Changes in EEG alpha power to different disgust elicitors: the specificity of mutilations

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Abstract

It is unclear in the literature whether the various disgust elicitors are differentially processed by the brain and/or able to elicit distinct psychophysiological response patterns. On the other hand, disgusting stimuli depicting mutilations have been proved to elicit a distinct autonomic response pattern and to demand greater attentional resources, as compared with other unpleasant visual stimuli. In this EEG study, 34 participants viewed 4 film-clips depicting surgery, cockroach invasion, human attack and neutral landscape during EEG recording, and then rated the clips for valence, arousal and the basic emotions. Independent of location, the highest cortical activation was found during the viewing of the surgery scene. Moreover, the above activation was prominent over the right posterior regions.

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Disgust is a complex emotion elicited by a number of stimuli with very heterogeneous contents. Several disgust domains have been identified, including rotting foods and odors, body envelope violations, death, offensive and contaminating animals, body products, violations of hygienic norms, and inappropriate sexual behaviors [20].

It is unclear in the literature whether these various disgust elicitors are differentially processed by the brain and/or able to elicit distinct psychophysiological response patterns. Indeed, the different disgust categories have been rarely examined separately when studying disgust emotional reactivity. Studies investigating the neural substrate of disgust have usually employed either pictures with facial disgust expressions [18], or vocal disgust expressions [17], or a broad range of disgusting visual stimuli (such as wounds, cockroaches, and dirty toilets) all clustered together [16,21,25]. On the other hand, a number of studies investigating emotional responding have specifically employed stimuli depicting surgeries, injuries or mutilations as prototypical disgust elicitors [1,4].

Strong and converging evidence emerge across studies investigating psychophysiological response patterns to stimuli depicting body envelope violations (e.g., blood, injuries, mutilations, gore). This semantic content has been proved to elicit a peculiar autonomic response pattern and to demand greater attentional resources, as compared with other unpleasant and equally arousing visual stimuli. In particular, larger and longer heart rate decreases are displayed by healthy subjects during the viewing of this emotional material [14]. This specific reaction is interpreted as an index of heightened attention to the stimulus and/or motor inhibition, and is in fact associated with greater cortical event-related potentials (ERPs) slow wave positivity [22]; longer reaction times to a probe presented during picture viewing [3]; relatively inhibited startle blink reflex (in spite of the high unpleasantness) [9]; larger reduction in spontaneous blink rate during film viewing [14]. Taken together, these data do not indicate a clear-cut rejection response, typical of disgust, but rather suggest increased cognitive engagement. Indeed, the expected disgust defense response would be associated with sensory shutdown in any modality representing a means of entry into the body, including cognitively turning away from the offensive stimulus (see [20]). Thus, there seems to be...
something special about blood-related information that results in distinctive emotional processing and responding.

In a recent fMRI study [26], the effects of pictures depicting contamination (e.g., bodily waste and spoiled food) and mutilations (e.g., murder victims and injuries) on brain hemodynamic responses were tested separately. Whereas the anterior insula responded to both disgust elicitors, mutilations uniquely activated the right superior parietal cortex, further supporting the idea that this emotional content might have distinct neural representation.

Brain activation can be also investigated by means of quantitative electroencephalogram (EEG), with EEG alpha activity (8–13 Hz) during wakefulness considered to inversely reflect cortical activation of the corresponding region of the underlying cerebral cortex (see [12]). Moreover, the use of EEG alpha power has been critical in studies on brain asymmetry and emotion. A large body of EEG data suggests that the right and left cerebral hemispheres are differentially involved in the regulation and processing of emotion (for a review, see [7]).

It has been proposed that the left prefrontal cortical regions are specialized for the experience and expression of positive emotions (e.g., [8]) and/or approach motivation (e.g., [5]), whereas the right regions are involved in the experience and expression of negative emotions, e.g., [8] and/or withdrawal motivation (e.g., [5]). However, most studies have recorded exclusively from frontal scalp locations and few EEG data are available on asymmetric activation of other cortical regions during emotion. Indeed, there is evidence that the right parietal cortex plays a role in the modulation of affective processing [23,24] and emotion-related arousal [8], although further research on the pattern for posterior asymmetry is needed.

The present study was designed to compare the pattern of EEG cortical activity measured from multiple scalp locations during the viewing of two different disgust elicitors (namely, Mutilation and Contamination). To test the specificity of mutilation-related activation, a non-disgusting, un-edifying scene was excerpted from a medical documentary depicting contamination (e.g., bodily waste and spoiled food) and contaminations (e.g., bodily waste and spoiled food) and shown a thoracic operation; the Contamination scene depicted a cockroach invasion; the Neutral scene was drawn from a landscape documentary.

Each participant viewed the emotional clips in one of four varied orders, according to a latin square. Participants wore earplug headphones and were instructed to keep their eyes open and to view each film-clip for its entire duration. Each film-clip was presented for 132 s, preceded by 60 s (baseline) of blank screen. At the end of each clip, subjects were asked to assign valence and arousal ratings and to rate the specific emotions they had experienced during film viewing. The rating procedure lasted about 1 min. A random intertrial interval (4–6 min) of blank screen lapsed between film presentations.

Valence and arousal ratings were obtained using the paper-and-pencil version of the Self-Assessment Manikin (SAM) [11], which consists of a nine-point rating scale for each dimension. Six basic emotional states (happiness, surprise, fear, anger, disgust and sadness) describing the reaction to the films were also evaluated on a five-point paper-and-pencil scale (0–4 score) for each emotion.

EEG was recorded using an Electro-Cap with tin electrodes (Electro-Cap, Inc.) from 58 scalp positions referenced online to Cz and digitally converted off-line to an average reference (AR). The EEG sites were Fp1, Fp2, F7, F5, F3, F1, Fz, P2, F4, F6, F8, FC5, FC3, FC1, FC2, FC4, FC6, T7, C5, C3, C1, C2, C4, C6, T8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP9, P7, P5, P3, P1, Pz, P2, P4, P6, P8, P07, P03, P0z, P04, P08, O1, Oz, O2, A1, A2. For the purpose of artifact scoring, vertical and horizontal electro-oculograms (EOGs) were recorded. Electrode pairs (bipolar) were placed at the supra- and suborbit of the right eye and at the external canthi of the eyes. All electrode impedances were less than 10,000 Ω and the differences of impedance of homologous sites were below 2000 Ω. The EEG and EOG signals were amplified with Neuroscan Synamps (El Paso, TX, USA), bandpass filtered (1–40 Hz), digitized at 500 Hz (16 bit AD converter, accuracy 0.034 μV/bit) and stored on to a Pentium II computer.

Continuous EEG data were corrected for eyeblinks using a regression-based correction algorithm (Scan 4.1 software). All EEG records were further visually scored for artifact, and each portion of data containing residual artifacts greater than ±50 μV in any channel was rejected for all the recorded channels prior to further analysis. The average number of seconds of rejected data for each film-clip was 2.6 s for Mutilation, 1.48 s for Neutral, 1.17 s for Fear and 1.61 s for Contamination. No significant difference was found among the film-clips in the number of rejected trials ($F_{3,99} = 1.71; p < 0.17$).

The Cz-referenced EEG was re-referenced to AR montage, which approximates an inactive reference when the head is sampled with a large number of electrodes. Chunks of artifact-free continuous EEG 1.024 s in duration were extracted through a Hamming window and overlapped by 50% to minimize loss of data. For each chunk, a Fast Fourier Transform (FFT) method was used to derive estimates of spectral power ($uV^2$) in the 1 Hz frequency bins for each electrode site.
For each experimental condition, spectral power values from all chunks were averaged across baseline and film epochs. Power density values (\(\mu^2/\text{Hz}\)) within the alpha (8–13 Hz) frequency range were obtained. These data were log transformed for all sites to normalize their distributions. For each site, change scores from baseline were computed by subtracting power values obtained during the 60-s baseline from those obtained during the 132-s film. Since alpha power is inversely related to cortical activity, lower change scores indicate greater cortical activation.

In order to compare cortical activation associated with the viewing of each film-clip, a 1st 4 (film) \(\times\) 8 (location) analysis of variance (ANOVA) was performed on the mean alpha power change scores along the midline (Fpz, Fz, FCz, Cz, CPz, Pz, POz and Oz). To test for differences in hemisphere asymmetries during film viewing, a 4 (film) \(\times\) 2 (hemisphere) ANOVA was performed on the mean alpha power reduction data, left and right from the midline (Fp1/2, F3/4, C3/4, C5/6, CP3/4, P3/4, PO3/4, O1/2). Following the suggestions of a reviewer, additional ANOVAs were performed subdividing the total alpha frequency band into alpha-1 (8–10.5 Hz) and alpha-2 (10.5–13 Hz) and including the frequency band factor in the above-mentioned designs. Indeed, slow and fast alpha frequencies are thought to respond differently during information processing, reflecting attentional processes and semantic encoding, respectively [10]. A 4 (film) \(\times\) 6 (basic emotions) ANOVA was performed on the mean subjective ratings describing the reaction to the films, in order to ensure that the target emotions could be specifically elicited. Valence and arousal mean ratings were entered into ANOVAs containing film as factor. Post hoc means comparisons (Newman–Keuls) were employed to further examine significant effects (using a \(p < 0.05\) criterion for significance).

Significant film main effects were obtained for both valence and arousal \((F[3,99] = 11.00; \ p < 0.00001, \ \text{and} \ F[3,99] = 35.47; \ p < 0.00001, \ \text{respectively})\). Fear, Mutilation and Contamination film-clips were rated as more unpleasant and arousal than neutral, with no significant differences among each other. The film \(\times\) basic emotions interaction was highly significant \((F[15,495] = 18.25, \ p < 0.00001)\), showing that the Mutilation and Contamination conditions each received comparably higher disgust ratings than Fear and Neutral, and that the Fear film-clip received higher fear ratings than the other three conditions (see Table 1 for a complete description of post hoc comparisons).

Table 1

<table>
<thead>
<tr>
<th>Affective ratings</th>
<th>Mutilation</th>
<th>Contamination</th>
<th>Fear</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
<td>3.91 (\pm) 2.14 a</td>
<td>3.76 (\pm) 1.71 a</td>
<td>3.04 (\pm) 2.03 a</td>
<td>5.70 (\pm) 1.29 b</td>
</tr>
<tr>
<td>Arousal</td>
<td>5.79 (\pm) 2.14 a</td>
<td>5.06 (\pm) 1.99 a</td>
<td>5.71 (\pm) 2.06 a</td>
<td>2.23 (\pm) 1.41 b</td>
</tr>
<tr>
<td>Happiness</td>
<td>0.18 (\pm) 0.58 a</td>
<td>0.26 (\pm) 0.62 a</td>
<td>0.21 (\pm) 0.59 a</td>
<td>1.00 (\pm) 1.21 b</td>
</tr>
<tr>
<td>Surprise</td>
<td>1.29 (\pm) 1.00 a</td>
<td>0.71 (\pm) 0.94 b</td>
<td>1.18 (\pm) 1.11 a</td>
<td>0.68 (\pm) 1.01 b</td>
</tr>
<tr>
<td>Fear</td>
<td>0.32 (\pm) 0.59 a,c</td>
<td>0.71 (\pm) 0.84 a</td>
<td>1.44 (\pm) 1.13 b</td>
<td>0.03 (\pm) 0.17 c</td>
</tr>
<tr>
<td>Anger</td>
<td>0.09 (\pm) 0.29 a</td>
<td>0.26 (\pm) 0.51 a</td>
<td>0.91 (\pm) 1.16 b</td>
<td>0.03 (\pm) 0.17 a</td>
</tr>
<tr>
<td>Disgust</td>
<td>1.71 (\pm) 1.36 a</td>
<td>1.94 (\pm) 1.23 a</td>
<td>0.62 (\pm) 0.78 b</td>
<td>0.12 (\pm) 0.41 b</td>
</tr>
<tr>
<td>Sadness</td>
<td>0.18 (\pm) 0.39 a</td>
<td>0.20 (\pm) 0.58 a</td>
<td>0.53 (\pm) 0.83 a</td>
<td>0.12 (\pm) 0.54 a</td>
</tr>
</tbody>
</table>

Mean \(\pm\) S.D. reports of rated pleasure, arousal and intensity of basic emotional states when viewing the four film-clips. Within each dependent measures, letter sets are used to indicate the results of post hoc comparisons. Conditions that share at least one letter do not significantly differ.
hemisphere interaction ($F_{[21,693]} = 3.28; p < 0.00001$) indicates that for Mutilation higher cortical activation was found in the right than left hemisphere at C4, CP4, P4 and PO4. For Contamination, significantly higher activity in the right hemisphere was found only at P4. For Fear, higher activation at right than left hemisphere was found at C4, CP4, and P4. For the neutral condition no significant differences between left and right cortical activation were found at any location (Fig. 2). The Mutilation film-clip elicited significantly greater increases in activation than the other conditions at both left and right locations, essentially replicating the effects observed for the midline sites.

The above-mentioned results were entirely replicated when considering alpha-1 and alpha-2 mean power density values. At the sagittal midline, the only significant effects involving the frequency band factor indicate that larger reductions during film viewing were obtained for alpha-1 than alpha-2 (frequency band main effect: $F_{[1,133]} = 4.17; p < 0.038$); furthermore, the frequency band × location interaction ($F_{[7,231]} = 9.01; p = 0.00001$) shows that alpha-1 reductions were maximal at CPz, Pz and POz, whereas alpha-2 maximal decrease was located at POz. Greater decreases in power density were observed for alpha-1 than alpha-2 at every location, except at POz and Oz. Asymmetric activation was found not to differ as a function of alpha frequency sub-bands, in that the effects found for the total band were entirely replicated.

The primary aim of the present study was to address the specificity of cortical activation induced by mutilations, as compared with a different type of disgust elicitor. As predicted, greater increases in cortical activation from baseline were found overall during Mutilation than Contamination and Fear film-clips, although all contents were equivalent in rated affective valence and arousal. Even more importantly, the Mutilation and Contamination conditions did not differ in reported disgust, thus excluding the possibility that differences in emotional experience affected the pattern of cortical activation. Since reductions in EEG alpha power are known to reflect cognitive engagement (e.g., [12]), these data suggest that mutilations demand heightened and more extensive processing than other negative input, thus extending previous findings from studies employing different psychophysiological measures [3,9,14,22]. Additional evidence for the strong involvement of attentional processes during film viewing is provided by the greater suppression of alpha EEG activity in the lower than the upper frequency band. Indeed, alpha-1 activity is thought to represent attentional and motivational processes related to the allocation of processing resources (see [10]). The evidence that the Contamination and Fear conditions elicited largely comparable degrees of cortical activation across scalp locations provided further support to the specificity of blood-related information processing. Moreover, it is worth noting that a distinct pattern of cortical activation as a function of scalp location was obtained for Mutilation, with a peak at CPz, Pz and POz, whereas Contamination, Fear and Neutral all showed the same spatial distribution pattern, with maximal activation extending more posteriorly (Pz, POz and Oz). The latter result is consistent with the evidence that greater activation in visual occipital–parietal cortex is observed for high-arousal emotional stimuli than for neutral material [2]. The present data further indicate a distinct activation pattern elicited by mutilations, suggesting a major involvement of the parietal cortical areas.

Mutilation induced greater cortical activation than all the other contents over both hemispheres, but this effect was enhanced over the right posterior locations. Interestingly, relatively greater right-sided activation did emerge in response to the unpleasant stimuli for posterior regions in the absence of differences in anterior activation. Indeed, this asymmetrical activation extended from central to parieto-occipital locations for Mutilation, while it was less extensive for Fear and limited to the parietal site for Contamination. The lack of frontal asymmetries in our results does not support conceptual models linking asymmetrical frontal EEG activity and affective valence and/or motivational direction [5,7]. Other research provided findings that are not in line with the models, while suggesting a role of the right parietal region in emotion [19,23].

Taken together, our data are consistent with previous fMRI findings demonstrating a unique activation for mutilation pictures in the right superior parietal cortex [26] and a more extensive functional activity for mutilation than threat pictures over the right posterior ventral cortex [2]. The posterior regions of the right hemisphere have been proposed to be involved in the evaluation and interpretation of emotional information and in the modulation of emotional autonomic and behavioral arousal [8]. On the other hand, the role of parietal activity in processing the perceptual salience or the behavioral relevance of stimuli [6] and in directing and maintaining attention towards sensory stimuli in the environment [8,15] has been well-established. Based on this evidence, our data suggest that stimuli depicting mutilations command enhanced cognitive engagement and resources relative to other...
equally unpleasant, arousing and disgusting stimuli, differentially engaging attentional processes. While limited in the spatial resolution of the employed measures, our study provides new information using a direct neurophysiological correlate of cortical activity, thus complementing recent fMRI data [2,26] and adding to the converging evidence that stimuli depicting body envelope violations induce distinctive emotional processing and responding [3,14,22].

We acknowledge some limitations of the present study. Only one film-clip was employed for each condition. Therefore, the possibility that the obtained effects are due to specific features of the selected stimuli (such as dynamic of the scenes and/or unique perceptual characteristics) cannot be ruled out. This issue should be addressed in future studies employing a sample of different film-clips for each emotional condition. Moreover, no information on the time course of cortical activation during film viewing could be provided. Although the selected film-clips were edited in order to maintain scene continuity, it is possible that their emotional impact changed over time, thus differing across conditions. In order to clarify this issue, the analysis of the time course of alpha power density changes should be considered in future studies by dividing the whole stimulus interval into shorter epochs. Lastly, given the multidimensional nature of arousal, the lack of differences in self-report measures among unpleasant conditions does not exclude a difference in autonomic arousal. Indeed, in a previous unpublished study employing the same stimuli and procedures while investigating autonomic responses only, we found no differences in skin conductance changes (a clear indicator of physiological arousal) among the unpleasant film-clips. This result gives further support to the idea that the specific activation pattern obtained for Mutilation is not determined by a generally higher arousal state. However, only a simultaneous recording of EEG and skin conductance changes in the same subjects could help addressing this potential confound.

In conclusion, stimuli depicting body envelope violations might be considered as a peculiar type of disgusting content that does not elicit a clear-cut avoidance response, and for which more information is needed in order to clarify environmental demands. This view is further supported by the notion that attention is easily captured by car accidents involving injured people as well as by horror movies, despite their obvious aversive content. Future research should elucidate the functional significance of this specific activation pattern, thus helping to understand the complexity of disgust along its different domains.

References


