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Decomposing unpleasantness: Differential exogenous attention to disgusting and fearful stimuli

L. Carretié[a,*], E. Ruiz-Padial[b], S. López-Martín[a], J. Albert[a]

[a] Facultad de Psicología, Universidad Autónoma de Madrid, 28049 Madrid, Spain
[b] Facultad de Humanidades, Universidad de Jaén, Spain

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ABSTRACT

Negative stimuli have consistently been shown to efficiently attract exogenous attention. Two different types of unpleasant stimuli, disgusting and fearful, sharing similar arousal and valence, are usually employed as a single category. However, since they diverge in several important aspects (biological functionality, associated feelings, and central and peripheral physiological correlates), it may be expected that their potential to capture attention differs. Event-related potentials and behavioral indices were recorded while participants were engaged in a digit categorization task in response to three types of irrelevant, distracting pictures: disgusting, fearful and neutral. Disgusting trials were associated with worse performance than fearful trials in the digit categorization task as revealed by reaction times and number of errors. Moreover, P2-associated cuneus activation and scalp anterior P2 amplitude were greater for disgusting than for fearful distracters. All these indices reveal that, under the experimental conditions employed in the present study, disgusting distracters are more efficient at attracting exogenous attention than are fearful distracters.

1. Introduction

Negatively arousing visual stimuli have been shown to efficiently attract exogenous attention (also termed automatic or bottom-up attention), as revealed by electrophysiological and behavioral responses to emotional distracters while subjects are engaged in a cognitive task (Carretié et al., 2008, 2004, 2009b; Constantine et al., 2001; Doallo et al., 2006; Huang and Luo, 2007; Thomas et al., 2007; Vuilleumier et al., 2001; Yuan et al., 2007). This ability to automatically capture attention has obvious adaptive and evolutionary advantages: the consequences of not detecting a negative event are often much more dramatic than the consequences of ignoring or reacting slowly to neutral or even appetitive stimuli. An important issue is that, in these studies on exogenous attention, negatively arousing stimuli are treated as a single category. In part, this is due to the fact that some of the most prototypical negative stimuli (e.g. spiders or bloody scenes) elicit a mixture of negative emotions (Olatunji and Sawchuk, 2005). Nevertheless, this type of event could be divided into different subcategories.

Fear and disgust are two emotions that share the same emotional valence (negative) and high ability to arouse (higher than that elicited by other negative emotions such as sadness: Russell, 1980). In functional terms, both types of emotion also share the same scope: avoiding the event that is causing, or may cause, displeasure. However, they differ in several respects. First, the subjective feeling associated with each of these two emotional states is clearly different. Second, their biological meaning is also divergent: while disgust is primarily related to contamination (Rozin, 2000), fear facilitates avoidance of a broader type of danger that may cause harm at many levels. Third, they appear to preferentially activate different brain areas. Whereas fear-related stimuli have been reported to mainly activate amygdala, disgusting events preferentially activate the anterior insula when processes other than exogenous attention are explored (see a review in Calder et al., 2001; but see, e.g. Schienle et al., 2006; Stark et al., 2007). Fourth, it has been proposed that, at the peripheral level, disgust is mainly parasympathetically mediated, while fear is a sympathetically mediated process (Levenson et al., 1990).

Therefore, a relevant question that arises once these differences are taken into account is whether disgusting stimuli and fearful stimuli have the same uniform ability to capture attention as previously assumed. Since the main reason why negative stimuli efficiently capture automatic attention is biological, one could contend that threatening and repugnant events, which have diverse biological meaning, should differ in their ability to attract attention. To the best of our knowledge, only two studies, both of a behavioral nature (no physiological responses were recorded), have compared the differences between automatic attention to fearful

* Corresponding author.
E-mail address: carretie@uam.es (L. Carretié).

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and to disgusting stimuli. In one of them, the emotional Stroop task was presented to subjects using neutral, threat-related and disgust-related words (Charash and McKay, 2002). While disgust-related words interfered with the cognitive ongoing task to a greater extent than did neutral words, no differences were found between fear-related and neutral words. In the second study (Cisler et al., 2009b), "fear words", "disgust words" and neutral words were presented to subjects during a cognitive task in which their emotional content was irrelevant. In this case, fear words were found to interfere with the cognitive task more than disgust words. Therefore, although fear- and disgust-related attention differences have been found, the question as to the direction of these differences remains unanswered. Since words tend to be less arousing than other types of visual emotional stimuli (Hinojosa et al., 2009; Keil, 2006; Kissler et al., 2006; Mogg and Bradley, 1998; Vanderploeg et al., 1987), it would be advantageous to obtain additional data using pictorial stimulation.

No studies on brain activity yet exist on the differential ability of fearful and disgusting stimuli to capture attention, although event-related potentials (ERPs) have been shown to be good indices of exogenous attention. More specifically, the P2 component of ERPs shows significant amplitude increments when a negative stimulus automatically attracts attention in a wide variety of tasks (Carretié et al., 2004; Doallo et al., 2006; Huang and Luo, 2007; Thomas et al., 2007; Yuan et al., 2007), in contrast to other components such as late positive potentials, which reflect top-down attention to emotional events (see the review by Olofsson et al., 2008; see also Hajcak et al., 2009). In previous experiments on attention to emotional pictures, P2 has been shown to originate in the visual cortex (Carretié et al., 2001; Carretié et al., 2004). This is an important issue, since Schienle et al. (2006), presenting disgusting and fearful pictures (but not exploring automatic attention: participants were asked explicitly to direct processing resources to pictures), found that maximal disgust > fear differences were produced in visual areas of the brain (fear > disgust was not explored). Stark et al. (2007) also explored brain responses to disgusting and fearful pictures that participants attended to in a top-down fashion. Again, disgust > fear contrasts yielded significant effects in visual areas, along with the insula. Fear > disgust analyses revealed extensive areas of visual cortices as the most sensitive, in statistical terms, to this contrast. Therefore, the role of P2 in automatic attention and its visual cortex origin make this component especially interesting for the scope of this study.

The present experiment was aimed at exploring whether a similar or differential pattern of exogenous attention exists in response to fear- and disgust-related distracters while subjects were engaged in a cognitive task. Both behavioral and neural indices of exogenous attention were recorded. Behavioral measures consisted of reaction times and number of errors in the cognitive task. Automatic capture of attention by distracters is reflected in poorer performance in the ongoing cognitive task. The neural index of attentional capture was P2, which, as explained, has been reported to reflect automatic attention to emotional stimuli. Analyses on this component involved source localization in order to spatially characterize possible experimental effects. Although fearful stimuli have been studied much more than disgusting stimuli in emotional attention research, thus becoming the prototypical negative category, the few existing data comparing both types of unpleasant events suggest that the latter are powerful attracters of exogenous attention. Moreover, some of the most frequently used fearful stimuli, such as threatening animals (e.g. spiders or snakes) or physical injury scenes, may be more associated with disgust than with fear (Olatunji and Sawchuk, 2005), so part of the attentional effect traditionally attributed to "negativity" may have been related to disgust processing. Therefore, we expected behavioral and neural indices of exogenous attention to be significantly modulated by disgustingness of distracters. In line with previous data described above, this disgust modulation of automatic attention could be even greater than fear modulation in several areas of the visual cortex.

2. Methods

2.1. Participants

Twenty-six subjects (21 women, age range of 19–30 years, mean = 22.73) participated in this experiment. All of them were students of Psychology at the Universidad Autónoma de Madrid and voluntarily took part in this experiment after providing their informed consent to participate, reporting normal or corrected-to-normal visual acuity.

2.2. Stimuli and procedure

Subjects were placed in an electrically shielded, sound-attenuated room. Three types of pictures were presented to participants, in a single run, through RGB projection on a back projection screen: fearful (F), disgusting (D), and emotionally neutral (N). There were 40 trials of each type (20 different pictures presented twice). The size for all stimuli was 75.17° (width) $\times$ 55.92° (height). Each of these pictures contained two central digits (4.93° height) colored in yellow and outlined in solid black so they were clearly distinguished from the background. The complete set of stimuli may be seen at http://www.uam.es/carretie/grupo/FearDisgust09.htm. Each picture was displayed on the screen for 350 ms, and stimulus onset asynchrony was always 3000 ms.

The cognitive task concerned the central digits: participants had to press, "as accurately and rapidly as possible", one key if both digits were even or if both were odd (i.e., if they were "concordant"), and a different key if one central digit was even and the other was odd (i.e., if they were "discordant"). Forty combinations of digits were composed, half of them being concordant and the other half discordant. The same combination of digits was repeated across emotional conditions in order to ensure that task difficulty was the same for F, N, and D. Stimuli were presented in semi-random order in such a way that there were never more than two consecutive trials of the same emotional category and that either the concordant or discordant condition never appeared more than twice consecutively. Participants were instructed to continuously look at a fixation mark located in the center of the screen and to blink only after a beep that sounded 1300 ms after each stimulus onset.

Pictures were taken both from the International Affective Picture System (IAPS; (Lang et al., 2005) and from our own emotional picture database (EmoMadrid; http://www.uam.es/carretie/EmoMadrid.htm). These images were selected according to objective criteria (valence and arousal assessments, which were similar for Fear and Disgust categories) and subjective criteria (trying to select "pure" fear and disgust, and avoiding stimuli in which the emotions could be mixed). After the recording session, participants filled out a multidimensional scale for each picture so their assessments on the valence, arousal, fearfulness and disgustingness content of the stimulation were obtained (Table 1). Wilcoxon's Chi-squared analyses were performed to test significance of pairwise contrasts, due to the non-parametric nature of measures. Fearfulness was significantly higher for F than for D stimuli, and disgustingness was significantly higher for D than for F stimuli ($p < 0.05$ in both cases). Valence and Arousal were higher for F than for D pictures ($p < 0.05$ in both cases) but, as explained later, these dimensions were controlled for in statistical contrasts. N stimuli were significantly lower in fearfulness, disgustingness, valence and arousal than were F and D stimuli ($p < 0.05$).

2.3. Recording

Electroencephalographic (EEG) activity was recorded using an electrode cap (ElectroCap International) with tin electrodes. Thirty electrodes were placed at the scalp following a homogeneous distribution. All scalp electrodes were referenced to the nosetip. Electrooculographic (EOG) data were recorded supra- and infraorbitally (vertical EOG) as well as from the left versus right orbital rim (horizontal EOG). Electrode impedances were always kept below 5 KΩ. A bandpass filter of 0.3–40 Hz was applied. Recordings were continuously digitized at a sampling rate of 200 Hz throughout the recording session. The continuous recording was divided into 1000 ms epochs for each trial, beginning 200 ms before stimulus onset. Trials for which subjects responded either out-of-time (>2400 ms) or erroneously were eliminated. Epochs containing eye movements or blinks over 100 μV in amplitude were deleted. For the rest of the epochs, the EOG-artifact removal procedure described by Gratton et al. (1983) was applied whenever EOG activity was observed. This artifact and error rejection led to the average admission of 79.32% F trials, 80.28% N trials, and 74.13% D trials. The minimum number of trials accepted for averaging was 50% per subject and condition. As already explained, data from four subjects were eliminated since they did not meet this criterion. Behavioral activity was recorded through a two-button keypad whose electrical output was continuously digitized at a sampling rate of 800 Hz.