



Affective picture processing and motivational relevance: Arousal and valence effects on ERPs in an oddball task

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ABSTRACT

There are two dominant theories of affective picture processing; one that attention is more deeply engaged by motivationally relevant stimuli (i.e., stimuli that activate both the appetitive and aversive systems), and two that attention is more deeply engaged by aversive stimuli described as the negativity bias. In order to identify the theory that can best account for affective picture processing, event-related potentials (ERPs) were recorded from 34 participants during a modified oddball paradigm in which levels of stimulus valence, arousal, and motivational relevance were systematically varied. Results were partially consistent with motivated attention models of emotional perception, as P3b amplitude was enhanced in response to highly arousing and motivationally relevant sexual and unpleasant stimuli compared to respective low arousing and less motivationally relevant stimuli. However P3b amplitudes were significantly larger in response to the highly arousing sexual stimuli compared to all other affective stimuli, which is not consistent with either dominant theory. The current study therefore highlights the need for a revised model of affective picture processing and provides a platform for further research investigating the independent effects of sexual arousal on cognitive processing.

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1. Introduction

Previous studies have shown reliable modulation of the event-related potential (ERP) in response to affective pictorial stimuli. Affective stimuli are discriminated from neutral stimuli as early as 200 ms post-stimulus onset and positive shifts in the ERP waveform may be sustained for several seconds (Cuthbert et al., 2000). Compared to neutral stimuli, affective stimuli (both pleasant and unpleasant) have been shown to elicit enhanced P3b (e.g., Keil et al., 2002; Cuthbert et al., 2000; Schupp et al., 2003) and Positive Slow Wave (PSW) (e.g., Amrhein et al., 2004; Cuthbert et al., 2000; Diedrich et al., 1997) activity. This pattern of equally enhanced ERP component amplitude in response to both pleasant and unpleasant stimuli, which could be described as a fully U-shaped function, is often taken as evidence that attention is more deeply engaged by motivationally relevant stimuli (i.e., stimuli that have relevance for survival and activate the brain's appetitive and aversive systems).

According to Lang et al.'s (1997) model of motivated attention and affective states, all emotional responses are organised along underlying appetitive and aversive systems that respond to primary reinforcers. Pleasant states that promote approach responses are driven by the appetitive system, unpleasant states that promote withdrawal responses are driven by the aversive system, and arousal

reflects the level of energy that is mobilised by either system (Lang et al., 1997). ERP component amplitudes have been shown to co vary with rated arousal (Cuthbert et al., 2000), meaning that images rated as increasingly more arousing than neutral evoke increasingly larger ERP component amplitudes. Research demonstrating enhanced P3b and PSW activity [collectively referred to as the Late Positive Potential (LPP: Ito et al., 1998)] in response to both pleasant and unpleasant stimuli compared to neutral has therefore been argued to index the processing of arousal information (Cuthbert et al., 2000; Schupp et al., 2000).

Although the majority of affective picture processing studies have shown equally enhanced activity to both pleasant and unpleasant stimuli, a number of studies have shown enhanced LPP amplitudes evoked in response to unpleasant stimuli (e.g., Delplanque et al., 2004; Delplanque et al., 2005; Delplanque et al., 2006; Ito et al., 1998). Enhanced LPP amplitudes in response to unpleasant stimuli compared to pleasant and neutral stimuli have been taken as support for the negativity bias, a theory which accounts for the observation that responses are more rapid and prominent to aversive compared to equally arousing appetitive stimuli (for reviews see Cacioppo and Berntson, 1994; Cacioppo et al., 1997; Ito and Cacioppo, 2005; Rozin and Royzman, 2001).

It could be argued that the fully U-shaped function (unpleasant = pleasant > neutral) and negativity bias effects observed in affective ERP studies are paradigm specific. The majority of affective ERP studies that have demonstrated a fully U-shaped function have

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used sustained picture viewing paradigms that involve long stimulus durations and inter-trial intervals (ITIs). Similarly, a negativity bias effect has been demonstrated almost exclusively within the context of modified oddball paradigms, which involve short stimulus durations and manipulation of stimulus probability and target context. Schupp et al. (2000) investigated whether certain experimental parameters such as stimulus duration could account for the frequently observed fully U-shaped function by presenting affective pictorial stimuli at short stimulus durations typical of modified oddball paradigms but without manipulation of target context or stimulus probability. A full U-shaped function was demonstrated in Schupp et al.'s study, casting some doubt on the notion that the full U-shaped function is paradigm specific. It therefore seems unlikely that the full U-shaped function is paradigm specific to sustained picture viewing and it can not be conclusively stated that the negativity bias is specific to the modified oddball paradigm, given the added control over 'classic' ERP effects provided by oddball paradigms (for example control of subjective probability and task relevance effects on P3b amplitude see Donchin, 1981; Donchin and Coles, 1988; Pritchard, 1981 for reviews). If the discrepancies cannot be explained in terms of differences in experimental paradigms, then perhaps they can be explained by differences in the experimental stimuli used in previous affective picture processing studies.

According to the model of motivated attention and affective states (Lang et al., 1997), the stimulus dimensions of hedonic valence and arousal elicit activation in the underlying appetitive and aversive systems. The effect of these stimulus dimensions can be systematically investigated using stimuli selected from the International Affective Picture System (IAPS; Lang et al., 1999) in which stimuli vary on levels of hedonic valence, arousal, and semantic characteristics such as motivational relevance. IAPS stimuli can therefore be categorised according to both valence (pleasant, neutral, and unpleasant) and arousal (high, low) dimensions and within each of these sub-categorisations of high and low arousing stimuli, different semantic characteristics are apparent. For example, highly arousing unpleasant stimuli typically depict images of human mutilation, death, and human/animal threat, whereas low arousing unpleasant stimuli depict images of pollution, contamination, human illness, or deceased animals. Highly arousing pleasant stimuli typically depict images of sport/adventure and erotica, and low arousing pleasant stimuli typically depict images of nature, animals, romance, families, or food. As noted, IAPS stimuli can be categorised by different semantic characteristics, one of which is motivational relevance, or the degree to which a stimulus conveys information that is of relevance for survival. For example, high arousing unpleasant stimuli that depict images of human injury and threat convey information that is of greater relevance for immediate survival compared to the low arousing unpleasant stimuli that depict images of pollution and illness. The same follows for pleasant stimuli: high arousing pleasant stimuli that depict erotic images convey information that is of greater relevance for procreation and hence survival compared to low arousing pleasant images of food, babies, and happy couples. The IAPS has been designed such that pleasant images of sport/adventure can be matched for valence with both low arousing pleasant images (e.g., animals, food, babies) and highly arousing sexual images. The arousal ratings of the pleasant sport/adventure images can also be matched with that of the erotic or sexual images and also that of the highly arousing unpleasant images of human mutilation, death, and human/animal threat. According to Lang et al.'s (1997) model of motivated attention and affective states, images that are higher in arousal are thought to activate the underlying appetitive and aversive systems more strongly. Following this assumption, the model suggests that high arousing sport/adventure images should activate the appetitive system to a similar extent as the sexual images which are matched for valence and arousal. However sport/adventure stimuli do not convey information that is of equal relevance to survival compared

to sexual images, and it may be argued that these stimuli do not activate the appetitive system to the same extent and this possibility will be investigated in the current study.

Electrophysiological responses have been shown to vary not only between picture categories (pleasant and unpleasant > neutral) but also within picture categories. Enhanced LPP (P3b and PSW) amplitude has been shown to vary within unpleasant picture categories, with enhanced amplitudes in response to unpleasant images depicting human/animal threat and mutilation compared to images depicting human illness and contamination (Schupp et al., 2004a,b). Similarly for pleasant images, enhanced LPP amplitudes have been demonstrated in response to pleasant images of erotic couples and opposite sex nudes compared to all other pleasant picture stimuli (Schupp et al., 2004a,b). As noted, highly arousing pleasant sport/adventure images are argued not to convey motivationally relevant information and are argued not to activate the appetitive system to the same extent as sexual stimuli even though they can be matched for valence and arousal. Schupp et al.'s research is one of few to highlight differences in ERP component amplitudes in response to stimuli that are matched for valence and arousal, but differ in terms of motivational relevance. As ERP component amplitudes have been shown to vary within pleasant and unpleasant picture categories, with the largest amplitudes shown for the most highly arousing and motivationally relevant stimuli, it is argued that the practice of intermixing arousal and semantic characteristics such as motivational relevance into general pleasant, unpleasant, and neutral categories presents a potential confound (e.g., Amrhein et al., 2004; Mini et al., 1996; Palomba et al., 1997).

The current study was designed to investigate the cognitive processing of motivationally relevant information by measuring ERP responses to affective pictorial stimuli. The processing of motivationally relevant information was investigated by comparing ERP responses to high and low arousing pleasant, unpleasant, and neutral stimuli which vary in term of semantic characteristics such as motivational relevance. For example, the high arousing unpleasant stimuli consist of different images depicting mutilation, human/animal threat, etc. all of which convey information that is relevant for immediate survival and are hence motivationally relevant. The low arousing unpleasant category of stimuli consist of images of contamination, illness, and deceased animals, which are rated lower in arousal and also convey information that is less relevant to immediate survival. The high arousing pleasant stimuli are broken down into two sub sets. High arousing sexual stimuli are both highly arousing and convey information that is relevant for procreation and hence survival. Pleasant images of sport/adventure are also highly arousing, however these stimuli do not convey information that is relevant for survival, hence differences in motivational relevance can be investigated within the same valence and arousal category. Low arousing pleasant stimuli are rated lower in arousal and also do not convey motivationally relevant information. The current study therefore aims to investigate the effect of motivational relevance by comparing behavioural and electrophysiological responses to stimuli that are matched for valence and arousal and differ in terms of motivational relevance (e.g., high arousing sexual and high arousing sport/adventure images) and stimuli that differ in terms of both motivational relevance and arousal (e.g., high vs. low arousing unpleasant and sexual stimuli).

By systematically varying levels of valence and arousal in order to investigate the cognitive processing of motivationally relevant information, the current study also aims to determine the theory that could best account for affective picture processing (the model of motivated attention and affective states inferred from a full U-shaped function or the negativity bias). A modified oddball paradigm was used to present the affective stimuli to control for 'classic' ERP effects, specifically the effect of subjective probability and task relevance on P3b amplitude. Subjective probability and task relevance are two

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