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Startle effects on saccadic responses to emotional target stimuli

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Abstract

Startle stimuli elicit various physiological and cognitive responses. This study investigated whether acoustic startle stimuli affect saccadic reactions in an emotional pro- or antisaccade task. Startle probes were presented either 500 ms before or simultaneous with an imperative stimulus that indicated whether a saccade towards or away from positive, neutral, or negative peripheral target pictures had to be performed. Valence interacted with saccade direction according to an approach-avoidance pattern of gaze behavior, with delayed prosaccades to negative targets and antisaccades away from positive targets. Acoustic startle stimuli preceding the presentation of peripheral target pictures speeded up the initiation saccades, irrespective of stimulus valence. Results indicate a speeding of cognitive-motor processing by preceding startle stimuli.

Descriptors: Prosaccade, Antisaccade, Affective startle modulation, Approach-Avoidance, StartReact, Electromyography, Prepulse inhibition, Accessory stimulus

The startle reflex is a defensive response that is found in many species. It protects the organism against potential injury and prepares for adaptive action (Koch, 1999). Some of the most prominent startle response components in mammals involve the immediate contraction of facial and skeletal muscles. This movement pattern induces a protective posture and shields sensitive organs, such as the eyes, against traumatic impact. Beyond that, startle stimuli may enhance reaction times (Valls-Sole, Kumru, & Kofler, 2008) and interrupt ongoing cognitive processes in order to focus attention towards the source of the startle stimulus (Graham, 1979; Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006). Startle stimuli elicit P300, event-related electroencephalogram (EEG) potentials, indicating that startle triggers the engagement of attention (Schupp et al., 2004; Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997). Attending to and identifying danger sources allows for specific defensive action, thereby enhancing the chance to avoid injury. This is what would be expected if an aversive startle stimulus primed defensive cognitive processing. However, it remains to be demonstrated that startle stimuli indeed drive attention specifically towards aversive, harmful, and threatening stimuli. Alternatively, startle may affect the cognitive processing of different sorts of stimuli, aversive and appetitive, in a similar, unspecific fashion.

Emotional stimuli reveal important information: Depending on the valence, they are considered either beneficial or harmful to the organism. Since they provide an indicator of biological significance, emotional stimuli engage attention more than neutral stimuli (Mayer & Merckelbach, 1999). Spatial orienting to those relevant stimuli is facilitated; emotional stimuli are detected faster in a visual array (Ohman, Lundqvist, & Esteves, 2001). This effect can be demonstrated with various behavioral paradigms such as the emotional Stroop task (Dresler, Meriau, Heekeren, & van der Meer, 2009), the dot probe task (Koster, Crombez, Verschuere, & De Houwer, 2004; Miyazawa & Iwasaki, 2009) or the go/no-go task (De Houwer & Tibboel, 2010). However, while mainly negative, threatening stimuli were initially considered to be preferentially processed (Ito, Larsen, Smith, & Cacioppo, 1998), recent studies suggest that the effect is based more on stimulus arousal than valence (de Oca, Villa, Cervantes, & Welbourne, 2012; McConnell & Shore, 2011; Most, Smith, Cooter, Levy, & Zald, 2007; Sheth & Pham, 2008; Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008). Additionally, several state and trait variables exert an influence on this attentional engagement. Highly anxious individuals are more strongly biased to process negative stimuli (Van Honk, Tuiten, de Haan, vann de Hout, & Stam, 2001; Wilkowski, Robinson, Gordon, & Troop-Gordon, 2007), an effect that has also been described for other personality variables (Amin, Constable, & Canli, 2004) and psychopathologies such as dysphoria (Sears, Thomas, LeHuquet, & Johnson, 2010) or depression (Sears, Newman, Ference, & Thomas, 2011).

State factors have a moderating effect on attentional biases: Higher state anxiety has been found to increase interference effects in an emotional Stroop paradigm (Dresler et al., 2009). Arousal, either evoked by the stimulus itself or by different sources, can increase the competitive advantage of emotional stimuli (for a review, see Mather & Sutherland, 2011). For example, stress could increase the impact of emotional distracters in a working memory task (Oei et al., 2012). Finally, motivational orientation (i.e.,

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approach or avoidance) can influence how attention is captured by emotional distracters (Memmert & Cañal-Bruland, 2009; Rothermund, Voss, & Wentura, 2008).

The current study evaluated the impact of approach and avoidance on cognitive processing by employing eye tracking methodology. Eye movements provide a valid measure of early orienting because the gaze is shifted to the attended location (Henderson, 2003). In a recent study that compared a manual versus saccadic response task, saccadic eye movements were more strongly influenced by target valence in a forced-choice reaction paradigm: Emotional and neutral faces were presented in pairs, and participants had to perform either button presses or saccades towards the emotional or neutral target stimulus (Bannerman, Milders, & Sahraie, 2009). When emotional and neutral pictures are presented together in peripheral vision, the emotional picture is more likely to be fixated first and for a longer time, even if the task explicitly demands that the emotional picture is to be ignored (Nummenmaa, Hyona, & Calvo, 2006). In a pro- and antisaccade task that required the participant to perform voluntary saccades toward or away from an emotional target stimulus, prosaccades were faster towards pleasant stimuli when presented in the right hemifield (Kissler & Keil, 2008). This task required the participant to initiate voluntary saccades towards a lateral, peripherally presented stimulus (prosaccade), or away from it (antisaccade), depending on an imperative stimulus at central fixation. Antisaccades induce a conflict situation between endogeneous and exogeneous attention: The reflexive tendency to look at the stimulus needs to be inhibited in favor of a controlled saccade in the opposite direction. While the emotionality of stimuli clearly has an influence on gaze patterns and saccades, the results regarding specific valence of the targets are less clear. Several studies have found enhanced processing of positive and negative stimuli (Calvo, Nummenmaa, & Hyona, 2008; Nummenmaa et al., 2006; Nummenmaa, Hyona, & Calvo, 2009), while others have found facilitating effects only for negative stimuli (Gutiérrez & Calvo, 2011; Lundqvist & Öhman, 2005).

In our study, participants had to perform pro- or antisaccades to emotional, parafoveally presented target pictures. At the beginning of each trial, the gaze was directed to a fixation cross in the center of the screen. An emotional or neutral picture would appear in the left or right periphery of the screen. With a stimulus onset asynchrony (SOA) of 200 ms, the fixation cross changed color to indicate which type of saccade was to be performed (imperative stimulus). Participants were instructed to keep their gaze at the fixation cross until the imperative stimulus appeared; that is, reflexive saccades towards the pictures had to be inhibited. During this time period, a processing of the "emotional gist" of the target images should have been achievable (Phillips, 2009).

Two startle conditions were included in the experiment, early and late. In the early condition, acoustic startle probes were presented before the target images appeared. The startle stimuli in this condition could exert an influence on the processing of the image content at an early stage. In the second startle condition, startle stimuli were presented simultaneous with the imperative stimulus. Startle in this condition would primarily affect premotor and motoric processes. Startle stimuli can accelerate the execution of voluntary motor responses in reaction time (RT) tasks, an effect known as "StartReact" (Valls-Sole et al., 2008). If an imperative stimulus that prompts the initiation of a voluntary motoric action is accompanied or preceded by a startle stimulus, the response latencies are reduced. Even though the effect can be seen with foreperiods of up to 1,500 ms (Carlsen & MacKinnon, 2010), it is most pronounced when the startle stimulus is presented simultaneous with the imperative stimulus. Given that the various modulatory effects exhibit different time courses, both conditions were included in this study to allow inferences about which stage of processing might be affected by the startle stimulus.

Method

Participants

Twenty-four male undergraduate students of the University of Trier participated in this study (mean age = 25.45 years, *SD* = 3.52). They were interviewed for present and past medical and/or psychiatric health problems. Participants were excluded for any acute or persistent medical or psychiatric diseases, current medication except the occasional use of pain killers (paracetamol, aspirin, or nonsteroidal antirheumatics [NSARs]), current or past hearing problems (e.g., tinnitus), or impaired vision. To simplify interpretation of responses to erotic slides, only heterosexuals were recruited. Participants gave their written informed consent and were financially compensated for participation. Experimental procedures were approved by the local ethics committee.

Design

At the beginning of each trial, the participant held his gaze on a black fixation cross in a central position. Target images appeared either in the left or right visual field. Participants were required to maintain fixation until the fixation cross changed color. With a delay of 200 ms from target onset, the fixation cross would change color for a period of 50 ms to indicate gaze direction (and thereby serve as an imperative stimulus): Green demanded a pro-, red an antisaccade. While a prosaccade meant to direct the gaze at the image, an antisaccade meant to look at the image's mirror position, that is, the opposite blank side of the screen. Both gaze shifts were to be performed as quickly as possible. The target image appeared for a total of 1,000 ms; the trial ended with the offset of the target image. Three different startle conditions were utilized: "startle-SOA −500 ms"—500 ms before imperative stimulus onset, "startle-SOA 0 ms"—synchronous with imperative stimulus onset, and no-startle as a control condition (see Figure 1).

A total of 162 trials were presented in pseudorandomized order. The intertrial interval was randomized between 4–6 s.

Procedure

Before the experiment started, the participant gave written, informed consent and was assessed for exclusion criteria. Color vision was measured with a color perception test (Broschmann & Velhagen, 1985). Subsequently, the participant was seated in front of a height-adjustable table. The eye tracker was fitted with a head and chin rest to minimize head movements and keep the distance to the screen constant. The experimenter attached the electrodes for electromyographic (EMG) recording and calibrated the eye tracker. He informed the participant that the experiment would start immediately and adjusted the headphones. The experimenter left the room and started the experiment from a control room. Throughout the experiment, the participant was able to communicate with the experimenter via an intercom system.

Prior to stimulus presentation, experimental instructions were given in written form on the screen. The participant was told to contact the experimenter in case of uncertainties. The experiment started with a practice block of eight test trials. These trials were

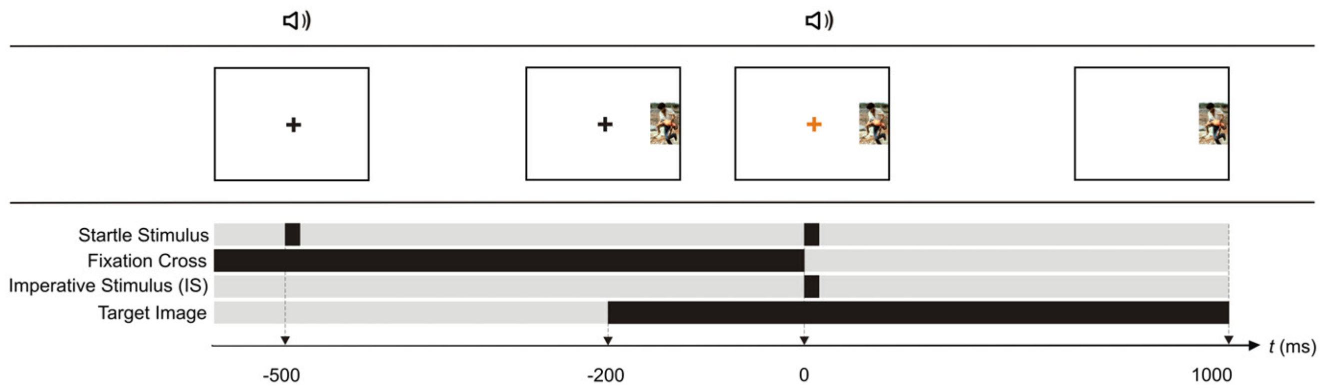

Figure 1. Experimental procedure.

identical to the experimental trials, with the only exception that gray rectangular forms instead of emotional pictures were used as stimuli. The purpose was to accustom the participant to the task, to check whether the task was correctly understood, and to serve as habituation trials for the startle stimulation (Blumenthal et al., 2005). These trials were not included in further analysis. Subsequent to the practice trials, the participant was asked if he fully understood the task or had further questions. After total comprehension of the task was ensured, the acquisition phase started.

Apparatus and Materials

Stimulus display. The stimuli were presented on a 19-inch flat screen monitor (1280 × 800 resolution, 150 Hz refresh rate). The monitor was positioned at a distance of 60 cm from the participant's eyes. Images were presented peripherally, in an upright position (resolution: 230 × 344, visual angle: 6.48° × 9.78°) against a white background. The horizontal distance between the fixation cross (center of the screen) and the center of the picture was 14.61° of visual angle, to the left or right.

Visual stimuli. Thirty-six photographic images of unpleasant, neutral, and pleasant scenes were used. Unpleasant images depicted scenes of threat, disgust, and mutilation, neutral pictures displayed scenes and objects such as household items or furniture, pleasant images depicted sport scenarios and erotic nudes. Unpleasant images, neutral images, and sport scenes were selected from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008), and erotic images were selected from an existing image set used in previous studies (Lass-Hennemann et al., 2010, 2011). The selection of images was based on previous ratings of valance and arousal. To evaluate the experimental manipulation, each image was rated on these two dimensions by the participants at the end of our study.

Low-level image features (luminance, contrast, saturation) and image complexity were matched between categories with MATLAB 7.12 (MathWorks, Natick, MA). To adjust low level image features, we used the SHINE-Toolbox for MATLAB (Willenbockel et al., 2010). Image complexity was measured by employing a method based on the compression rate of previously generated saliency maps (Da Silva, Courboulay, & Estraillier, 2011). We generated "Itti-Koch-Niebur saliency maps" for each image (Itti, Koch, & Niebur, 1998) by using the graph-based visual saliency (GBVS) algorithm (Harel, Koch, & Perona, 2007). The size values of the compressed saliency maps were submitted to an analysis of variance (ANOVA), which yielded no significant differences between categories, $F(2,33) = .67$; $p = .55$.

Eye tracking. Eye movement data were recorded with an SMI iView-X HiSpeed 500 (500 Hz sampling rate, spatial accuracy better than 0.5°). The eye tracker was mounted on a height-adjustable table, at a distance of 60 cm to the monitor.

Startle stimulation. Startle stimuli were acoustic white noise probes (105 dB, 50-ms duration, instantaneous rise time, binaural stimulation) presented via audiometric headphones (Holmco PD-81, Holmberg GmbH & Co. KG, Germany).

Data Acquisition and Analysis

Eye tracking. Horizontal and vertical gaze data were recorded as analogue data, saved on hard disc, and analyzed offline. Analysis was made with a C++ based, semiautomated program. Saccadic onset and peak (reaching target location) were automatically detected within a range of 200–1,000 ms after imperative stimulus-onset. All trials were manually checked and artifact corrected when necessary. Trials were excluded from analysis when a blink was detected 200 ms prior to imperative stimulus-onset or when eyes were not focused on the central fixation cross at target onset. When a saccade was initiated in a time window between −200 ms before and 80 ms after imperative stimulus-onset, or when the saccade was directed to the wrong side, the trial was considered to be an error trial.

We calculated the RT as the latency between the onset of the imperative stimulus and the onset of the saccade, and the saccade duration as the time between saccade onset and first fixation.

Startle analysis. Electrodes for EMG recording of the m. orbicularis oculi were attached below the participant's right eye at an interelectrode distance of 1.5 cm. The EMG signal was recorded on hard disk with a BIOPAC MP 150 system and an EMG 100 C amplifier via Tyco Healthcare H124SG electrodes at 16-bit resolution and 1 kHz sampling rate. Hardware band-pass filter settings were 10 to 500 Hz, followed by a 28 Hz software high-pass filter (van Boxtel, Boelhouwer, & Bos, 1998). The raw signal was rectified and integrated online with a time constant of 10 ms (Blumenthal, 1994). The data of seven participants had to be discarded from further analysis because of data acquisition problems.

The EMG startle responses were analyzed offline with a C++ based, semiautomated program. Startle response magnitude was defined as the difference between peak and baseline signal. The integrated algorithm identified peak in a time interval between 20–150 ms after stimulus onset. Baseline was assessed 50 ms prior to stimulus onset (Lass-Hennemann et al., 2010). Each response was manually confirmed and corrected for nonresponses and artifacts. Nonresponses (cases with no discernible response) were set to zero and included in the analysis (25.4% of all trials). Cases with electrical and physiological artifacts (such as voluntary or spontaneous eye blinks coinciding with the startle stimulus, or trials with excessive background noise or multiple peaks) were excluded from analysis (0.7% of all trials). Response magnitude was averaged across trials for each condition (Blumenthal et al., 2005).

Subjective ratings. After the data acquisition phase, the participant was asked to rate the previously presented images on the dimensions of valence and arousal. Each image was displayed together with a five-digit scale for both dimensions. The rating was based on the Self-Assessment Manikin rating system (Lang, Bradley, & Cuthbert, 2008).

Statistical Analysis

The saccade reaction data were analyzed in a 2 (Saccade Direction: prosaccade vs. antisaccade) × 3 (Startle Stimulus: −500 ms SOA vs. 0 ms SOA vs. no) × 3 (Valence: positive vs. neutral vs. negative) within-subjects ANOVA. The EMG response data were analyzed for the startle stimulus condition (–500 ms SOA vs. 0 ms SOA) in a *t* test. For the startle-SOA 0 ms condition, the factor valence was analyzed in a one-factorial ANOVA (positive vs. neutral vs. negative). Significant interactions were analyzed with Bonferroni-adjusted post hoc *t* tests. Response magnitude between both startle stimulus conditions was compared with a paired-sample *t* test. Subjective rating data for valence and arousal were subjected to a one-factorial ANOVA (positive vs. neutral vs. negative). Reported *p* values for factors with more than two conditions are Greenhouse–Geisser corrected. The critical alpha level was set to .05 in all analyses.

Results

Subjective Ratings

A significant difference between image categories was found for the valence dimension, $F(2,42) = 147.78$; $p < .001$; $\eta^2 = .88$, and the arousal dimension, $F(2,42) = 85.7$; $p < .001$; $\eta^2 = .80$. Positive images were rated as more pleasant than neutral images, and neutral as more pleasant than negative images ($M = 1.78$ [negative], 3.27 [neutral], 4.06 [positive]). Negative and positive images were both rated as more arousing than neutral images, and scores for negative and positive images were equivalent ($M = 3.64$ [negative], 1.46 [neutral], 3.63 [positive]).

Saccadic RTs

A significant main effect of startle stimulus condition was found, $F(2,42) = 24.55$; $p < .001$; $\eta^2 = .54$. Saccades were initiated faster in the preliminary startle-SOA −500 ms condition, compared to startle-SOA 0 ms and no-startle conditions. The main effect of saccade direction was significant, $F(2,42) = 4.84$; $p < .05$; $\eta^2 = .19$, in that prosaccades were initiated faster than antisaccades. The main effect of valence was significant, $F(2,42) = 4.08$; $p < .05$; $\eta^2 = .16$, with reactions to neutral images being faster compared to positive or negative images. However, the significant interaction of the factors Saccade Direction × Valence, $F(2,42) = 6.98$; $p < .05$; $\eta^2 = .25$, showed that the slowest reactions in the prosaccade condition were to negative images, $t(22) = 3.88$; $p < .05$, but in the antisaccade condition, the slowest reactions were to positive images, $t(21) = 2.46$; $p < .05$ (see Figure 2).

Saccade Duration

The only significant difference was found for the factor saccade direction, $F(2,44) = 64.08$; $p < .001$; $\eta^2 = .75$: Prosaccades had a significantly shorter duration between saccade onset and first fixation than antisaccades.

Saccade Error Rate

The only significant difference was found for the factor startle stimulus, $F(2,44) = 13.88$; $p < .001$; $\eta^2 = .39$, with significantly lower error rates in the startle-SOA -500 ms condition ($M = 1.78$ [startle-SOA −500 ms], 3.27 [startle-SOA 0 ms], 4.06 [no-startle]).

Startle EMG Response

Average response magnitude in the startle-SOA 0 ms condition was significantly lower compared to that in the startle-SOA −500 ms condition, $t(16) = 4.12$; $p < .05$. The effect of the factor valence was investigated in the startle-SOA 0 ms condition only (since the startle stimulus preceded picture onset in the startle-SOA −500 ms condition, no effect of valence would be possible in that condition). The effect of valence was significant when comparing the response magnitude in the startle-SOA 0 ms condition, $F(2,38) = 3.58$; $p < .05$; $\eta^2 = .17$. Response magnitude was significantly higher when neutral pictures were shown, compared to positive and negative pictures.

Discussion

The present experiment investigated the effects of acoustic startle stimulation on the processing of visual emotional stimuli. We included two startle conditions with different SOAs (500 ms before and simultaneous with an imperative stimulus) in a saccadic reaction task.

We found an effect of the acoustic startle probe on saccadic reactions. Saccades were initiated faster when preceded by a startle stimulus. This effect is consistent with the literature on accessory stimuli: The startle stimulus could have functioned as an accessory stimulus, which would have resulted in increased alertness for the upcoming task (Hackley et al., 2009). Unlike Castellote, Kumru, Queralt, & Valls-Sole (2007), the effect was not found when the startle probe was delivered simultaneous with imperative stimulus-onset. While participants in that study performed reflexive saccades to peripherally appearing targets, our task required voluntary, effortful saccades. The externally guided saccades in that study resembled a simple RT task. In contrast, our manipulation was a more complex choice RT task, which needed further processing and is therefore less prone to the Start-React effect (Oude Nijhuis et al., 2007; Reynolds & Day, 2007). Castellote et al. interpreted the response acceleration as an effect of the startle stimulus on motor preparation. However, with a foreperiod of 500 ms, sensory and attentive processes or a surge in arousal are likely mechanisms for RT shortening as well. We found no significant differences for saccade duration, indicating

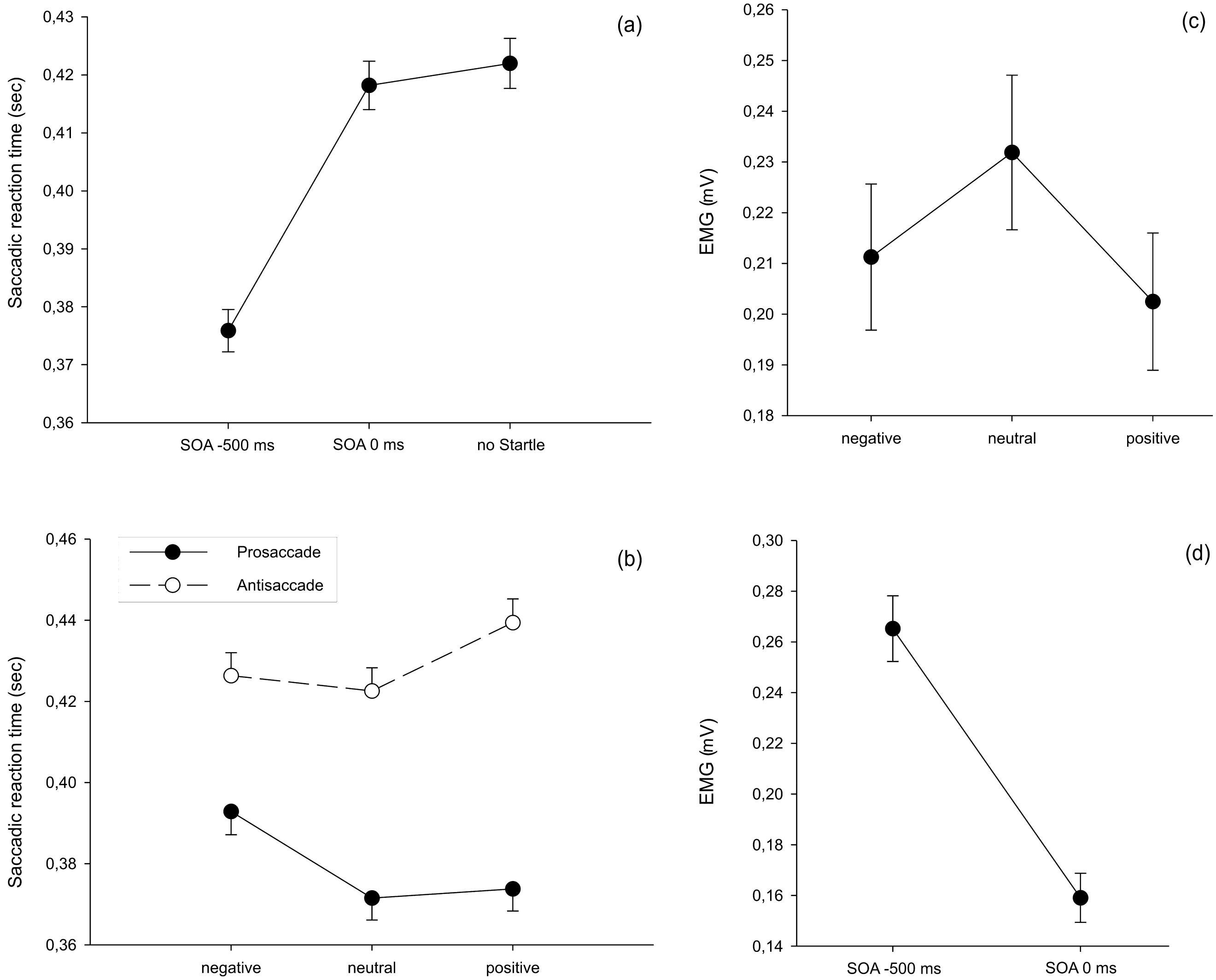

Figure 2. Saccadic reaction times (mean, *SD*) for (a) the startle SOA conditions, (b) the interaction between target valence and saccade direction. Startle EMG magnitude (mean, *SD*) and target valence (c) in the startle SOA 0 ms condition, and (d) between startle SOA conditions.

that the motoric execution of saccades was not affected by startle presentation. Furthermore, there was no trade-off between speed and accuracy. Instead, responses in the early startle condition were not only faster, but also had reduced error rates. Therefore, mere response guessing or a preprogramming of the motor response seem unlikely. Hackley and Valle-Inclán (2003) proposed response selection as a candidate mechanism for accessory stimulus effects, which would fit well with the improved performance in our rather complex choice-reaction task. The absence of an accelerating effect in the startle-SOA 0 ms condition could be attributed to the lack of a foreperiod (Diederich & Colonius, 2008). If the simultaneous startle coincided with response selection, distracting interference could have outweighed a possible accelerating effect in this condition.

Compared to the early startle-SOA −500 ms condition, the average startle EMG magnitude was reduced in the simultaneous startle-SOA 0 ms condition. This attenuation can be explained by the concept of "prepulse inhibition" (Graham, Putnam, & Leavitt, 1975): The target pictures, which appeared 200 ms prior to startle onset, served as a prepulse. Compared to neutral images, EMG magnitudes were even more decreased for emotional images in the startle-SOA 0 ms condition. This effect seems to rely on the arousal induced by the visual stimuli, since it was independent of valence. The averaged EMG magnitudes in the startle-SOA 0 ms condition were decreased for emotional pictures. Since these pictures potentially served as prepulses, the prepulse inhibition effect was stronger for emotional pictures (Bradley, Cuthbert, & Lang, 1993). Since these valenced pictures were also more arousing, this can be taken as evidence that the arousal information of the parafoveal target images was processed.

As expected from previous literature, antisaccades were initiated with longer response latencies than prosaccades (Gilchrist & Proske, 2006; Kissler & Keil, 2008; Morand, Grosbras, Caldara, & Harvey, 2010). Whereas both forms of attentional gaze control converge in the case of a prosaccade, an antisaccade induces a conflict situation. While the target draws attention in a bottom-up way, the automatic saccade needs to be actively inhibited. By drawing on executive resources, the antisaccade is described as more challenging and, as we found in this study, takes more time to be performed (Everling & Fischer, 1998).

Furthermore, we found an interaction between saccade type and stimulus valence. Previous studies have demonstrated that emotional content, even when presented to the parafovea, can influence saccadic reactions. However, the gaze pattern in our study reflects quite specific effects of valence: Reactions were slowed for saccades towards negative and away from positive targets. Many studies that required saccadic responses to emotional targets have found responses towards negative stimuli to be faster than towards neutral or positive stimuli, which is explained by an attentional bias to potentially dangerous situations (Bannerman, Milders, de Gelder, & Sahraie, 2009; Gerdes, Pauli, & Alpers, 2009; Wieser, Pauli, & Muhlberger, 2009). However, an attentional bias to negative stimuli is not without exception. Other studies have found RT shortening for emotional content, irrespective of valence, or faster reactions to positive stimuli (Bannerman, Milders, & Sahraie, 2009; Kissler & Keil, 2008; Nummenmaa et al., 2009). We assume that the slowed responses in our study reflect the tendency to avoid those pictures. This would be in line with results from a study using the free-viewing paradigm: When angry, fearful, or happy faces were presented simultaneously with neutral faces, participants actively avoided looking at the negative images (Becker & Detweiler-Bedell, 2009). While the standard pro/antisaccade paradigm requires immediate responses to target stimuli, the target stimuli in our study were already present for 200 ms before a response was required. We might speculate that an initial capture of attention for negative stimuli is followed by the tendency to avoid them. Indeed, the "vigilance-avoidance" hypothesis would predict exactly such a pattern (Mogg, Bradley, Miles, & Dixon, 2004).

Divergent effects have been reported for antisaccades away from emotional stimuli. While some studies found slower responses away from negative stimuli (Wieser et al., 2009), others reported slower responses away from positive stimuli (Phillips, 2009). In our study, antisaccades took longer when positive targets were presented. Again, this would be indicative of approach behavior in the sense of the approach-avoidance concept: The tendency of directing the gaze to the positive content needs to be overridden while an effortful, opponent response is initiated.

Contrary to our initial hypothesis, startle did not interact with valence in our saccadic task. One possible explanation is that the foreperiod of 500 ms was too short to induce emotion-specific effects. Even though affective startle modulation was found under certain conditions with lead times as low as 250 ms (Vanman, Boehmelt, Dawson, & Schell, 1996) or 300 ms (Gard, Gard, Mehta, Kring, & Patrick, 2007; Stanley & Knight, 2004), these early effects are not commonly found. In the standard paradigm, the emotional foreground stimulus is presented with lead times of more than 1 s. One suggestion is that these early emotional effects draw on processes other than motivational priming (Filion, Dawson, & Schell, 1998). We speculate that, even for the startle-SOA -500 ms condition, motivational priming effects did not have enough time to build up. It would therefore be of interest to investigate the effect of even longer foreperiods. On the other hand, unlike an emotional picture, a startle stimulus extends over a brief moment in time. By the time of the behavioral response, motivational priming effects might have vanished. Touching on the "cardiac defense" paradigm, one could think of extending the duration of the white noise exposure to overcome this problem (Ramirez, Sanchez, Fernandez, Lipp, & Vila, 2005; Sanchez et al., 2009).

Some further limitations of the study should be addressed. Since we included only males in this study, female responses in such a setting need to be investigated as well. While women might respond more to startle (Kofler, Müller, Reggiani, & Valls-Solé, 2001), the gaze pattern in response to emotional pictures might be different as well (Bradley, Codispoti, Sabatinelli, & Lang, 2001). With this study, we cannot disentangle the accessory stimulus effect from those that are unique to startle stimuli. Therefore, it would be of interest to see how nonstartling accessory stimuli affect saccade programming in such a paradigm.

In conclusion, startle was shown to speed saccadic reactions and improve accuracy when presented with sufficient lead time before an imperative stimulus. Furthermore, we could demonstrate that emotional information of parafoveally presented images has a moderating influence on prepulse inhibition, perhaps due to increased arousal of those images. We hypothesized that startle, because of its defensive character, would differentially affect responses depending on target valence. However, the results do not provide support for a valence-dependent effect of startle on oculomotor reactions. While startle responses are affected by emotional foreground stimuli, responses to emotional stimuli seem to be unaffected by previous startle stimuli. Independent of the startle-related effects, we found a remarkable interaction pattern between saccade direction and target valence, which suggests that approach-avoidance motivation can be extended to gaze behavior.

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