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Behavioral assessment of emotional and motivational appraisal during visual processing of emotional scenes depending on spatial frequencies

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ABSTRACT

Previous studies performed on visual processing of emotional stimuli have revealed preference for a specific type of visual spatial frequencies (high spatial frequency, HSF; low spatial frequency, LSF) according to task demands. The majority of studies used a face and focused on the appraisal of the emotional state of others. The present behavioral study investigates the relative role of spatial frequencies on processing emotional natural scenes during two explicit cognitive appraisal tasks, one emotional, based on the self-emotional experience and one motivational, based on the tendency to action. Our results suggest that HSF information was the most relevant to rapidly identify the self-emotional experience (unpleasant, pleasant, and neutral) while LSF was required to rapidly identify the tendency to action (avoidance, approach, and no action). The tendency to action based on LSF analysis showed a priority for unpleasant stimuli whereas the identification of emotional experience based on HSF analysis showed a priority for pleasant stimuli. The present study confirms the interest of considering both emotional and motivational characteristics of visual stimuli.

1. Introduction

Results from behavioral and neuroimaging studies have revealed that emotional intrinsic properties of visual stimuli affect their perceptual processing (Bradley et al., 2003; Briggs & Martin, 2008; Hajcak, Dunning, & Foti, 2009; Hansen & Hansen, 1988; Ito, Larsen, & Cacioppo, 1998; Phan et al., 2003; Rozin & Royzman, 2001; Vuilleumier, 2005; Öhman, Flykt, & Esteves, 2001). For instance, participants are generally faster when they have to detect and identify emotional (e.g., snake, spider, and emotional faces) than neutral stimuli (Fox et al., 2000; Hansen & Hansen, 1988; Öhman et al., 2001). The amygdala, specifically involved in the emotional processing may be the cerebral structure which mediates the modulation of visual processing by the emotion (Amaral, Behniea, & Kelly, 2003; Anderson & Phelps, 2001; Morris et al., 1998; Ochsner & Gross, 2005; Vuilleumier, 2005). Visual processing of emotional stimuli also depends on the type of cognitive evaluation required by the task (Ferrari, Codispoti, Cardinale, & Bradley, 2008; Hajcak, Moser, & Simons, 2006; Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003; Keightley et al., 2003; Ochsner & Gross, 2005; Schaefer, 2002; Schupp et al., 2007). Affective tasks facilitate and amplify the perceptual processing of emotional stimuli compared to non-affective tasks (Hajcak et al., 2006; Keightley et al., 2003). Affective tasks explicitly involve the emotional and motivational processes and specifically include several types of cognitive evaluation such as identification of his (her) emotional state or that of others (emotional appraisal), or of his (her) tendency to action or coping potential (motivational appraisal) during visual emotional stimuli. Non-affective tasks are unrelated to emotional and motivational processes and include cognitive tasks such as counting people in an emotional scene or judging the gender of an emotional face (in this type of task, any emotional processing would be implicit).

Interestingly, it has been shown that cognitive evaluation of visual stimuli may be driven by a specific spatial frequency content (Delord, 1998; Oliva & Schyns, 1997; Rotshtein, Schofield, Funes, & Humphreys, 2010; Schyns & Oliva, 1999). Indeed, a considerable number of studies on the visual system of humans and animals suggest that spatial frequencies are crucial in visual perception. On the basis of different data from the functional neuro-anatomy of magnocellular and parvocellular visual pathways (Van Essen & Deyoe, 1995), neurophysiological recordings in primates (Bullier, 2001), psychophysical and neuroimaging results in humans (Ginsburg, 1986; Hegdé, 2008; Hughes, Nozawa, & Kitterle, 1996; Mermillod et al., 2011; Parker, Lishman, & Hughes, 1992; Peyrin et al., 2010; Schyns & Oliva, 1994) and computational data (Guyader, Chauvin, Peyrin, Herault, & Marendaz, 2004; Mermillod, Guyader,

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& Chauvin, 2005), influential theories of visual recognition postulates that visual analysis may start with a parallel extraction of different visual features at different spatial frequencies, but with a predominant coarse to fine sequence. Accordingly, a rapid extraction of low spatial frequencies (LSF) should provide a global outlook of the stimulus structure, thus allowing an initial perceptual categorization. This first coarse analysis might then be refined by high spatial frequencies (HSF) whose extraction takes place later. Recent behavioral and neuroimaging studies (Alorda, Serrano-Pedraza, Campos-Bueno, Sierra-Vazquez, & Montoya, 2007; Bocanegra & Zeelenberg, 2009, 2011; Carretié, Hinojosa, Lopez-Martín, & Tapia, 2007; Holmes, Green, & Vuilleumier, 2005; Holmes, Winston, & Eimer, 2005; Mermillod, Droit-Volet, Devaux, Schaefer, & Vermeulen, 2010; Vuilleumier, Armony, Driver, & Dolan, 2003) as well as computational data (Mermillod, Bonin, Mondillon, Alleysson, & Vermeulen, 2010; Mermillod, Vermeulen, Lundqvist, & Niedenthal, 2009) suggest that emotional processing in visual stimuli may rely on the rapid processing of LSF, especially for threat. For example, using functional Magnetic Resonance Imaging (fMRI), Vuilleumier et al. (2003) showed that the amygdala's responses to fearful expressions were greater for LSF than HSF faces. An event-related potentials (ERPs) study conducted by Carretié et al. (2007) also highlighted that negative scenes filtered on LSF induce a higher amplitude of early ERP visual component than not-filtered negative scenes suggesting that LSF information is essential in the initial affect-related processing of visual stimuli. Although the coarse-to-fine processing of spatial frequencies appears to be the predominant way of operating, the sequence and the use of spatial frequency information has been found to be relatively flexible depending on the task demands (Oliva & Schyns, 1997, Rotshtein et al., 2010). Few studies have demonstrated a flexibility of spatial frequency processing on emotional visual stimuli (Schyns & Oliva, 1999, Vuilleumier et al., 2003). For example, by using hybrid faces (superposition of two faces, one filtered in LSF and the other one in HSF), Schyns and Oliva (1999) showed that HSF information of hybrids were preferentially used to determine whether a face was expressive or not, whereas LSF information were preferentially used to categorize emotion as happy or angry. According to Vuillemier et al. (2003), LSF information was also preferentially used for implicit discrimination of facial expression (fearful or neutral) whereas HSF information was preferred for explicit judgements of emotional intensity. However, to our knowledge, all studies exploring the effect of spatial frequency bands on visual emotional processing depending on task demands only used faces as stimuli and not complex stimuli such as emotional natural scenes. Furthermore, when exploring the explicit processing of emotions, these studies only used discrimination tasks of the emotional state of others, such as processing facial expressions (Mermillod, & Bonin et al., 2010; Schyns & Oliva, 1999; Vuilleumier et al., 2003) and not discrimination tasks of self-emotional experience. It remains unclear if discrimination tasks of self-emotional state and emotional state of others preferentially use the same spatial frequency band. Importantly, visual processing of emotional stimuli would also strongly depend on two motivational systems, one defensive and another one appetitive. The motivational systems stimulate individuals to act and respond with adapted behaviors and tendencies to action using avoidance (defensive system) and approach (appetitive system) (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley et al., 2003; Frijda, 1986, 1987; Lang, Bradley, & Cuthbert, 1997). The role of spatial frequencies on the motivation appraisal has not yet been studied.

Overall, this behavioral study aimed to investigate the relative role of spatial frequencies on processing emotional complex natural scenes during explicit emotional and motivational appraisal tasks. Scenes were filtered in LSF and HSF, and non-filtered. Participants were required to perform: (a) an emotional appraisal task consisting of the explicit discrimination of emotional scenes, based on the *emotional experience* (pleasant, unpleasant, neutral) and (b) a motivational appraisal task consisting of the explicit discrimination of emotional pictures, based on the *motivated action or the tendency to action* (avoidance, approach, and no action). Importantly, for both tasks, we strictly used the same paradigm (same stimuli, order and time of presentation) in order to investigate the influence of cognitive demands of task irrespective of low-level visual processing. A minimal stimuli duration of 300 ms was used in our study in order to avoid a prevalence of LSF information processing related to its temporal characteristic compared to HSF information and, based on pre-test studies, to guarantee a good recognition of emotional information when complex scenes filtered in HSF and LSF are used. This procedure makes it possible to identify the most relevant spatial frequency content, to efficiently perform each of the appraisal tasks. Specifically, we hypothesized that visual analysis of emotional scenes was mainly based on processing HSF if an explicit emotional appraisal task based on emotional experience (pleasant, unpleasant, neutral) was required as suggested by previous studies that evaluated explicitly emotional state for the stimuli durations used in our study (Mermillod et al., 2011). We thus assumed better behavioral performances for HSF stimuli compared to LSF stimuli. Moreover, for the motivational appraisal task, our hypothesis was based on previous studies that suggest the processing-for-action depends on the dorsal visual pathway specialized for LSF frequencies (Livingstone & Hubel, 1988) which projects on the dorsolateral prefrontal cortex (DLPFC; Wilson, Scalaidhe, & Goldman-Rakic, 1993), a region intrinsically related with the tendency to action (Harmon-Jones, 2003; Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). We thus hypothesized that a motivational task for action (avoid vs. approach) performed with emotional scenes is preferentially based on LSF processing. Consequently, the performances should be better for LSF than for HSF stimuli. These effects could be explained by an attentional bias or attention focalization on a specific type of spatial frequency according to cognitive demands: LSF related to fast responses and gross analysis such as required by the motivation for action; HSF related to slower and analytical analysis such as emotional judgment. We also included a passive visualization task in which participants were required to passively observe emotional scenes. This third task was used as a control task in order to behaviorally test the role of spatial frequencies in the processing of emotional intrinsic properties of scenes without any explicit cognitive appraisal. Specifically, this task allows us to identify the spatial frequency content preferentially used during the implicit processing of the emotional content in visual scenes. The relative influence of the emotional content of visual stimuli was also considered during emotional and motivational appraisal tasks.

Finally, we also manipulated the duration of stimulus presentation in order to evaluate whether this factor interacts with the effect of task demands on the processing of emotional stimuli and thus modulates the relative influence of spatial frequencies in a given task. Such an interaction could reflect an additional potential influence of attentional processes more controlled (more conscious) with an increase in stimulus duration as suggested by several studies (Holmes, & Green et al., 2005; Wells & Matthews, 1994).

2. Materials and methods

2.1. Participants

Forty-seven participants (3 men and 44 women; mean age: 20.5 ± 3.9 years), right-handed, with normal or corrected-to-