart processes of perceptual features from emotional processes a condition was included in which the faces were presented in inverted orientation. As expected, results showed that saccade trajectories curved more strongly away from angry faces than happy ones. Importantly, this effect was only evident, when the face distractors were presented in upright orientation. Therefore, the emotion effect is unlikely to be due to different perceptual features of the face types. We can compare this with the marginally significant interaction of emotional distractors and distractor location, which was *not* further moderated by orientation. There was a trend of stronger curvature away with emotional distractors in the lower visual field as compared to the neutral distractors in the lower visual field. It might be that the components that constitute emotional faces in contrast to neutral ones (e.g., curved mouth compared to straight mouth) are more salient (see Horstmann & Bauland, 2006) and that observers' perceptual sensitivity is better in the lower visual field for these features. However, such an effect is presumably not caused by the emotionality of the faces.

As predicted, the vertical location of the target modulated the effect of emotion on saccade curvatures. If we focus on the angry vs. happy contrast, we found a significant interaction of this contrast with target location. The stronger curvature effect for angry faces (compared to happy ones) was restricted to lower targets, indicating that target location drives the effect of emotional faces on saccade curvature. Given that the lower visual field represents near space (Previc, 1990), a downward saccade might have induced representations of near space, therefore increasing the vigilance for stimuli of action relevance such as angry faces (regardless of their position). However, it remains open whether the interaction with target location observed in this experiment was driven by the specialization of the lower visual field for action. Experiment 2 aimed at investigating this possibility by replicating the results from Experiment 1 with conceptually more meaningful targets that afford actions.

Previous studies showed that the magnitude of the trajectory curvature effect was greater with distractors that appeared in the same hemifield as the target compared to distractors that appeared in the opposite hemifield (see, e.g., Doyle & Walker, 2001; McSorley, Haggard, & Walker, 2004; Tipper, Howard, & Paul, 2001). One possible reason why no effect of distractor location (same vs. opposite) was observed in Experiment 1 might be that the distractors were perceptually more salient than the target, thus inducing a highly potent competition and great inhibition, which might eventually have led to a ceiling effect.

3. Experiment 2

Experiment 2 aimed at conceptually replicating the findings from Experiment 1 with a new kind of task that relates our study to recent research on the perception–action link. The task was modified from a study by Forti and Humphreys (2008), in which pictures of eight different (graspable) objects were presented in a circular arrangement. Participants were instructed to look for and to fixate the target object that was previously defined by a cue. Several eye movement parameters (e.g., probability of first fixation on the target) were analyzed as a function of visual field. As expected, the authors found increased probability of first fixation on prototypical-view targets (i.e., a view that resonates with action schemata represented in the dorsal stream) in the lower visual field. The authors attributed this result to the strong representation of the lower visual field in the dorsal visual stream, which is known to be functionally specialized for object-directed actions.

In Experiment 2, we presented participants with pictures of two graspable objects (in prototypical view) above and below the fixation cross. One of the objects was predefined by a preceding cue as the target. Thus, in contrast to Experiment 1, where saccades were exogenously triggered by a single sudden-onset meaningless target, the task in Experiment 2 had stronger action character, as intentional selection of a semantically defined object was required. Again, a task-irrelevant distractor face appeared in one of the four quadrants of the screen simultaneously with the two objects. Thus, if we again observe an effect of emotion (i.e., stronger curvature away for angry vs. happy faces) which is restricted to targets at the lower vertical meridian, we can more plausibly interpret our findings in terms of perception–action coupling.

As an aside, we varied the cue type (i.e., noun vs. verb, e.g., scissors vs. cut paper) since Forti and Humphreys (2008) found an interaction of cue type and target location for some of their dependent variables (e.g., the duration of the first fixation was shorter on targets in the lower visual field only in the verb cue condition). Thus, verb cues might enhance the action character of the task. Therefore, we were open for a further moderation of the distractor emotion × target location interaction by cue type (i.e., that the distractor emotion × target location interaction is enhanced in the verb cue condition). However, Forti and Humphreys did not find a cue type × target location interaction for the probability of first fixation, which compared to the other measures used by the authors rather reflects attentional capture and is thus more comparable to saccade trajectories. Thus, we could not strongly hypothesize a second-order interaction of distractor emotion, target location, and cue type.

3.1. Method

3.1.1. Participants

Twenty-two non-psychology students of Saarland University participated in the experiment (11 female). Their median age was 22.5 years (ranging from 19 to 28 years). All reported having normal or corrected-to-normal vision. Participants were paid 8 € for their participation. They gave their informed consent prior to the experiment session.

3.1.2. Apparatus and material

The apparatus was the same as in Experiment 1. The stimuli were presented on a white background. The fixation cross was a black cross subtending a visual angle of 1.79° × 1.79°. The stimuli were black-and-white photographs of real objects that were highly

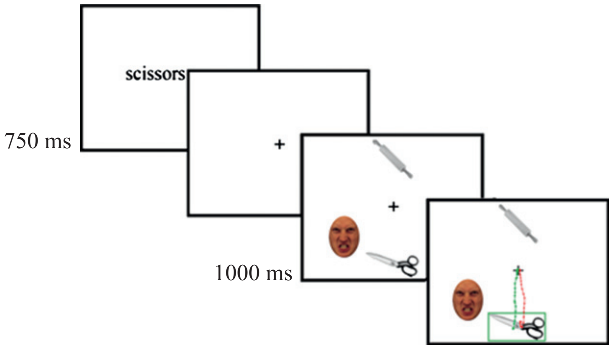

Fig. 3. An illustration of the trial sequence in Experiment 2. The target (e.g., scissors) appeared above or below the fixation cross; the distractor face appeared in the upper-left, upper-right, lower-left, or lower-right quadrant of the display. A green frame appeared around the target object photograph as soon as participants fixated it. Depicted are also two sample saccade trajectories from the distractor condition (red line) and the corresponding no-distractor baseline condition (green line).

likely to activate a grasp response (e.g., scissors; see Appendix A for a complete list of the stimuli used in Experiment 2). The photographs of the objects subtended a visual angle of approx. 6° × 6°. They appeared at a vertical distance of approx. 7° between the fixation cross and their inner edge. Distractors were the same as in Experiment 1.

3.1.3. Design

The design comprised five within-subject factors, namely distractor emotion (angry vs. happy vs. neutral), target location (upper vs. lower), vertical distractor location (upper vs. lower), horizontal distractor location (left vs. right), and cue type (noun vs. verb). In addition, four no-distractor conditions (target location × cue type) were included, which served as a baseline. Each participant completed a total of 600 trials (10 trials per distractor condition and 30 trials per no-distractor condition).

3.1.4. Procedure

Participants first provided informed consent. Individual eye-tracker adjustments were performed followed by a 13-point-calibration. Subsequently, the instructions were given on the display. The two cue type conditions were presented in two separate blocks of 300 trials each. Block order was randomized across participants. There were four practice trials prior to each block. The object photographs used in the practice trials were different from those used in the experimental trials. After every 75 trials participants could take a break, after which the eye tracker was recalibrated.

Each trial started with the instruction regarding what to look at for 750 ms (see Fig. 3 for an illustration of the trial sequence). Subsequently, a central fixation cross was presented until the experimenter pressed a key. If participants' gaze did not land on the fixation cross due to impairment in tracking accuracy, a recalibration was performed and the instruction regarding what to look at reappeared. Subsequently, the target display appeared for 1000 ms. The target display consisted of the distractor face, which appeared obliquely from the fixation cross, and two object photographs presented above and below the fixation cross, one of which was the saccade target. The target display was followed by an inter stimulus interval of 500 ms, after which the next trial started. Participants were instructed to look at the target object photograph without making erratic eye movements to the other object photograph and to maintain their gaze on the target as long as it remained on the display. To provide participants with feedback on task compliance, a green frame appeared around the target object photograph as soon as participants fixated it. Participants were told that in most trials, a face would appear at one of the intercardinal points of the display, simultaneously with the target. Participants were told that these faces were totally irrelevant for their task and therefore were to be ignored.

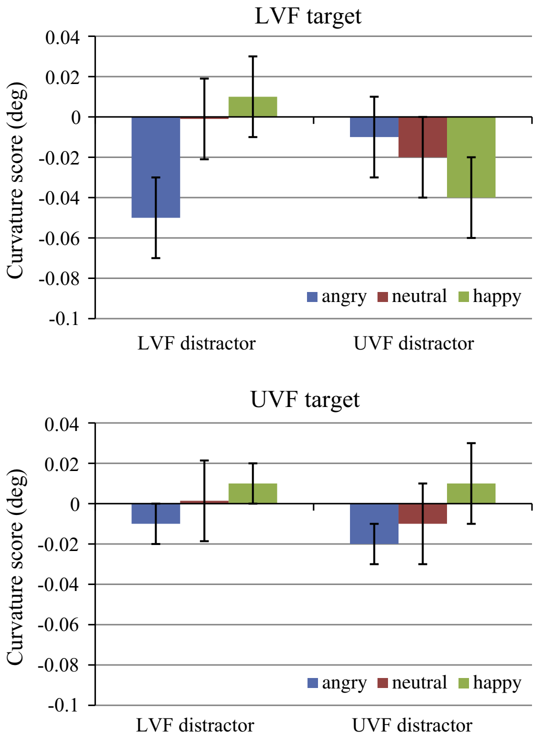

Fig. 4. Mean curvature scores (i.e., difference in curvature relative to the corresponding no-distractor baseline condition) in Experiment 2 (in degrees; error bars represent the standard error of the mean); positive values indicate curvature towards the distractor, negative values indicate curvature away from the distractor; UVF (upper visual field), LVF (lower visual field).

3.1.5. Data analysis

Data were prepared in the same way as in Experiment 1 with the exception that in Experiment 2 the only threshold value for the saccade amplitude was 4°.[1]

3.2. Results

The exclusion criteria led to a mean loss of 20.89% of the trials.

3.2.1. Saccade curvature

Preliminary analyses showed that the horizontal distractor location and the cue type did not significantly modulate any emotion effect, all Fs < 2.76. Therefore, to reduce the complexity of the analyses we collapsed across the horizontal distractor location and the cue type. Fig. 4 depicts the mean curvature scores of the remaining conditions. Curvature scores were submitted to a 3 (distractor emotion: angry vs. happy vs. neutral) × 2 (target location: upper vs. lower) × 2 (distractor location: upper vs. lower) within-subject MANOVA. The main effect of target location was significant, $F(1,21) = 4.76$, $p < .05$, $\eta_p^2 = .19$, indicating that the curvature away was stronger with downwards saccades than upwards ($M = -0.02$, $SD = 0.03$ vs. $M = -0.003$, $SD = 0.03$). With regard to

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[1] We made the amplitude criterion in Experiment 2 more liberal since the targets were bigger in size, which resulted in a bigger saccade amplitude variance.

distractor emotion, it can be easily seen in Fig. 4 that target location as well as distractor location did matter. This is reflected in a significant three-way interaction of distractor emotion, target location, and distractor location with regard to the contrast angry vs. happy, $F(1,21) = 3.94$, $p = .03$ (one-tailed[2]), $\eta_p^2 = .16$ ($F(1,21) < 1$, for emotional vs. neutral; $F(1,21) = 4.27$, $p = .05$, $\eta_p^2 = .17$, for angry vs. neutral; $F(1,21) < 1$, for happy vs. neutral; $F(2,20) = 3.01$, $p = .07$, $\eta_p^2 = .23$, for the overall interaction). With upwards saccades, the interaction of distractor emotion and distractor location was not significant, $F(2,20) < 1$. With downwards saccades, the interaction of distractor emotion and distractor location was significant, $F(2,20) = 4.39$, $p < .05$, $\eta_p^2 = .31$. When the distractor appeared in the lower visual field (i.e., matched the target location), the contrast between the happy and angry distractors was significant, $F(1,21) = 4.17$, $p = .05$, $\eta_p^2 = .17$ ($F(1,21) = 2.32$, $p = .14$, $\eta_p^2 = .10$, for emotional vs. neutral; $F(1,21) = 6.96$, $p = .02$, $\eta_p^2 = .25$, for angry vs. neutral; $F(1,21) < 1$, for happy vs. neutral; $F(2,20) = 3.38$, $p = .055$, $\eta_p^2 = .25$, for the overall emotion effect). In contrast, when the distractor appeared in the upper visual field (i.e., mismatched the target location), no significant effect of distractor emotion emerged, $F(2,20) < 1$. There were no other significant main effects or interactions, all $Fs < 2.00$.

3.2.2. Saccade latency

The saccade latencies in the distractor conditions were submitted to a 3 (distractor emotion: angry vs. happy vs. neutral) × 2 (target location: upper vs. lower) × 2 (distractor location: upper vs. lower) within-subject MANOVA. The main effect of target location was significant, $F(1,21) = 20.83$, $p < .001$, $\eta_p^2 = .50$, indicating that upwards saccades had faster latencies than downwards saccades ($M = 312$ ms, $SD = 68$ ms vs. $M = 334$ ms, $SD = 70$ ms). The interaction of target location and distractor location was significant, $F(1,21) = 10.74$, $p < .01$, $\eta_p^2 = .34$, indicating that saccades were faster if target and distractor appeared in the same visual hemifield. Importantly, the three-way interaction of distractor emotion, target location, and distractor location was not significant, $F(2,20) < 1$. There were no other significant main effects and interactions, all $Fs < 1$.

As latencies in this experiment were again faster with upwards compared to downwards saccades, we tested the possibility that the effect of distractor emotion found with downwards saccades was due to their slower latencies, using a multiple regression approach for repeated measures (Lorch & Myers, 1990; see Experiment 1 for details). However, whereas – corresponding to our main analysis – the interaction of target location, distractor location, and distractor emotion was again significant, $F(1,21) = 4.35$, $p < .05$, the interaction of latency, distractor location, and distractor emotion was not significant, $F(1,21) = 2.48$, $p = .13$.

3.3. Discussion

Experiment 2 aimed at conceptually replicating the main result of Experiment 1 by showing again that the effect of emotion on saccadic curvature was restricted to targets at the lower vertical meridian. To this end, participants were required to select between two action-affording objects by saccading towards one of them, which had been previously defined as the target. As expected, angry faces produced stronger curvature away than happy ones. Again, this was observed only when the target object appeared at the lower vertical meridian. In addition, the effect of emotion on saccade trajectories in Experiment 2 was further qualified by the vertical distractor location, indicating that angry faces produced stronger curvature away than happy faces only when the distractor appeared in the lower visual field as well. The present findings go beyond a simple replication of Experiment 1 since they allow to relate saccade trajectories to the perception–action coupling. The task in Experiment 2, which was a modified version of the object search task introduced by Forti and Humphreys (2008), had a stronger action character than the task in Experiment 1, which is traditionally used in research on saccade trajectories. Thus, the present findings can be even more plausibly attributed to the lower visual field specialization for action.

It should be noted that cue type (i.e., noun vs. verb) had no effect in Experiment 2. We admit that a moderation of the distractor emotion × target location interaction by cue type in terms of a greater emotion effect with lower targets in the verb condition than in the noun condition would have further supported the interpretation in terms of perception–action coupling. However, although it was rational to employ this manipulation, a strong hypothesis with regard to this factor was impeded from the start on as Forti and Humphreys (2008) found no effect for this manipulation on the probability of first fixation on the target, which compared to the other measures used by the authors rather reflects attentional capture and is thus more comparable to saccade trajectories.

A final word has to be said on the fact that some distractors in Experiment 2 did not induce a curvature different from zero (i.e., no curvature; see Fig. 4), which might seem surprising given the literature on saccade trajectories. We believe this was due to the great task difficulty of Experiment 2, where the target competed with another potential target in addition to the distractor. As a result, the relative salience of some distractors might have diminished leading to reduced activation. To our knowledge, this kind of rather complex cuing-and-selection procedure with conceptually meaningful targets was used for the first time in combination with saccade trajectories.

4. General discussion

In two experiments, we investigated whether saccade curvatures are influenced by a higher-level representation of the distractor (i.e., emotional valence) with simultaneous presentation of target and distractor. In addition, possible modulation of this effect by the vertical location of target and/or distractor was examined. In both experiments, we found that angry faces produced stronger saccade curvature away than happy faces only when the target appeared in the lower visual field. In Experiment 1, we used inverted face distractors as a control condition. The effect was found with upright faces only. Therefore, it is unlikely to be due to differences in processing of face components. In Experiment 2, we employed a more complex task, which encompassed intentional selection of a semantically predefined object and had therefore a stronger action character as compared to the simple task used in Experiment 1. Even in this context, the emotion effect found in Experiment 1 was replicated. There was only one difference in results between the two experiments. Whereas in Experiment 1 distractor location (i.e., whether the distractor appeared near or far from the lower target) did not matter, in Experiment 2 the modulation of the emotion effect by target location was qualified by an interaction with distractor location, indicating that the emotion effect occurred only when both target and distractor appeared in the lower visual field. We will return to this difference below.

The present findings are consistent with accounts according to which emotional information reaches the amygdala through a fast subcortical route through the superior colliculus – a structure playing an important role in the saccade control (e.g., Vuilleumier, 2005). It has been shown that saccade curvatures reflect the

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[2] Note, given the specific prediction (i.e., curvature angry > curvature happy) and the equivalence of an F-test with one numerator df to a two-tailed t-test, a one-tailed test is allowed even for F-tests (see, e.g., Maxwell & Delaney, 1990).

strength of the oculomotor programs present on a common motor map (possibly situated in the intermediate layers of the superior colliculus) at the moment the eye movement is initiated (McSorley, Cruickshank, & Inman, 2009). Thus, the present results suggest that the angry distractors were more strongly activated than the happy distractors and therefore required a greater amount of inhibition than the happy distractors. Moreover, as the distractors in the present study were completely task-irrelevant and saccade trajectories have been shown to measure the amount of spatial attention, the present results suggest a stronger attentional capture by the angry distractors as compared to the happy ones. This conclusion is consistent with the large literature on the "anger superiority effect" on manual reaction times (e.g., Fox & Damjanovic, 2006; Hansen & Hansen, 1988; Mogg & Bradley, 1999; Öhman, Lundqvist, & Esteves, 2001). The present findings might, however, seem contradicting to previous studies on the effects of emotional stimuli on eye movements, where a general emotion effect was observed (i.e., positive and negative scenes caused faster saccade latencies and more deviation than neutral scenes; Nummenmaa, Hyönä, & Calvo, 2006, 2009). This discrepancy might be attributed to the fact that a different category of emotional stimuli was used in these studies compared to our study (scenes instead of faces), a different SOA (see below), and a different design (two distractors – one emotional, one neutral – were presented in each trial). Another possible reason why we failed to find a general contrast between emotional and neutral faces might be that neutral faces differ from neutral scenes in the way they behave as a baseline condition. Compared to neutral scenes, neutral faces are rather ambiguous in nature. Previous studies showed that neutral faces are perceived as negative (e.g., Bar, Neta, & Linz, 2006), and that neutral faces can appear positive or negative depending on contextual and individual variables (Cooney et al., 2006; Jellema et al., 2011; Lee et al., 2008). However, at an abstract level our findings are in line with those studies as they all reveal a modulation of saccadic metrics by higher-level distractor information (i.e., emotional valence).

The present study extends the findings by Nummenmaa, Hyönä, and Calvo (2009) by demonstrating an effect of emotional faces on saccade curvatures (i.e., activity at saccade initiation) with simultaneous target and distractor presentation — Nummenmaa et al. reported effects of saccade curvature only if emotional scenes preceded the target by an SOA of 150 ms. Furthermore, the effect of emotional faces on saccade trajectories in the present study occurred only when the target (Experiments 1 and 2) and distractor (Experiment 2) appeared in the lower visual field.[3] We believe that the vertical asymmetry observed in our experiments was driven by the functional specialization of the lower visual field for action in peripersonal space (Previc, 1990). This conclusion is supported by evidence showing that saccade trajectories are affected by whether a reach movement to the target is produced (Tipper, Howard, & Paul, 2001). The authors of this study interpreted this cross-talk effect between the visual and motor systems as the influence of a hand-centered frame used in reaching on the spatial frame of reference required for the saccade.

It should be noted that in Experiment 1 only target location modulated the emotion effect, whereas in Experiment 2 both target and distractor location influenced the emotion effect. This difference, however, can be attributed to two facts. First, the relative salience of the distractors was different: Although the absolute size of the distractors was the same in both experiments, their relative size was much bigger in Experiment 1 than in Experiment 2, making them perceptually more salient in Experiment 1 than in Experiment 2. Second and more important, the difference in results can be attributed to the fact that in Experiment 2 there were two sources of potential interference – i.e., the face distractor and the non-target object. Especially in trials, in which the target object appeared in the lower visual field and the distractor in the upper field, the non-target object was close to the distractor, which might have made potential distractor effects more noisy.

We have to admit that we cannot completely rule out the possibility that asymmetries in the retinal representation of the upper and lower visual fields account for the present findings as retinal asymmetries have been found to exist already at about 5° (e.g., Drasdo et al., 2007) and target and distractors in the present study were presented in the near periphery.

Moreover, the processing advantage of stimuli in the lower visual field might be due to differences in sensitivity between the upper and lower visual field. Targets in the present study were presented at the vertical meridian, where the upper vs. lower asymmetry in sensitivity has been shown to be strongest. However, Abrams, Nizam, and Carrasco (2012) recently showed that the upper vs. lower asymmetry in sensitivity is gone by 30° of polar angle from the vertical meridian. Whereas this suggests that the lower targets in the present study were better processed due to the better sensitivity at the lower vertical meridian, the distractor interference effect observed here is rather unlikely to be due to differences in sensitivity because the distractors in the present study were presented at approx. 67° angular distance from the vertical meridian. However, the differences in experimental design and stimulus material between our study and the study by Abrams et al. make it difficult to definitely exclude differences in sensitivity as a possible explanation. In any case, the evidence that the upper–lower asymmetry changes over space points to more caution with the interpretation of the findings in terms of hemifield specialization.

In conclusion, the present study demonstrates that higher-level information about the distractor influences the oculomotor processing already at a very early stage (i.e., saccade initiation) as indicated by saccadic metrics. Angry faces produced stronger curvature away than happy faces. This effect is unlikely to be due to differences in processing of low-level image features. In addition, the present study showed that the vertical location of target and distractor determined the interference potential of emotional distractors, suggesting a delicate interplay between emotion processing and action relevance.

Acknowledgment

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Appendix A. Stimulus material in Experiment 2

Targets: Axt (axe) – Holz schlagen (chop wood), Besen (broom) – Boden kehren (sweep floor), Büroklammer (paper clip) – Seiten zusammenhalten (hold paper sheets), Fotokamera (camera) – Bilder aufnehmen (take pictures), Gabel (fork) – etwas essen (eat something), Gießkanne (watering pot) – Pflanzen bewässern (water plants), Gitarre (guitar) – Musik spielen (play music), Hammer (hammer) – Nägel einschlagen (hit nails), Hantel (dumbbell) – Muskeln trainieren (train muscles), Kamm (comb) – Haare frisieren (tidy hair), Kleiderbügel (hanger) – Kleidung aufhängen (hang clothes), Koffer (suitcase) – Reisebedarf transportieren (carry travel items), Korkenzieher (corkscrew) – Weinflasche öffnen (open wine bottle), Kugelschreiber (pen) – etwas aufschreiben (write something), Lineal (ruler) – Länge messen (measure length), Lupe (magnifier) – Dinge vergrößern (magnify things), Pfanne (pan) – etwas braten (fry something), Pinsel (paint brush) – Wände anstreichen (paint walls), Schere (scissors) – Papier schneiden (cut paper),

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[3] In fact, target location was not taken into account in the analyses of Nummenmaa, Hyönä, and Calvo (2009).

Schlüssel (key) – Tür öffnen (open door), Schneebesen (egg whisk) – Eier schlagen (whisk eggs), Streichhölzer (matches) – Zigaretten anzünden (light cigarettes), Tasse (mug) – etwas trinken (drink something), Telefon (phone) – jemanden anrufen (call someone).

Fillers: Aktentasche (briefcase), Einkaufstasche (shopping bag), Etui (little case), Fernbedienung (remote control), Geldbeutel (purse), Kompass (compass), Korb (basket), Locher (perforator), Maus (mouse), Nagellack (nail polish), Ordner (folder), Pfeffermühle (pepper mill), Pinzette (tweezers), Radiergummi (rubber), Reibe (grater), Schmucktruhe (coffer), Schneidebrett (cutting board), Spitzer (sharpener), Stecker (plug), Taschenrechner (calculator), Teigrolle (rolling pin), Tennisschläger (tennis racket), Thermometer (thermometer), Zahnbürste (tooth brush).

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