The drive to control : how affect and motivation regulate cognitive control

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Emotion, Arousal, and Focused Attention

"To desire something and to recognize what must be done to attain it, as well as to recognize when its attainment has succeeded or failed, is to be inevitably emotional. In this way, emotions and reason are inextricably linked in an inescapable logic."

Richard S. Lazarus (1991)

This chapter is based on:

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Abstract

It has been shown that negative affect causes attentional narrowing. According to Easterbrook's (1959) influential hypothesis this effect is driven by the withdrawal motivation inherent to negative emotions and might be related to increases in arousal. We investigated whether valence-unspecific increases in physiological arousal, as measured by pupil dilation, could account for attentional narrowing effects in a cognitive control task. Following the presentation of a negative, positive, or neutral picture, participants performed a saccade task with a prosaccade versus an antisaccade instruction. The reaction time difference between pro- and antisaccades was used to index attentional selectivity, and while pupil diameter was used as an index of physiological arousal. Pupil dilation was observed for both negative and positive pictures, which indicates increased physiological arousal. However, increased attentional selectivity was only observed following negative pictures. Our data show that motivational intensity effects on attentional narrowing can occur independently of physiological arousal effects.

Introduction

In order to cope with threatening events, organisms often recruit extra resources. Regarding cognitive resources, there is evidence that affectively negative stimuli immediately prioritize the perceptual processing (Öhman, Flykt, & Esteves, 2001) and recall (Christianson, 1992) of related information at the cost of other processes (Bocanegra & Zeelenberg, 2009; Pessoa, 2009), and it has been argued that these effects are mediated by the organism's current state of arousal (Schimmack, 2005). According to Easterbrook's (1959) influential hypothesis, increased arousal may lead to the narrowing and focusing of attention, thus facilitating appropriate subsequent responding and coping behavior.

Although threatening events and stress have been demonstrated to narrow attention (Cohen, 1980; Chajut & Algom, 2003; Gable & Harmon-Jones, 2010a; for a discussion of opposite effects in trait anxiety, see Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010), it is not clear whether these observations are due to nonspecific arousal or the activation of affect-specific emotional/motivational systems (Bradley, 2000). Even though Easterbrook's original hypothesis relates to unpleasant situations only, several authors have suggested that any increase of arousal—e.g., whether induced by caffeine ingestion or impulsivity traits—may modulate attentional selectivity (e.g., Anderson, 1990). Along similar lines, increasing motivational intensity has been reported to increase focused attention irrespective of the motivational system (approach versus avoidance) involved (Gable & Harmon-Jones Gable & Harmon-Jones, 2008; 2010a; Gable & Harmon-Jones, 2010b; Harmon-Jones & Gable, 2009). However, whether arousal can be conceived of as a unitary construct has been questioned (Lacey, 1967; Neiss, 1988; 1990) and it is not entirely clear how motivational intensity and arousal are conceptually related (cf. Gable & Harmon-Jones, 2010b). Accordingly, it remains to be shown whether the emotional modulation of the selective attention reflects nonspecific arousal that can vary orthogonally to the valence of the present affective state or whether it is specific to negative, potentially threatening events.

To index a possible narrowing of the attentional focus we used a visual antisaccade task (for a review, see Hutton & Ettinger, 2006). This task is typically used as a measure of cognitive control, which is closely related to attentional selectivity. That is, the amount of information that is entering the focus of attention may be limited by cognitive control exerted at a perceptual or more central processing level (Desimone & Duncan, 1995; Pessoa, Kastner, & Ungerleider, 2003; Miller & Cohen, 2001). Moreover, given that the neural mechanisms underlying the antisaccade task are well known and can easily be studied in monkeys as well (cf. Munoz & Everling, 2004), we considered this task to be particularly well suited for studying the neuro-cognitive effects of emotion on attentional selectivity. As a first step, our study aimed at disentangling the relative contributions of arousal and affective valence on attentional control using physiological and behavioral measures of arousal and focused attention, respectively.

In the antisaccade task, participants are presented with a peripheral, emotionally neutral target stimulus that appears with an abrupt onset on the left or right of the central fixation. Depending on the instruction, they are to move their eyes either to this target (prosaccade condition) or to the opposite side of the display (antisaccade condition). The common finding is that saccades are initiated more slowly and less reliably in the antisaccade than in the prosaccade condition. This cost is commonly attributed to the automatic tendency to look at novel events, which requires active inhibition in the antisaccade condition (Olk & Kingstone, 2003). Because improved attentional control decreases automatic capture by the target stimulus (Yantis & Jonides, 1990), reflexive saccades toward the stimulus become suppressed. Thus, we expected that manipulations improving focused attention reduce the size of the latency costs, with antisaccades becoming faster and prosaccades becoming slower (cf., Kristjansson, 2007).

Affective states were induced prior to each saccade-task trial using positive, negative, or neutral pictures from the International Affective Pictures System (IAPS). Valence and arousal ratings of these pictures show a quadratic relationship, such that positive and negative stimuli are typically highly arousing and neutral stimuli low arousing (Lang et al., 2008). To ascertain that the pictures induced a physiological response we used pupillometry. Recent work by Bradley, Lang, and co-workers has validated this approach (Bradley et al., 2008). In that study, both negative and positive IAPS pictures were shown to produce pupil dilation, a response reflecting emotional arousal which is associated with increased sympathetic nervous activation. By means of this setup we were able to contrast two competing hypotheses. If more attentional selectivity in affectively laden circumstances would be driven by nonspecific arousal, the difference in saccadic reaction time (RT) between anti- and prosaccades should be reduced following negative as well as positive arousing pictures as compared to the non-arousing neutral pictures. Alternatively, if more attentional selectivity is specific to threatening situations, this latency cost should be reduced following negative stimuli but comparable for positive and neutral stimuli.

Methods

Participants

Eleven students from Leiden University (18-22 years old; 2 males; 1 left-handed) participated for either payment (5 Euros) or course credits.

Materials

Thirty-two highly arousing negative, 32 neutral, and 32 highly arousing positive pictures were selected from the IAPS set (Lang et al., 2008)*. The stimulus set was almost identical to the one used by Bradley et al. (2008). Like that study, negative and positive stimuli could be differentiated on the basis of valence IAPS ratings, whereas they were matched for arousal IAPS ratings (Lang et al., 2008, see Table 1). Neutral pictures had low arousal ratings and intermediate valence ratings. In order to avoid light reflex confounds we used gray-scaled pictures (cf. Bradley et al., 2008); brightness and contrast were adjusted to ensure identical mean luminosity values for all pictures.

Task

Each trial started as soon as participants had successfully looked at the central fixation cross for at least 1 second. Then an IAPS stimulus appeared for 500 ms, which was replaced by the fixation cross for a jittered interval ranging from 1500 to 2500 ms. Following a 200-ms blank gap (cf. Everling & Fischer, 1998), the target stimulus (also a cross) appeared for 500 ms 8° to the left or right to the screen center. Then the central fixation cross appeared for another interval (ranging from 1000 to 2500 ms) before the next trial started. At the beginning of each block an 8-s verbal cue (approximately 5.7° x 1.4°; width x height) indicated whether a pro- (target position) or an antisaccade (mirror position of the target) was to be made to the next target stimulus. The picture (16° x 12°) and the black fixation cross (0.8° x 0.8°) were shown on a gray background with luminosity equal to the mean

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* The library numbers for the IAPS stimuli used in the present study are: Negative: 2120, 2205, 2520, 2590, 2691, 2730, 2750, 2800, 3015, 3030, 3053, 3100, 3170, 3180, 3181, 3400, 3500, 3530, 3550, 6210, 6211, 6212, 6821, 6834, 6838, 9041, 9250, 9300, 9341, 9405, 9800, 9921. Neutral: 2020, 2190, 2200, 2210, 2214, 2215, 2220, 2221, 2235, 2240, 2270, 2272, 2278, 2383, 2393, 2410, 2441, 2491, 2493, 2514, 2579, 2620, 2749, 2752, 2810, 2850, 2870, 2890, 3210, 5455, 7550, 9210. Positive: 2208, 2250, 2260, 2501, 2560, 2650, 4611, 4617, 4640, 4650, 4653, 4658, 4659, 4689, 5621, 8041, 8080, 8090, 8116, 8120, 8161, 8180, 8200, 8280, 8300, 8320, 8330, 8370, 8380, 8400, 8420, 8465.

of the pictures. In rare cases (0.2% of the time), eye tracker recording problems delayed the trial presentation (inter-trial intervals > 9 seconds). Because the interruption of the ongoing presentation sequence by either delayed presentation or by the onset of a new block is likely to compromise the experimental manipulation of the arousal and valence, the first five trials after such events were excluded.

Procedure

Participants were instructed to attend to the emotional pictures and to make pro- and antisaccades to the target as fast and accurate as possible. They were also asked to avoid eye blinks during picture and target presentation. After informed consent and eye tracker calibration, subjects practiced with 6 prosaccade and 6 antisaccade trials preceded by neutral IAPS pictures and followed by accuracy feedback for 1 second. Calibration and/or practice were repeated in case of eye tracking problems or when the subject did not follow the instructions. The task consisted of 6 alternating prosaccade and antisaccade blocks (counterbalanced order), with two self-paced breaks in between. Each block consisted of 48 trials, and every chosen IAPS picture appeared three times in randomly chosen trials. Participants were debriefed after the experiment.

Data acquisition and analysis

Saccadic behavior and pupil diameter were recorded at 120 Hz using a Tobii T120 eye tracker, which was integrated into a 17-inch TFT monitor. Participants were seated at a distance of approximately 60 cm from the monitor while their head was stabilized by using a chin rest. Artifacts and blinks as detected by the eye tracker were corrected by using a linear interpolation algorithm. A saccade was considered to begin as soon as the horizontal angle exceeded 2° and speed passed a 30°/sec threshold. For all analyses, we excluded the following trials: trials including and following recording-related delays (see above), trials following performance errors, trials with saccadic reaction time outliers (< 80 ms or > 500 ms), and trials where no saccades could be detected. Repeated-measures ANOVAs with the factors picture content (negative, neutral, positive) and task (pro versus anti) were run on pupil dilation and saccadic behavior measures. Paired t-tests were used for post-hoc tests.

Results

Pupil dilation

Following Bradley et al. (2008), pupil dilation to the picture content was measured after the initial light reflex. Dilation was defined as the mean pupil diameter in a window from 2 to 2.5 seconds after picture onset, using a 200 ms pre-picture baseline. As Table 1 shows, both negative and positive pictures caused dilation in comparison to neutral pictures. Analyses revealed a main effect of picture content ($F(2,20) = 4.74$, $p < .05$, $MSE = .005$), independent of task ($F(2,20) = 1.02$, n.s., $MSE = .003$). Replicating Bradley et al. (2008), planned t-tests confirmed that arousing pictures increased pupil diameter ($t(10) = 2.49$, $p < .05$). As in that study, there was also a trend for negative pictures to induce more dilation than positive pictures ($t(10) = 1.822$, $p = .09$).

Saccadic behavior

See Table 1 for details. As usually found, correct saccadic reaction times were slower during anti blocks than during pro blocks ($F(1,10) = 77.08$, $p < .001$, $MSE = 1073.76$). More importantly, this task effect interacted with picture content (F(2,20 = 3.82, $p < .05$, $MSE = 112.48$). Planned t-test showed that the latency cost (anti-

Table 1. *Emotion and performance measures as a function of picture content*

Measure	Picture content					
	Negative		Neutral		Positive	
Self report						
Valence rating	2.4	(.11)	5.0	(.11)	7.0	(.11)
Arousal rating	5.9	(.16)	3.6	(.16)	5.5	(.16)
Physiology						
Pupil diameter (mm)	4.25	(.040)	4.19	(.026)	4.23	(.033)
Behavior						
Pro-saccadic RT (ms)	196	(8.3)	185	(7.5)	189	(7.4)
Anti-saccadic RT (ms)	257	(12.7)	260	(10.8)	265	(9.8)

Note: Table shows means with standard errors between brackets.

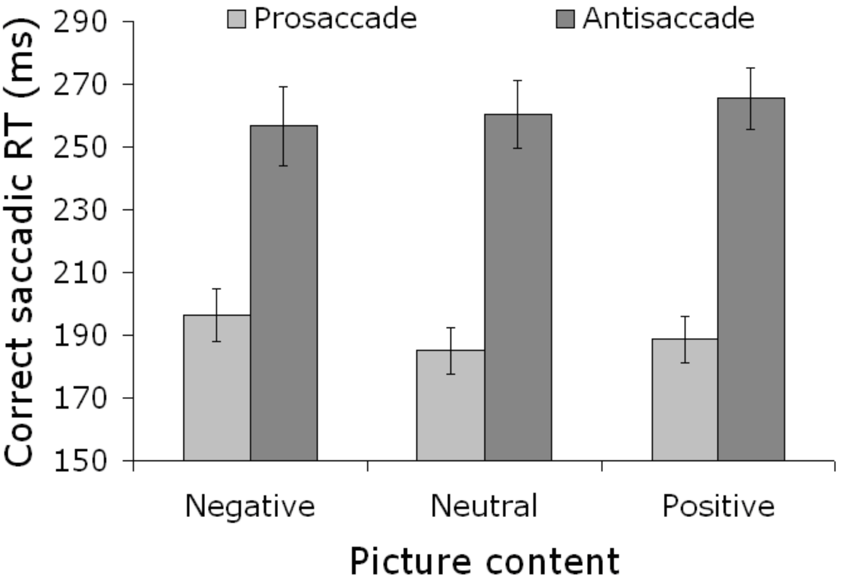

Figure 1. *Correct saccadic RT as a function of picture content and task context.*

RT minus pro-RT) was reduced following negative pictures ($t(10) = 2.84$, $p < .02$) in comparison to neutral pictures, but not for positive pictures ($t(10) = .21$, n.s.). As Figure 1 illustrates, relative to the neutral baseline, negative pictures slowed down prosaccadic reaction time (11 ms; $t(10) = 3.34$, $p < .01$) but did not significantly speed up antisaccadic reaction times (3 ms; $t(10) = .71$, n.s.), whereas positive pictures did not make any reliable difference (4 ms and 5 ms, respectively, all n.s.).

Task also affected the error rates ($F(1,10) = 17.90$, $p < .01$, $MSE = .025$): subjects committed 18% erroneous saccades in antisaccade blocks but only 1.5% in prosaccade blocks. This effect did not interact with picture content ($F(2,20) = .97$, n.s., $MSE = .006$).

To further test whether arousal might mediate any of these negative emotion effects we re-ran the analyses of correct saccadic reaction times with strong vs. weak pupil dilation as an additional factor. For this purpose, we categorized the trials following emotional pictures by means of a median split of the corresponding dilation measures. However, even though we replicated the task effect and its interaction with picture content, the dilation factor was not involved in any main effect or interaction (*F*s < 1).

Discussion

The aim of our study was to test whether attentional narrowing is due to general arousal or is selectively triggered by negative affective events. Although pupil dilation data confirmed that both negative and positive pictures increased the arousal level – a finding replicating Bradley et al. (2008) – attentional narrowing was observed following negative pictures only. This indicates that attentional narrowing is not caused by emotional arousal per se, at least as it can be measured by pupil dilation following the presentation of high-arousing pictures. In other words, increased emotional arousal may be a necessary condition, but it is not a sufficient condition for increased attentional selectivity. The same conclusion is suggested by the lack of impact of pupil dilation in the combined analysis. Hence, our observations do not provide any evidence for a role of arousal in driving attentional narrowing. Instead, the attentional focus seems to narrow whenever individuals are encountering events of negative affective valence.

How may negative affect regulate attentional narrowing? According to one account, dangerous situations may mobilize executive functions that protect against interference from disruption by irrelevant, distracting information (Norman & Shallice, 1986). Neuroimaging studies have suggested that these adjustments in cognitive control are implemented in the prefrontal cortex (Miller & Cohen, 2001), probably via signaling from the anterior cingulate cortex, a brain region involved in the detection of demanding and aversive situations (Botvinick et al., 2001; Shackman et al., 2011). Frontal cortex modulation, in turn, may modulate saccadic eye movements via the basal ganglia (Munoz & Everling, 2004). Thus, the reduced latency costs triggered by the negative pictures may originate from affect-driven modulation of cognitive control. This interpretation also fits earlier work that has used the antisaccade task to assess inhibitory control (cf. Munoz & Everling, 2004). A similar explanation may also apply to earlier published studies such as effects on Stroop tasks usually attributed to attentional narrowing (e.g., Agnew & Agnew, 1963; Callaway, 1959; cf. Wachtel, 1967).

However, it is important to emphasize that the reduced latency cost with negative pictures was driven by a slowing of RT during the prosaccade block rather than a speeding of RT during the antisaccade blocks. This indicates that processes other than improved control may also play a role in the affective modulation of behavior. For example, although it is likely that negative emotions increased control and attentional selectivity, which inhibits the visuo-motor grasp reflex resulting in delayed prosaccadic RTs (Kristjansson, 2007), this effect may have become attenuated during the antisaccade blocks. Because a state of high cognitive control is known to attenuate the effects of negative emotions (Ochsner & Gross, 2005), it might be that the effects of emotions on cognitive control were less pronounced in situations of higher task demands. Alternatively, it could be that the possible speeding of antisaccades is masked by an overall slowing effect induced by the negative pictures. Indeed, several studies suggest that the processing of negative events may compete for perceptual and/or executive resources, which may slow down performance on a subsequent task (e.g., Cohen, Henik, & Mor, 2011; Gehring, Goss, Coles, Meyer, & Donchin, 1993; Notebaert et al., 2009; Pessoa, 2009). It remains an important aim for future studies to disentangle the role of these bidirectional interactions between emotions, perception, and executive function (cf. Vuilleumier, Armony, & Dolan, 2003).

Our study demonstrates for the first time that increased emotional arousal is not a sufficient condition to produce focused attention: prosaccadic slowing presumably reflecting attentional narrowing was observed for negative affect, but not for positive affect. Consistent with this finding, and in contrast to a common misinterpretation, Easterbrook's (1959) original hypothesis attributed attentional narrowing not to general arousal but to a drive or motivation to withdraw. Given that positive emotions with approach-motivation have been shown to increase attentional focus (e.g., Gable & Harmon-Jones, 2008; for a review, see Gable & Harmon-Jones, 2010b), it is an important challenge for future research to determine which affective dimension, other than arousal accurately predicts attentional narrowing induced by positive emotions. In line with very recent discussions (cf. Friedman & Forster, 2011; Harmon-Jones, Gable, & Price, 2011), our results imply that it is now time to start research programs that search for emotional dimensions beyond valence and arousal that are responsible for tuning one's attentional scope.

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