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

B. Fradcourt [a], C. Peyrin [b], M. Baciu [a], A. Campagne [a,*]

[a] Université de Grenoble Alpes, Laboratoire de Psychologie et Neurocognition, F-38040 Grenoble, France
[b] CNRS, Laboratoire de Psychologie et Neurocognition, F-38040 Grenoble, France

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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.

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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,

& 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-
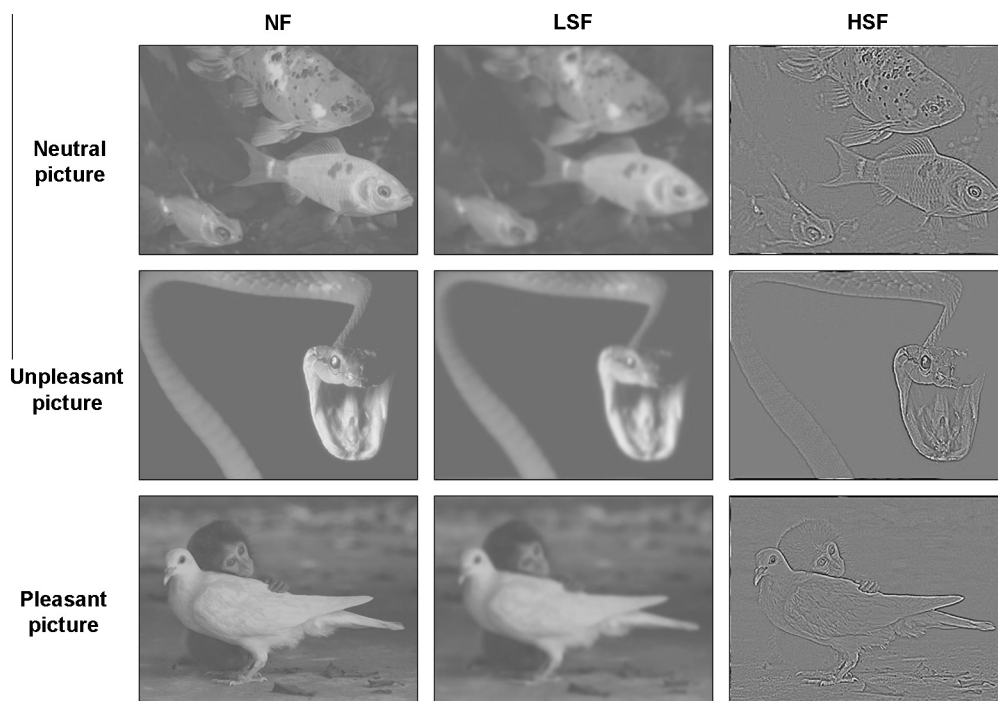
Fig. 1. Examples of natural scenes presented during the experiment. Pictures composed of all spatial frequencies (non-filtered, NF; left column) were subsequently filtered in order to keep only low range (low spatial frequency, LFS; middle column) and only high range of spatial frequencies (high spatial frequency, HSF; right column). It should be noted that the perception of spatial frequencies could be affected by the picture reduction of scene for the illustrative purpose. Picture size is about 10 times smaller than the actual picture size on the screen used for the experiment (23.7 × 18.7 cm).

normal vision, were selected for the experiment. They were graduate and undergraduate students and were divided into three groups according to stimulus duration (16 participants for 300 ms stimulus duration; 15 participants for 500 ms stimulus duration and 16 participants for 1000 ms stimulus duration, see details in the *Procedure* sub-section). They provided informed written consent to participate in the experiment.

2.2. Stimuli

Stimuli were displayed against a black background using E-prime software (E-prime Psychology Software Tolls Inc., Pittsburgh, USA) onto a 19-in. monitor with a 1024 × 768 pixels resolution located 85 cm from the participants. They consisted of 198 black and white pictures of natural scene images (640 × 480 pixels, i.e., 23.7 × 18.7 cm). Their angular size was thus 16 × 13° of visual angle. Stimuli were composed of 66 pleasant, 66 unpleasant and 66 neutral scenes. Visual scenes were in close-up and directly involved the participant. Pictures were selected from several sources: the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), the Internet (noncopyrighted) and an in-house database. Unpleasant scenes included dangerous animals (sharks, snakes, spiders, etc.), unsafe environments (tornadoes, fires, tsunamis, etc.) and aggressive people (carrying weapons, angry expression, etc.). Pleasant scenes included images showing safe, happy and friendly animals, idyllic landscapes (beach, mountains, etc.) as well as happy and friendly people. Neutral scenes included the same type of stimuli (animals, environments and people) in neutral situations. For each scene, an LSF or an HSF stimulus was created (Fig. 1). Filtered images were created using the image processing toolbox in MATLAB (Mathworks Inc., Sherborn, MA, USA). They were obtained by multiplying the Fourier transformation of the original images with Gaussian filters. We used a two-dimensional Gaussian centered on the null frequency with a maximal value equal to one and standard deviations

equal to 28 and 38 cycles per image for LSF stimuli and 172 and 230 for HSF stimuli. With this filter design, we obtained a gaussian filter with a frequency cut-off (amplitude attenuation with a square root of 1/2) of 1.5 cycle/degree of visual angle (i.e., low-pass cut-off of 24 cycles per image) for LSF stimuli, and below 9 cycles/degree of visual angle (i.e., high-pass cut-off of 144 cycles per image) for HSF stimuli. Then, the luminance and contrast of LSF, HSF and non-filtered (NF) stimuli was equalized for each scene to obtain a global luminance with zero mean and a standard deviation equal to 1 (root mean square [RMS] contrast; see Bex & Makous, 2002). Based on a pretest[1] performed with 60 volunteers, pleasant and unpleasant stimuli (5.11 ± 0.74 for pleasant and −6.43 ± 1.42 for unpleasant on valence scale from 10-pleasant to −10−unpleasant with 0− no or weak valence) were characterized by the tendency to approach or to avoid respectively (approach for pleasant stimuli: 5.06 ± 1.14 and avoidance for unpleasant stimuli: −7.27 ± 1.18 on an action tendency scale from 10-approach to −10-avoid with 0− no or weak tendency for action) and by the following emotional arousal: 4.90 ± 0.92 for pleasant and 5.51 ± 0.93 for unpleasant (on an intensity scale from 1 to 10). Neutral scenes judged without emotional content (neutral valence: 0.02 ± 1.01) were defined by low arousal (1.81 ± 0.97) and weak preferential tendency to action (0.61 ± 1.56). It should be noted that the action tendency was slightly positively correlated with the pictures' arousal for both

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[1] Preliminary tests were performed in order to select the visual scenes. From 567 black and white pictures, 375 were retained in a first pretest based on their arousal, emotional valence and action tendency (116 neutral stimuli, 125 pleasant stimuli, and 134 unpleasant stimuli). Once filtered in HSF and LSF, the preselected pictures were again evaluated to select only the pictures correctly identified and presenting maintained emotional characteristics, i.e., 198 pictures (66 per valence). Neutral, pleasant and unpleasant pictures were correctly categorized in living/non-living scenes at the rate of 97.11 ± 6.91%, 96.02 ± 7.32% and 97.54 ± 5.47% respectively and were subjectively perceived at the rate of 8.70 ± 1.09, 8.99 ± 0.86 and 8.94 ± 0.91 respectively (on an identification scale from 1-non-perceived to 10-clearly-perceived). Emotional parameters are provided in the manuscript.

unpleasant ($r = 0.47$ between arousal and tendency to avoid) and pleasant ($r = 0.40$ between arousal and tendency to approach), but these correlations were not significant.

2.3. Procedure

We manipulated the duration of stimuli in order to evaluate whether this factor interacts with the effect of task demands on the processing of emotional stimuli. 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. Stimuli were thus presented for 300, 500 or 1000 ms in three participant groups.

The experiment was composed of three tasks. Each task was performed during 3 spatial frequency-experimental blocks that lasted 6 min (1 LSF-block, 1 HSF-block and 1 NF-block) including 22 pleasant, 22 unpleasant and 22 neutral pictures displayed randomly. In order to limit repetition effect, three different stimuli groups were used. They were randomized between tasks and between SF-blocks across participants within a group. Each trial (Fig. 2) of blocks began with a central fixation cross for a variable period (mean duration: 1300 ms ± 174 ms) followed by stimulus presentation: 300 ms, 500 ms or 1000 ms, according to the participant group (Groups 1, 2 and 3 respectively). A response screen was then displayed for 1500 ms during which participant had to respond according to task demands. The average inter-stimuli duration was 3800 ms. Therefore, in order to equalize trial duration between participants groups, a central fixation cross during 700 ms and 500 ms ended each trial for Group 1 and Group 2, respectively.

The following three tasks were performed by each participant: (i) an explicit emotional appraisal task: participants were required to specify their *emotional experience*, i.e., they had to decide for each trial whether the scene was pleasant, unpleasant or neutral/no emotion by pressing on the corresponding response key; (ii) an explicit motivational appraisal task: participants were required to indicate the action they would adopt if they were inside the scene or action tendency, i.e., they had to decide for each trial whether they would approach, avoid or not act by pressing on the corresponding response key, and (iii) a passive visualization task of emotional scenes (perceptive task): participants were required to passively observe the scene and perform a motor task unrelated to picture's content. They had to identify the location of a "X" target displayed within a gray circle among two other "X" displayed within a white circle by pressing on the corresponding response key. Each task involved three key choices and for each trial, participants were instructed to respond as quickly and as accurately as possible with their dominant hand by pressing one of the three manual keys specifically assigned for each task (see Fig. 2). In the two main tasks, the assignment of the three emotions (emotional task) or the three actions (motivational task) to three keys varied between trials. In the perceptive task, the X displayed within a gray circle was associated alternately and randomly to one of the three response buttons across trials; the two others being associated with the X displayed within a white circle. In each task, the assignment of response keys was indicated during the response screen after the presentation of each stimulus. The third task was used as a control task in order to behaviorally test the effects of the emotional intrinsic properties of scenes without any explicit cognitive appraisal. In order to avoid covert emotional and motivational appraisal during the passive visualization task, participants always started the experiment with the three SF-blocks of this control task. In order to limit order
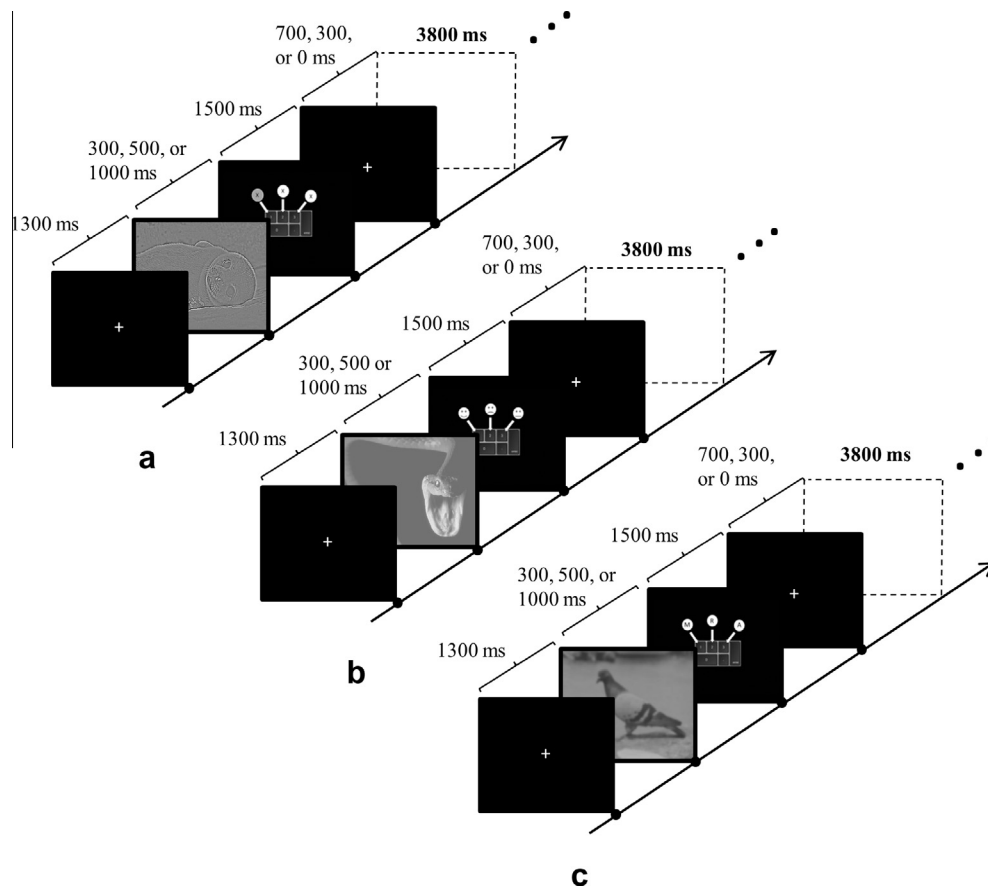

Fig. 2. Examples of a trial during (a) the passive visualization task, (b) the emotional appraisal task and (c) the motivational appraisal task.

effects, the three SF-blocks of each appraisal task were then performed randomly, with an alternation of two appraisal tasks. In the control task as well as in appraisals tasks, the SF-block order was randomized across participants in each participant group. Before the perception task and before the two appraisal tasks, participants underwent a training session in order to get familiarized with the tasks and stimuli.

2.4. Data processing

For each participant, the mean reaction time in milliseconds (RT, ms) and the accuracy, as the mean rate of correct responses (%ACC), were measured for each stimulus in each experimental condition. In the passive visualization task (see Fig. 2), a response was considered as correct when participants press the response key associated with an "X" displayed within a gray circle and randomly presented on the response screen among two other possible choices of response, each key associated with an "X" displayed within a white circle. The RTs were only evaluated for the correct responses. In the emotional and motivational appraisal tasks, a response for a given scene was considered as correct when the response (emotional valence or tendency to action) given by the participant was the same as the one given by the pretest participants, i.e., when the response is congruent. Specifically, during the emotional task, a correct response corresponded to: "press the unpleasant response key" for the pictures categorized as unpleasant during the pretest; "press the pleasant response key" for the pictures categorized as pleasant during the pretest; "press the neutral response key" for the pictures categorized as neutral during the pretest. During the motivational task, a correct response corresponded to: "press the avoidance response key" for the pictures characterized by a tendency to avoidance during the pretest (the case of all unpleasant stimuli); "press the approach response key" for the pictures characterized by a tendency to approach during the pretest (the case of all pleasant stimuli); "press the no

action response key" for the pictures characterized by no action during the pretest (case of all neutral stimuli). All different responses (i.e., noncongruent and button errors) were considered as errors. It should be noted that some accuracy differences appeared between our participants and our pretest group, mainly for neutral stimuli which were rated as pleasant for some pictures. Some unpleasant and pleasant pictures were rated as neutral. These differences were taken into account in the measure of mean reaction times in order to avoid a bias in our results: thus, mean reaction times (mRT) were only calculated and statistically analyzed on correct responses, i.e., only for pictures similarly rated between the current group of participants and the pretest group. Regardless of this point, RTs values lower than 100 ms and higher than two standard deviations were also discarded. Statistica 10.0 software was used to analyze data. A $3 \times 3 \times 3 \times 3$ mixed analysis of variance (ANOVA) was performed with mRT and mean %ACC for each participant with *stimuli duration* (300 ms, 500 ms and 1000 ms) as a between-subject factor and with *spatial frequency* (NF, HSF, and LSF), *emotional valence* (pleasant, unpleasant, neutral) and *task* (passive visualization, emotional appraisal, motivational appraisal) as within-subject factors. In case of sphericity violation, the Greenhouse-Geisser correction was applied. Mean comparisons were explored using Tukey post hoc. The significant level of tests was set at 0.05.

3. Results

3.1. Mean reaction times (mRT)

Consistent with our hypotheses, statistical analysis revealed that Task ($F(2,88) = 580.95$, $p < 0.001$, $\eta^2 = .93$) and two-way interaction Task $\times$ Spatial frequency ($F(4,176) = 25.82$, $p < 0.001$, $\eta^2 = .36$; Fig. 3a) significantly influenced mRT. Specifically, mean comparisons revealed that participants responded faster for HSF (785.32 ms, $SE \pm 25.1$ ms) and for NF stimuli (788.09 ms,
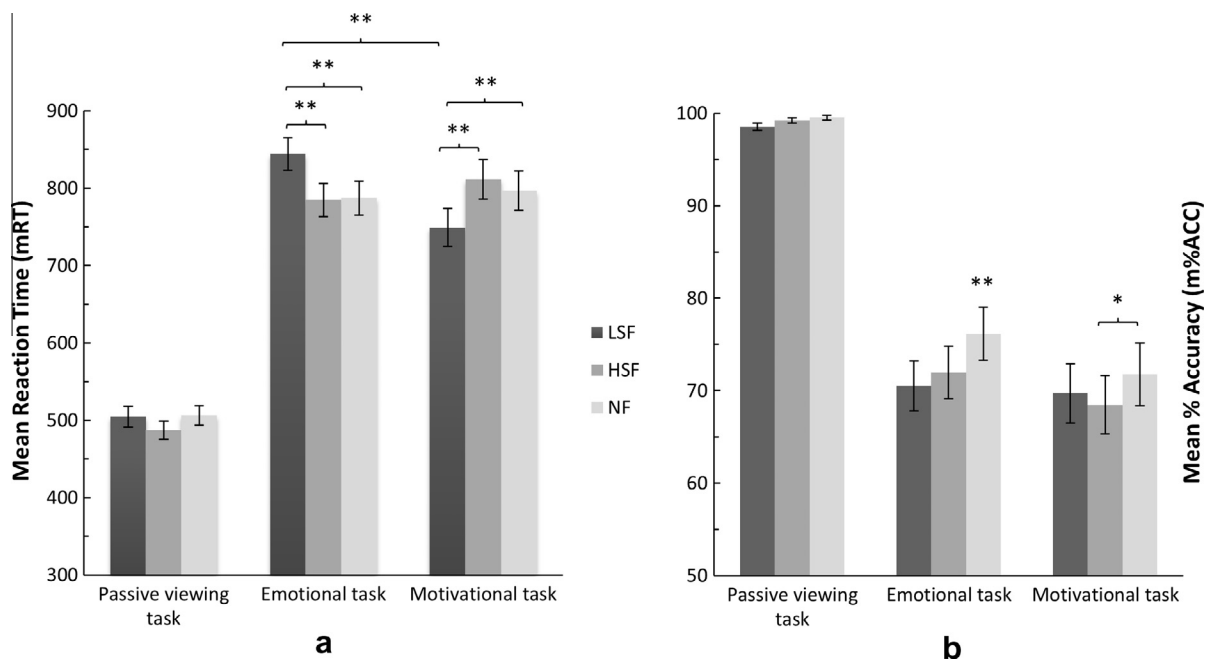

Fig. 3. Illustrates the participants' performance for each task according to spatial frequency of visual information (mRT in ms Panel a; Accuracy % ACC in Panel b) Participants were faster for motivational than for emotional tasks regardless the type of spatial frequency. Additionally, the mRT during the emotional task was shorter for HSF and for NF than for LSF scenes. Conversely, the mRT was shorter during motivational task for LSF than for HSF and NF scenes. The passive visualization task induced the shortest mRT and the highest % ACC without difference between LSF, HSF and NF scenes. **0.01 Significant threshold after Bonferroni correction, *0.05 significant threshold after Bonferroni correction.

$SE \pm 25.96$ ms) than for LSF stimuli (844.71 ms, $SE \pm 24.9$ ms) during the emotional task ($p < 0.001$ for the two comparisons). The opposite pattern – shorter mRT for LSF (749.95 ms, $SE \pm 29.67$ ms) than for HSF (812.10 ms, $SE \pm 25.1$ ms) and NF stimuli (797.31 ms, $SE \pm 25.2$ ms) - was observed during the motivational task ($p < 0.001$ for the two comparisons). No difference was observed between HSF and NF in the emotional and motivational tasks. The passive viewing task of emotional scenes revealed the shortest mRT compared to others tasks, independently of spatial frequency information ($p < 0.001$ for each spatial frequency). In this task, no difference was observed in terms of mRT between LSF, HSF and NF stimuli. Secondarily, it is also noted that mRT was shorter in the motivational than the emotional task only for LSF stimuli

(MOT_{LSF}: 749.95 ms, $SE \pm 29.67$ ms and EMO_{LSF}: 844.71 ms, $SE \pm 24.9$ ms, $p < 0.001$). All results are reported in Fig. 3a.

We also showed that emotional valence ($F(2,88) = 31.78$, $p < 0.001$, $\eta^2 = .42$) and the following interactions Task × Emotional valence ($F(4,88) = 41.94$, $p < 0.001$, $\eta^2 = .48$; Fig. 4a) and Spatial frequency × Emotional valence ($F(4,88) = 2.70$, $p < 0.04$, $\eta^2 = .03$) significantly influenced the mRT. A tendency to significance was also obtained for the three-way interaction Task × Spatial frequency × Emotional valence ($F(8,352) = 1.81$; $p < 0.074$, $\eta^2 = 0.04$). Independently of spatial frequency, emotional stimuli significantly differed in terms of mRT depending on task demands as illustrated in Fig. 4a. Specifically, during the emotional task, participants responded faster for pleasant stimuli (759.14 ms,
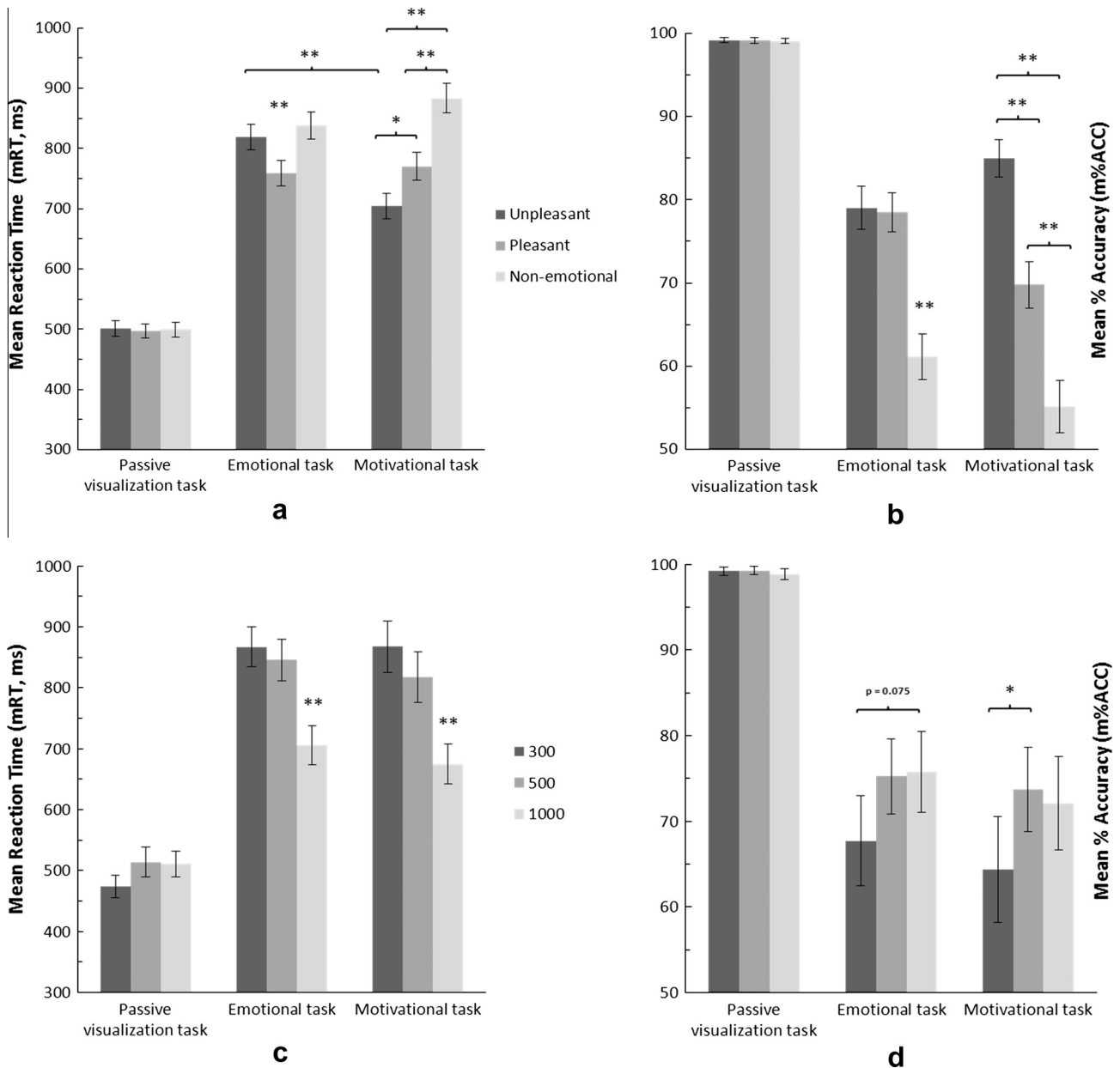

Fig. 4. Illustrates participants' performance for each task according to emotional content and stimulus duration (300, 500, 1000 ms) (mRT in ms Panel a; Accuracy % ACC in Panel b). Panel a: during the emotional task, participants were more accurate for emotional than for neutral stimuli and faster for pleasant than for unpleasant and neutral stimuli. During motivational task, participants were more accurate and faster for unpleasant than for pleasant and neutral stimuli, as well as for pleasant than for neutral stimuli. No effect was obtained during the passive visualization task. Panel b: participants were faster for 1000 ms duration and the accuracy was lower for 300 ms duration for both emotional and motivational tasks. **0.01 Significant threshold after Bonferroni correction; *0.05 significant threshold after Bonferroni correction.

$SE \pm 27.79$ ms) compared to unpleasant (839.02 ms, $SE \pm 27.8$ ms, $p < 0.001$) and neutral stimuli (884.42 ms, $SE \pm 30.17$ ms, $p < 0.001$). No significant difference was obtained between unpleasant and neutral stimuli. The motivational task revealed shorter responses for unpleasant stimuli (704.67 ms, $SE \pm 27.79$ ms) compared to pleasant (770.28 ms, $SE \pm 31.1$ ms, $p < 0.001$) and neutral stimuli (884.42 ms, $SE \pm 30.17$ ms, $p < 0.001$) and for pleasant stimuli compared to neutral stimuli ($p < 0.001$). In the passive visualization task of emotional scenes, no significant difference was observed between unpleasant, pleasant and neutral stimuli.

Concerning the effect of spatial frequencies depending on emotional valence of stimuli, mean comparison revealed no difference in terms of mRT between spatial frequencies for each emotional valence, regardless the task under consideration. The observed biases toward HSF or LSF stimuli in emotional and motivation tasks respectively were also similar between three emotional valences. For each emotional valence, no difference between spatial frequencies was observed in the passive visualization task. Secondary, analysis revealed that, for LSF stimuli, responses are faster for the motivational task compared to the emotional task for unpleasant ($p < 0.001$), pleasant ($p < 0.003$) and neutral stimuli ($p < 0.008$). For HSF stimuli, a similar pattern was observed for unpleasant stimuli ($p < 0.001$). In contrast, an opposite pattern (i.e., faster responses for the emotional task compared to motivation task) was obtained for pleasant ($p < 0.005$) and neutral ($p < 0.001$) stimuli filtered in HSF.

Finally, the Stimulus duration ($F(2,44) = 8.22$, $p < 0.001$, $\eta^2 = .27$) and the interaction Task $\times$ Stimulus duration ($F(4,88) = 26.72$, $p < 0.001$, $\eta^2 = .54$; Fig. 4c) showed a significant effect on mRT. No other interaction was observed with the stimulus duration. Participants responded faster for the 1000 ms duration (EMO: 705.8 ms, $SE \pm 69.7$ ms and MOT: 674.95 ms, $SE \pm 72.85$ ms) compared to 500 ms (EMO: 845.44 ms, $SE \pm 71.99$ ms and MOT: 817.01 ms, $SE \pm 75.24$ ms) and 300 ms duration (EMO: 866.88 ms, $SE \pm 69.71$ ms and MOT: 867.41 ms, $SE \pm 72.85$ ms) during the emotional task ($p < 0.002$ and $p < 0.001$ respectively) and the motivational task ($p < 0.002$ and $p < 0.001$ respectively), irrespective of spatial frequencies. No difference was observed for the passive visualization task. Results are reported in Fig. 4c.

3.2. Correct responses (congruent responses, %ACC)

Statistical analysis yielded a significant effect on mean percentage of correct responses (%ACC) for Spatial frequency ($F(2,88) = 18.75$, $p < 0.001$, $\eta^2 = .30$), Task ($F(2,88) = 355.17$, $p < 0.001$, $\eta^2 = .89$) and the two-way interaction Task $\times$ Spatial frequency ($F(4,176) = 4.99$, $p < 0.001$, $\eta^2 = .10$; Fig. 3b). Mean comparisons revealed better %ACC for NF stimuli compared to LSF and HSF in the emotional task (NF: 76.14%, $SE \pm 2.86\%$; LSF: 70.50%, $SE \pm 2.73\%$, $p < 0.001$ and HSF: 71.95%, $SE \pm 2.84\%$, $p < 0.001$), and for NF stimuli compared to HSF stimuli only in the motivational task (NF: 71.76%, $SE \pm 2.92\%$; HSF: 68.47%, $SE \pm 3.16\%$; $p < 0.007$). No statistical difference was observed between LSF and HSF stimuli in both the emotional and motivational tasks. No difference between LSF, HSF and NF was also obtained during the passive viewing task of emotional scenes. Secondarily, it is also noted that the emotional task induced better performance than motivation task only for HSF (72%, $SE \pm 2.25\%$ and 68.57%, $SE \pm 2.6$ respectively, $p < 0. 003$) and NF stimuli (76.18% $SE \pm 2.43\%$ and 71.87%, $SE \pm 2.74\%$ respectively, $p < 0.001$). These results are all illustrated in Fig. 3b.

We also showed that emotional valence ($F(2,88) = 33.90$, $p < 0.001$, $\eta^2 = .43$) and the following interactions Task $\times$ Emotional valence ($F(4,176) = 24.76$, $p < 0.001$, $\eta^2 = .36$; Fig. 4b) and

Spatial frequency $\times$ Emotional valence ($F(4,176) = 4.15$, $p < 0.004$, $\eta^2 = .09$) significantly influenced the %ACC. No significant effect was obtained for the three-way interaction Task $\times$ Spatial frequency $\times$ Emotional valence. Independently of spatial frequency, it also appeared that emotional stimuli significantly differed in terms of %ACC depending on task demands as illustrated in Fig. 4b. Specifically, during the emotional task, performance was better for emotional stimuli (unpleasant: 79.08%, $SE \pm 3.95\%$ and pleasant: 78.53%, $SE \pm 3.43\%$) compared to neutral stimuli (61.13, $SE \pm 4.34\%$; $p < 0.001$ for the two comparisons). No significant difference was obtained between unpleasant and pleasant stimuli. The motivational task showed better performances for unpleasant stimuli (85.03%, $SE \pm 3.44\%$) compared to pleasant (69.86%, $SE \pm 4.08\%$, $p < 0.001$) and neutral stimuli (55.27%, $SE \pm 4.88\%$, $p < 0.001$) and for pleasant compared to neutral stimuli ($p < 0.001$). No difference was obtained for the passive visualization task of emotional scenes.

Concerning the effect of spatial frequencies depending on the emotional valence of stimuli, mean comparisons revealed better performance for NF stimuli compared to LSF and HSF for unpleasant (NF: 90.52%s, $SE \pm 2.04\%$; LSF: 85.85%, $SE \pm 2.60\%$; HSF: 86.69%, $SE \pm 2.28\%$; $p < 0.001$ and $p < 0.005$ respectively) and for pleasant stimuli (NF: 85.17%, $SE \pm 2.67\%$s; LSF: 80.95%, $SE \pm 2.70\%$; HSF: 81.21%s, $SE \pm 2.89\%$s; $p < 0.002$ and $p < 0.005$ respectively). No effect was observed for neutral stimuli.

Finally, the Stimulus duration ($F(2,44) = 4.45$, $p < 0.02$, $\eta^2 = .17$) and the following interactions Task $\times$ Stimulus duration ($F(4,88) = 3.76$, $p < 0.008$, $\eta^2 = .15$; Fig. 4d) and Task $\times$ Spatial frequency $\times$ Stimulus duration ($F(8,176) = 3.51$, $p < 0.002$, $\eta^2 = .13$) showed a significant effect on %ACC. No other interaction was observed with the stimulus duration. Independently of spatial frequency, mean comparisons revealed in the motivational task that the %ACC was significantly lower for the 300-ms stimuli duration compared to the 500-ms stimuli duration ($p < 0.05$). In the emotional task, the %ACC tended to be significantly lower for the 300-ms duration compared to 1000-ms duration. No difference between stimulus duration was obtained during the passive visualization of emotional scenes. Regarding the effect of spatial frequency depending on stimuli duration, analysis showed that NF stimuli induced higher %ACC than LSF and HSF in the emotional task only for the 300 ms duration. No significant difference was observed between spatial frequencies for the three stimuli duration in the motivational task and in the passive visualization task. Part of these results is illustrated in Fig. 4d.

4. Discussion

The main goal of this study was to determine the relative role of spatial frequencies on visual processing of natural emotional scenes during two explicit cognitive appraisal tasks: one *emotional* based on one's own emotional experience and one *motivational* based on one's own tendency to action. Specifically, we aimed to evaluate if a particular spatial frequency content, LSF or HSF was preferred to perform these emotional and motivational appraisal tasks. Moreover, a passive visualization task of emotional scenes 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, we want to identify the spatial frequency content preferentially used in processing the emotional content of visual scenes. To evaluate the relative role of spatial frequency information in the different tasks, we manipulated the spatial frequency content of complex scenes and created filtered (HSF, LSF) and unfiltered scenes.

Independently of the spatial frequency of visual scenes, our results showed that motivational appraisal induced faster responses

than emotional appraisal task. However, accuracy was lower for the motivational than the emotional task. Overall, participants were faster but less accurate in the motivational than the emotional task. This result suggests that the motivational system (defensive vs. appetitive) promotes rapid processing and fast decision-making but may generate more "errors" (Bradley, 2000; Bradley et al., 2001; Frijda, 1986, 1987; Lang et al., 1997).

Our study revealed a difference between the two cognitive tasks in the relative role of spatial frequencies. During the emotional appraisal task, participants were faster for HSF and NF than for LSF. No difference was observed between HSF and NF. Additionally, during the emotional appraisal task accuracy was significantly higher for NF than for HSF and LSF. No difference was obtained between HSF and LSF in terms of %ACC. Taken together, these results suggest a prevalence of HSF information in our emotional appraisal task in agreement with results reported by other studies exploring the emotional states of others with stimuli duration beyond 100 ms (Mermillod et al., 2011; Vuilleumier et al., 2003). Our results show that this bias for HSF may also be applicable to tasks evaluating the self-emotional experience induced by natural scenes. Specifically, participants evaluated their emotional experience based on a detailed analysis of scenes conveyed by HSF rather than on coarse analysis conveyed by LSF. Our results also showed that accuracy improves when HSF information is coupled with LSF information in unfiltered stimuli. These results thus suggest that, although HSF information is preferred to rapidly discriminate our own emotional experience, LSF information may also contribute to this discrimination. Conversely, LSF information seems to prevail and to be sufficient to categorize natural scenes during a motivational task. Indeed, in this task, participants were faster for LSF than for HSF natural scenes. The coarse information conveyed by LSF appears to be essential and the most effective to rapidly decide the action tendency (avoidance, approach or no action). According to previous studies exploring visual information for action (Costantini, Ambrosini, Tieri, Sinigaglia, & Committeri, 2010; Costantini, Committeri, & Sinigaglia, 2011), our results suggest that the tendency to action would be guided by the processing of spatial information in visual stimuli (e.g., information depth, distance between elements, etc.) contained in LSF information and involving the dorsal visual pathway (Kravitz, Saleem, Baker, & Mishkin, 2011; Livingstone & Hubel, 1988). In this sense, the fact that visual scenes used in our study were close-up and directly involved the participant has probably contributed to the prevalence of LSF information in rapidly identifying the action tendency. Based on our results, it also appears that a detailed analysis of scenes conveyed by HSF may influence our capacity to identify our action tendency. Specifically, HSF information seems to delay the identification of action tendency. Indeed, in HSF stimuli as well as when HSF information was coupled with LSF in unfiltered stimuli (NF stimuli), the mRT was significantly increased. In addition, it can suppose that the tendency to action may be modulated by the level of emotional arousal felt by participants. According to a previous study (Vuilleumier et al., 2003), the judgment of emotional intensity would preferentially use the HSF information. However, the pre-test revealed no significant correlation between these two dimensions (action tendency and level of emotional arousal) for stimuli used in our study. The arousal level of stimuli used was also relatively moderate. Therefore, the influence of arousal level on action tendency judgment would be limited here. Note however that the arousal level was not directly assessed in the present experiment; we thus cannot exclude such an effect. This hypothesis should be explored in a future work. Overall, all effects related to task demands suggest «top-down» processes which would guide perceptual processing via attention toward specific spatial frequencies of visual information. These processes could imply fronto-parietal areas as suggested by fMRI studies (Bar, 2003, 2004; Bar et al., 2006; Bullier,

2001; Hegdé, 2008; Peyrin et al., 2010). The attention focus may provide the best efficiency to perform the task and seems to be oriented toward HSF when we explicitly identify our own emotional experience (emotional task) and toward LSF when we explicitly identify our tendency to action (motivational task). In contrast, no bias toward a specific spatial frequency was observed during the passive visualization task (control task). This task was used in order to identify the type of spatial frequency preferentially used in processing the emotional content of scenes without any explicit cognitive appraisal. In disagreement with previous studies (Bocanegra & Zeelenberg, 2011; Holmes, & Green et al., 2005; Vuillemier et al., 2003), our result suggests that implicit (involuntary) processing of the emotional content of scenes does not require a specific type of spatial frequency. This difference with previous studies could be explained by the fact that our task was not related to scene content and was perhaps too low-level and too easy (performances already maximal) for highlighting effects related to an implicit emotional processing of scenes.

A second objective in this study was to determinate whether the relative role of spatial frequencies in processing visual scenes during each of the tasks depended on the emotional valence of scenes. Our results suggest that the preference for HSF during emotional appraisal and the preference for LSF during motivational appraisal were independent of the emotional content of scenes. We also assessed how the emotional valence of scenes influenced the processing of visual scenes during each of the tasks depending on the spatial frequency content. For the different conditions of spatial frequency, no difference between the three categories of emotional scenes was observed during the passive visualization task confirming the potential absence of implicit emotional processing of scenes. In contrast, in the motivational task, the best performances (in terms of reaction times and accuracy) were obtained for unpleasant compared to positive and neutral stimuli and for pleasant scenes compared to neutral scenes, suggesting an attentional shift on unpleasant stimuli. It should also be noted that unpleasant stimuli are processed significantly faster in the motivational task than in the emotional task. It seems that negative stimuli induce the greatest motivational meaning. From an evolutionary standpoint, events that threaten life have a greater adaptive value than any other type of stimuli (Ito & Cacioppo, 2005; Ito et al., 1998; Rozin & Royzman, 2001). In this situation, the motivational system may give temporal priority and focus attention on unpleasant stimuli (Ito & Cacioppo, 2005; Ito et al., 1998; Rozin & Royzman, 2001), crucial for adaptation and survival (Briggs & Martin, 2008; LeDoux, 1995). Conversely, in the emotional task, better performances were measured for pleasant compared to negative stimuli (mRT) and for emotional (unpleasant and pleasant) compared to neutral stimuli (%ACC), suggesting an attentional shift toward pleasant stimuli. During the emotional task, pleasant scenes seem to have more significant value than negative scenes and neutral scenes. No difference was observed between unpleasant and neutral stimuli in terms of reaction time. This result is quite surprising and differs from data in the literature by showing a bias towards negative stimuli (negativity bias) or a bias towards emotional stimuli for this kind of task (Ito & Cacioppo, 2005; Ito et al., 1998; Rozin & Royzman, 2001). This prevalence of the pleasant stimuli in the emotional task would mainly be related to a modulation in the processing of unpleasant stimuli with respect to the motivational task. Indeed, no statistical difference was observed in processing pleasant stimuli between tasks. In contrast, for the unpleasant stimuli, reaction time was significantly longer in the emotional task compared to the motivational task; this modulation leads to a positivity bias in the emotional task. These data suggest that the pleasant stimuli seem to be similarly processed in the two tasks whereas the unpleasant stimuli seem to be more relevant in motivational task than in emotional task.

Given this last point, we assume that the random alternation of the blocks of appraisal tasks (emotional and motivational) in each participant has perhaps modulated the processing of unpleasant scenes in the emotional task and contributed to favor a positivity bias in this task. It should be also noted that participants were previously informed about the two tasks to perform and that they were previously familiarized with both. However, our hypothesis cannot be tested here and should be explored in future work.

Finally, we also manipulated the duration of stimuli in order to evaluate whether this factor interacts with the effect of task demands on the processing of emotional stimuli. While RT values were the shortest for 1000-ms stimuli duration in two cognitive appraisal tasks, the preference of HSF information in rapidly identifying our self-emotional experience (emotional task) and the preference of LSF information in rapid identification of our tendency to action (motivational task) were maintained for the three stimuli durations suggesting the absence of an additional potential influence of more controlled (more conscious) attentional processes with increased stimulus duration. Only the accuracy would be improved with stimulus duration.

5. Conclusion

Our results confirmed the interest in considering both emotional and motivational processes during visual processing of stimuli with emotional significance. We showed a distinct role of the spatial frequencies in processing emotional scenes in emotional and motivational tasks. Specifically, HSF was significantly relevant in identifying our self-emotional experience, while LSF was sufficient and the most effective in rapidly identifying our self-tendency to action. These results were independent of the emotional content of the information. Moreover, motivational evaluation would give priority to negative stimuli, independently of spatial frequencies. Conversely, emotional experience identification would give priority to pleasant stimuli.

Acknowledgment

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