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Emotion Perception Is Mediated by Spatial Frequency Content

Devpriya Kumar and Narayanan Srinivasan
University of Allahabad

Spatial frequencies have been shown to play an important role in face identification, but very few studies have investigated the role of spatial frequency content in identifying different emotions. In the present study we investigated the role of spatial frequency in identifying happy and sad facial expressions. Two experiments were conducted to investigate (a) the role of specific spatial frequency content in emotion identification, and (b) hemispherical asymmetry in emotion identification. Given the links between global processing, happy emotions, and low frequencies, we hypothesized that low spatial frequencies would be important for identifying the happy expression. Correspondingly, we also hypothesized that high spatial frequencies would be important in identifying the sad expression given the links between local processing, sad emotions, and high spatial frequencies. As expected we found that the identification of happy expression was dependent on low spatial frequencies and the identification of sad expression was dependent on high spatial frequencies. There was a hemispheric asymmetry with the identification of sad expression, especially in the right hemisphere, possibly mediated by high spatial frequency content. Results indicate the importance of spatial frequency content in the identification of happy and sad emotional expressions and point to the mechanisms involved in emotion identification.

Keywords: emotion identification, spatial frequency, hemispheric asymmetry, facial expressions

Emotions are perceived through gestures, voice, and most important, facial expressions. Facial expressions help us to identify the affective state of the individual and decide on behavioral strategies (e.g., approach or avoid). Processing face information depends on many factors, including configural relations and spatial frequency content (Goffaux & Rossion, 2006; Isabelle, Collin, & Jocelyn, 2003). Spatial frequency is a characteristic of luminance variations across space. Different spatial frequencies convey different information about a stimulus. In general, low spatial frequency (LSF) content provides information about the global aspects of a stimulus, and high spatial frequency (HSF) content provides information about local details in a stimulus (Goffaux & Rossion, 2006; Sergent, 1994; Shulman & Wilson, 1987).

What is the role of spatial frequencies in emotion perception? Does identification of different emotions depend on specific spatial frequencies? Some studies have suggested that spatial frequency affects not only face identification, but also the identification of facial expressions. The dual-route model of emotion (LeDoux, 1996) argues for two parallel routes for processing of emotional information: a short quick route, which processes global stimulus features, and a longer slower route that processes more detailed information. Based on the dual-route model, Vuilleumier, Armony, Driver, and Dolan (2003) found larger amygdala activation for low frequency, as compared with high frequency faces with fearful expression. Subcortical pathways including the pulvinar and superior colliculus showed more activation with fearful faces with only LSF content, suggesting a role for the subcortical pathways in providing coarse information (Vuilleumier et al., 2003). Some studies have argued that all emotions are processed in a similar fashion without any effect of LSF (Eimer & Holmes, 2002).

One possible indication of the link between emotion and spatial frequencies comes from studies linking emotions and global–local processing, as well as global–local processing and spatial frequencies. The links between emotions and global–local processing have been motivated by theoretical approaches that have linked differences in scope of attention and processing strategies affected by scope of attention to differences in emotional processing (Frederickson & Branigan, 2005; Srinivasan & Gupta, 2010; Srinivasan & Hanif, 2010; Srivastava & Srinivasan, 2010). For example, broad scope of attention and global processing is linked to happy emotions, whereas narrow scope of attention and local processing is linked to sad emotions (Frederickson & Branigan, 2005; Gasper & Clore, 2002; Srinivasan & Gupta, 2011; Srinivasan & Hanif, 2010). Happy expression preceded by global processing was identified faster as compared with local processing, and vice versa (Srinivasan & Hanif, 2010). Global processing facilitated the identification of faces with the happy expression and local processing facilitated the identification of faces with the sad expression (Srinivasan & Gupta, 2011). Participants experiencing positive emotions, when asked to chose a configuration that is similar to a given target, picked the target at the global level versus a target at the local level, as compared with those experiencing negative or neutral emotional states, suggesting a link between global processing and positive emotions (Frederickson & Branigan, 2005; Gasper & Clore, 2002).

On the other hand, global processing has been linked to LSF and local processing is linked to HSF (Badcock, Whitworth, Badcock,

Devpriya Kumar and Narayanan Srinivasan, Centre of Behavioural and Cognitive Sciences, University of Allahabad, Allahabad, India.

Correspondence concerning this article should be addressed to Dr. Narayanan Srinivasan, Centre of Behavioural and Cognitive Sciences, University of Allahabad, Allahabad 211002, India. E-mail: nsrini@cbcs.ac.in

& Lovegrove, 1990; Lamb & Yund, 1996; Shulman & Wilson, 1987). Electrophysiological data also supports similar findings (Boeschoten, Kemner, Kenemans, & Van Engeland, 2005). These two sets of findings suggest a putative link between emotions, specifically happy and sad, and spatial frequency content. This is also consistent with the LSF content-specific priming effect found with happy faces (Phaf, Wendte, & Rotteveel, 2005).

Another important aspect of emotional, global, and spatial frequency processing is hemispherical asymmetry. With respect to emotions, valence theory assumes that the lateralization of an emotion depends on the valence of the concerned emotion. Negative emotion seems to facilitate processes relying on right hemisphere, and vice versa for positive emotion (Heilman, 1997). Davidson has suggested that approach-related emotions (positive) are attached with processing in the left hemisphere, and withdrawal-related emotions (negative) with the right hemisphere (Davidson, Ekman, Saron, Senulis, & Friesen, 1990). It has also been argued that there is a right hemisphere bias (Alpers, 2008), especially with the processing of negative, but not positive emotions (Hartikainen, Ogawa, & Knight, 2000; Smith & Bulman–Fleming, 2005; Simon–Thomas, Role, & Knight, 2005). For example, negative emotional stimuli primed right hemisphere to benefit performance on the processing of right-hemispheric targets (van Strien & Morpurgo, 1992). Negative distractors interfered more with a simple discrimination task when targets were presented to the left visual field (LVF) or the right hemisphere (Hartikainen et al., 2000) indicating a preferential bias for negative emotions in the right hemisphere. Baijal and Srinivasan (2011) investigating the effects of emotional information on shifts of attention found an asymmetrical interaction attention shifts and emotion across the two hemispheres. They found a right-hemispheric advantage in the capture of attention for sad faces, but no asymmetry was found for happy faces.

Hemispherical asymmetry has also been observed with spatial frequency processing. Sergent (1994) argued that the two hemispheres have a preferential sensitivity to particular spatial frequencies present in the stimuli. He also argued that the left hemisphere is specialized for local (detailed information) processing and right hemisphere is specialized for global processing. The hemispheric difference in visuospatial processing could be linked to asymmetries in spatial frequency processing. Electroencephalographic studies on P300 (a component that is sensitive to attention and expectancy manipulations) have found that it is not affected by spatial frequencies in the right hemisphere (Saunoriute–Kerbeliene, Benson, & Ruksenas, 2001). However, P300 in the left hemisphere shows a significant lag for HSF. Kitterle**,** Hellige, and Christman (1992) suggest that this asymmetry not only depends on the spatial frequency content of the image, but also on the task relevant aspect of spatial frequencies. When the task requires LSF, there is a LVF/right hemisphere advantage. However, when the task requires HSF, there is a right visual field (RVF)/left hemisphere advantage.

In the current study, we investigated the links between spatial frequency content of a face and its effect on emotion perception. Given the putative links between happy emotions, global processing, and LSFs, as well as sad emotions, local processing, and LSFs, we hypothesized that the identification of sad facial expression would be linked to HSF components and happy facial expression would be linked to LSF components in an emotional face. The second experiment investigated the role of hemispheric asymmetries in emotion identification in the context of differing spatial frequency content.

Experiment 1

Previous studies linking global, and local, processing to specific spatial frequency content (Badcock et al., 1990; Boeschoten et al., 2005; Lamb & Yund, 1993; Shulman & Wilson, 1987) as well as specific emotions, that is happy, and sad, respectively (Srinivasan & Hanif, 2010; Srinivasan & Gupta, 2011) perception of happy/sad expressions suggest a specific linkage between spatial frequency content and emotion perception. We hypothesized a greater advantage for the identification of happy expression containing only LSF content compared to HSF content. Similarly, we hypothesized a greater advantage for the identification of sad expression containing only HSF content compared to LSF content. We also expected that the removal of LSFs would result in worse performance for happy expression and removal of HSFs would result in worse performance for sad expression as compared with corresponding expression with broad-band information.

Method

Participants

Eighteen student volunteers from the University of Allahabad (nine females) with normal or corrected-to-normal vision participated in the Experiment.

Stimuli

Fifty-two grayscale full-front pictures of unfamiliar faces with equal number of happy and sad faces were used in the study. All the faces were Indian faces and were taken from a set of pictures that have been rated for valence on a 7-point rating scale from 1 (*very sad*) to 7 (*very happy*). The mean valence for happy faces (5.67) and mean valence for sad faces (2.54) was significantly different, $F(2, 50) = 9.306$, $p < .01$. Out of the 52 faces, 26 were male faces and 26 were female faces. These broad band (BB) faces were resized and were matched for overall luminance. The faces were filtered using Gaussian filters to obtain low-pass filtered (LPF: below 8 cpf) and high-pass filtered (HPF: above 32 cpf) faces (see Figure 1). It has been suggested that the optimal spatial frequency range for face recognition is 8–32 cpf (Goffaux & Rossion, 2006). Given that there are no specific data available on the range of spatial frequencies important for identifying specific facial expressions, we used the same cutoffs used in the Goffaux and Rossion (2006) study. The faces subtended 5° × 6° and were presented on a black background. The stimuli were presented on a 17-in monitor (85 Hz refresh rate; 1024 × 768 resolution) at a viewing distance of 120 cm from the participants and responses were obtained through the keyboard. The stimulus presentation and data collection was performed using DirectRT (Empirisoft Corp., U.S.A.).

Procedure

In a given trial, a fixation point was presented centrally for 150 ms followed by a target face presented at the center for 300 ms.

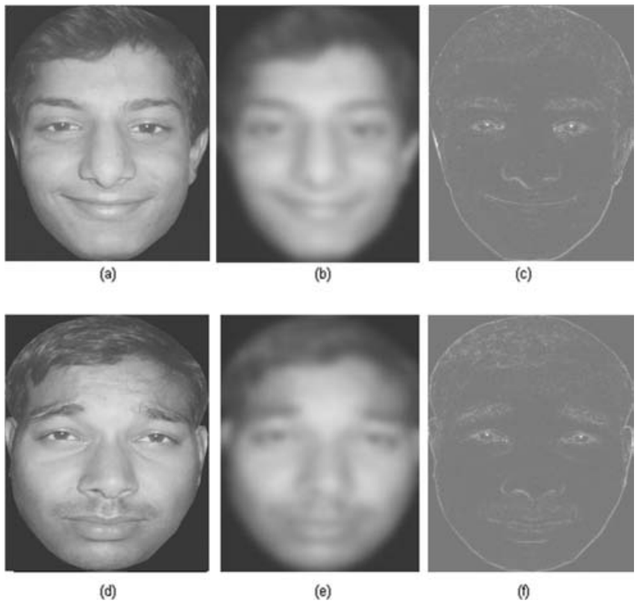

Figure 1. Examples of happy (a) BB, (b) LPF, and (c) HPF faces, and examples of sad (d) BB, (e) LPF, and (f) HPF faces used in the study.

Participants were asked to identify the facial expression in the face (happy or sad) by pressing the right arrow key for happy and left arrow key for sad expression. Each face appeared three times (the BB, LPF, and HPF versions) in the experiment. The experimental session consisted of a total of 156 trials. A practice session of 50 trials preceded the experimental session.

Results and Discussion

Trials exceeding the mean response time by more than two standard deviations (*SD*) in a given condition were excluded from the analysis. Reaction time and accuracy were subjected to a 3 (spatial frequency content: BB, LPF, HPF) $\times$ 2 (emotion: happy, sad) repeated-measures analysis of variance (ANOVA). Data from one participant were not included in the analysis, due to high error rate (greater than 30%).

Reaction Time

Reaction time results are shown in Figure 2. There was a significant main effect of spatial frequency, $F(2, 16) = 21.95$, mean standard error [MSE] = 1484.602, $p < .01$. Post hoc analysis showed that reaction times for emotion identification with BB faces were significantly faster than with the HPF, $t(16) = 9.369$, $p < .001$, and LPF, $t(17) = 4.593$, $p < .05$ faces. Also, emotion identification with the LPF faces were significantly faster than the HPF faces, $t(17) = 4.775$, $p < .05$. The main effect of emotion was significant, $F(1, 16) = 15.509$, $MSE = 4532.733$, $p < .01$ with faster identification of the happy expression as compared with the sad expression.

There was a significant interaction between the spatial frequency content and emotions, $F(2, 16) = 11.891$, $MSE = 1560.408$, $p < .001$. Post hoc comparisons showed that the identification of the happy expression was faster than the sad expression with the BB, $t(16) = 6.89$, $p < .01$ and the LPF, $t(16) = 9.497$, $p < .0001$ faces. This advantage for the identification of happy expression over the sad expression was not present with the HPF faces, $p = 1.0$. With the happy expression, identification was faster with both the BB, $t(16) = 9.88$, $p < .0001$, and the LPF faces, $t(16) = 8.015$, $p < .001$, as compared with the HPF faces indicating the importance of LSFs for identifying the happy expression. The difference between BB and LPF faces was not significantly different for identifying the happy expression. Conversely, the identification of the sad expression with the LPF faces was slower compared to the BB faces, $t(16) = 4.471$, $p = .056$. There was no significant difference between BB and HPF faces in identifying the sad expression, $p = .31$.

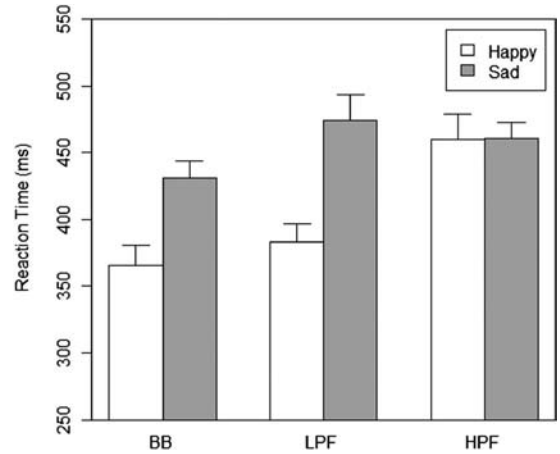

Figure 2. Reaction times for the identification of happy and sad expressions as a function of SF content in Experiment 1.

Errors

Error results are shown in Figure 3. Substantial similarities were obtained with results for errors. There was a significant main effect of spatial frequency content, $F(2, 16) = 11.416$, $MSE = 33.441$,

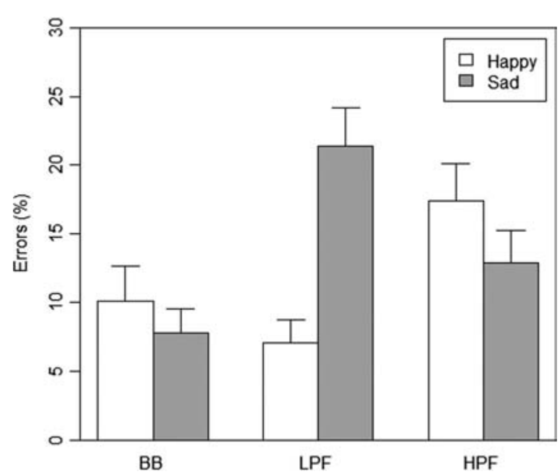

Figure 3. Errors for the identification of happy and sad expressions as a function of SF content in Experiment 1.

$p < .001$. Post hoc analysis showed that there were more errors with the LPF faces, $t(16) = 5.338$, $p < .01$, and the HPF faces, $t(16) = 6.258$, $p < .01$, as compared with the BB faces. The difference in accuracy of identification of the happy and sad expressions was not significant. There was a significant interaction between spatial frequency content and emotions, $F(2, 16) = 13.411$, $MSE = 67.123$, $p < .001$. Post hoc comparisons indicate that error percentage was higher with the LPF sad faces as compared with happy faces, $t(16) = 7.223$, $p < .01$. There was no difference in emotion identification accuracy between BB happy and sad faces, $p = .95$, as well as HPF happy and sad faces, $p = .62$. Emotion-identification performance for the happy expression was better for the LPF faces, $t(16) = 5.181$, $p < .05$, as compared with the HPF faces. In contrast, sad expression identification performance was worse for the LPF, as compared with BB faces, $t(16) = 6.868$, $p < .01$. The difference between sad expression identification for the BB and HPF faces was not significantly different. The difference in identification of sad expression in HPF versus LPF faces, was close to significance, $t(16) = 4.263$, $p = .073$, with better performance with HPF faces as compared with LPF faces, indicating the relative importance of HSFs for sad emotion identification. Once again, the results with errors indicate the importance of LSFs for happy and higher spatial frequencies for sad faces.

Our results suggest that the happy expression is recognized faster than the sad expression. This is consistent with the previous findings indicating an advantage for the identification of the happy compared to the sad expression (Alves, Aznar–Casanova, & Fukusima, 2009; Eastwood, Smilek, & Merikle, 2001; Hitenan & Leppanen, 2004; Kirita & Endo, 1995; Srivastava & Srinivasan, 2010). This advantage for the happy facial expression could be due to the fact that less attentional resources are needed to make this identification (Srivastava & Srinivasan, 2010). Another possible reason is that people might be more familiar (experienced) with happy faces, relative to sad faces, in pictures.

Whereas previous studies have explored the role of spatial frequencies in face recognition (Goffaux & Rossion, 2006), the current study has directly investigated the role of spatial frequencies in the perception of happy and sad expressions. In terms of spatial frequency content, LSFs were more important for perception of happiness in faces. In addition, when HSFs were removed from the face, recognition of sad expression was impaired, suggesting the importance of HSFs in identifying the sad facial expression. The result is also consistent with larger priming effect with LSF happy faces (Phaf et al., 2005). These results further validate the link between happy emotion and global processing, and between sad emotion and local processing (Srinivasan & Gupta, 2011; Srinivasan & Hanif, 2010).

Experiment 2

We investigated the link between spatial frequency and emotion identification in Experiment 1, but in Experiment 2, we investigated the asymmetries in emotion identification as a function of spatial frequency content and visual hemifield. We hypothesized that, similar to Experiment 1, there would be an advantage for the identification of happy expression with only LSF content as compared with HSF content. Similarly, we hypothesized a greater advantage for the identification of sad expression with only HSF content, as compared with LSF content. We also expected that the removal of LSF would result in worse performance for happy expression, and removal of HSF would result in worse performance for the sad expression, relative to corresponding BB faces.

In terms of laterality effects, we predicted that the sad emotion would be identified better when presented in the LVF (right hemisphere), due to the preference for negative emotions in the right hemisphere (Baijal & Srinivasan, 2011). Further, we expected that this right hemispheric bias for sad faces would be greater for the high-pass filtered faces than the low-pass filtered faces, given the reliance of sad expression identification on HSF content. For happy faces, we expected no asymmetry with the BB and HPF faces. Given the preference for low spatial frequency processing in the right hemisphere, a right-hemispheric bias for low-pass faces was expected, especially for the happy facial expression.

Method

Participants

Twenty-seven student volunteers (12 females) from the University of Allahabad with normal or corrected-to-normal visual acuity participated in the study.

Stimuli and Apparatus

Sixty grayscale full-front pictures of unfamiliar faces, with equal number of happy and sad faces, were used in the study. All the faces were Indian and were taken from set of pictures from that have been rated for valence on a 7-point rating scale, with 1 indicating *very sad* and 7 indicating *very happy*. The mean valence for happy faces was 5.68 and mean valence for sad faces was 2.3. The mean valence ratings for happy and sad faces were significantly different. Out of the 60 faces, 30 were male faces and the remaining were female faces. Rest of the details was the same as in Experiment 1.

Procedure

Participants were asked to identify the facial expression (sad or happy) as in Experiment 1. In a given trial, a fixation point was presented at the center for 150 ms followed by a target face presented centrally, at the left or at the right side for 150 ms. The duration was kept at less than 200 ms to ensure that the performance would not be affected by eye movements. The presentation (left vs. right) of the faces was counterbalanced across conditions. Subjects were asked to report the emotional expression displayed by the face. Subjects were instructed to fixate at the central cross at the initiation of trial and give response by pressing a key: right arrow key for happy and left arrow key for sad. The next trial immediately followed as soon as the response was made. There were a total of 50 practice trials and 360 experimental trials. Same face was used in all three conditions: LPF, HPF, and BB faces. Each of these images was presented twice, once in the LVF, and other time in the RVF.

Results and Discussion

Trials exceeding individual mean response time by more than two *SD* in a given condition (6.28% of the total trials) were excluded from further analysis. Data from seven participants were not included in the analysis due to high error rates (greater than 30%). A repeated-measures ANOVA with spatial frequency (high pass, low pass, and broad-band) x Emotion (happy, sad) x Visual field (LVF, RVF) was performed on reaction times and accuracy values.

Reaction Time

Reaction time results are shown in Figure 4. The main effect for spatial frequency content was significant $F(2, 19) = 13.762$, $MSE = 5190.68$, $p < .001$. Post hoc comparisons showed that identification reaction times for BB faces was significantly faster than that for the LPF, $t(19) = 7.404$, $p < .001$ and the HPF faces, $t(19) = 4.122$, $p < .05$. The difference in emotion-identification times for the LPF and HPF faces was close to significance, $p = .077$. The main effect for emotion was significant, $F(1, 19) = 24.803$, $MSE = 8861.92$, $p < .001$ with the happy expression identified faster than the sad expression. The effect for the visual field was not significant, $F(1, 19) = 1.633$, $p = .217$.

The interaction between spatial frequency content and emotion[1] was significant $F(2, 38) = 3.846$, $MSE = 3597.22$, $p < .05$. Post hoc comparisons showed that the happy expression was identified faster than the sad expression with the BB, $t(19) = 6.148$, $p < .01$ and the LPF faces, $t(19) = 9.266$, $p < .0001$. With HPF faces, sad expression was identified faster than happy expression with the difference being close to significance, $p = .13$. The identification of the happy expression was significantly with BB faces as compared with HPF faces, $t(19) = 7.496$, $p < .0001$. As expected, the difference in identification times for the happy expression with BB and LPF faces was not significant, $p = .74$ These results are consistent with the result from Experiment 1 suggesting the importance of LSF information for the identification of the happy expression. The identification of the sad expression in the BB faces was faster relative to both the HPF faces $t(19) = 5.081$, $p < .05$ and the LPF faces $t(19) = 5.06$, $p < .05$. The difference between the identification times for the sad expression in the LPF and HPF sad faces was not significant, $p > .05$.

There was a significant interaction between the visual field and emotion $t(19) = 5.04$, $MSE = 3582.01$, $p < .05$. Post hoc comparison showed an advantage for the identification of the happy expression over the sad expression in both the LVF, $t(19) = 5.59$, $p < .01$ and the RVF, $t(19) = 10.08$, $p < .0001$. The happy advantage was more in the RVF (78 ms) versus the LVF (44 ms). There was no significant difference between the identification of the sad expression in the LVF and RVF. The difference in identification times for the identification of the happy expression in LVF and the RVF was close to significance, $p = .13$.

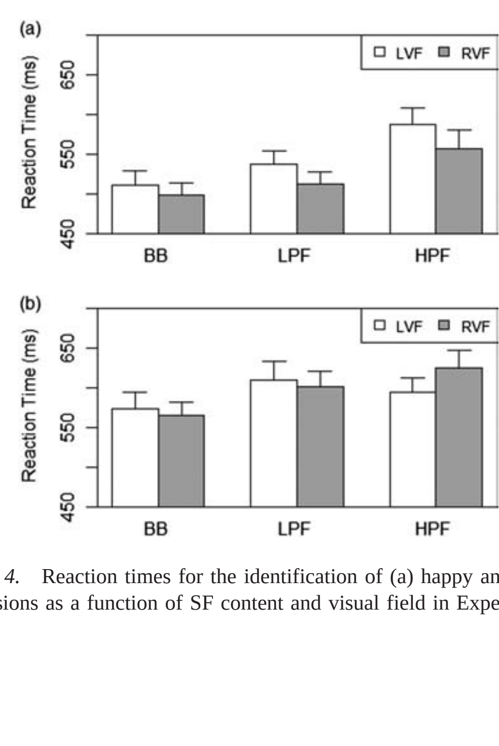

Figure 4. Reaction times for the identification of (a) happy and (b) sad expressions as a function of SF content and visual field in Experiment 2.

Errors

Error results are shown in Figure 5. The pattern of results for errors was similar to the reaction time results. The difference in emotion identification for faces presented in the LVF versus the RVF was close to significance $F(1, 19) = 3.671$, $MSE = 3.952$, $p = .071$ with better identification in the LVF. The main effect for spatial frequency was significant $F(1, 19) = 102.97$, $MSE = 12.745$, $p < .0001$. Emotions in the BB faces were identified more accurately than in the LPF, $t(19) = 4.122$, $p < .05$ and the HPF, $t(19) = 7.4$, $p < .001$ faces. The difference in performance between the LPF and the HPF faces was not significant, $p = .15$. The main effect of emotion was significant with the happy expression identified more accurately than the sad expression, $F(1, 19) = 15.53$, $MSE = 50.762$, $p < .001$.

The interaction between spatial frequency and emotion was also significant $F(1, 19) = 19.25$, $MSE = 41.946$, $p < .001$. The difference in identification performance for the happy and sad expressions was significant only with the LPF faces, $t(19) = 10.522$, $p < .0001$. The difference in identification performance for the happy and sad expressions was not significant for the BB and the HPF faces. With happy expression identification, performance for the HPF faces was significantly worse than for the BB, $t(19) = 8.716$, $p < .0001$, and the LPF $t(19) = 7.077$, $p = .001$. The difference in identification performance with the happy expression between the BB and the LPF faces was not significant. With sad expression identification, performance for the BB faces was better than both the LPF, $t(19) = 10.791$, $p < .0001$, and HPF, $t(19) = 5.932$, $p < .01$ faces. In addition, the identification of the sad expression was better with the HPF than LPF faces, $t(19) = 4.858$, $p < .05$. These results indicate the importance of frequencies above 8 cpf in the identification of the sad expression. The interaction between the visual field and spatial frequency was significant, $F(2, 19) = 5.377$, $MSE = 4.782$, $p < .01$. Post hoc comparisons show that emotions in the BB faces were identified more accurately than emotions in the LPF and the HPF faces in

[1] We also replicated Experiment 1 with contrast balanced images similar to those used in the Aguado, Serrano–Pedraza, Rodríguez, and Román (2010) study. The results were similar to those in Experiment 1 with significant interactions between emotion and spatial frequency content. The two-way interaction between emotion and spatial frequency content was significant for both reaction times, $F(2, 34) = 14.14$, $p < .001$, and accuracy, $F(2, 34)$, 3.614, $p < .05$. The results show that even with contrast balanced images, LSFs are important for identification of happy expression and HSFs are important for identification of sad expression.

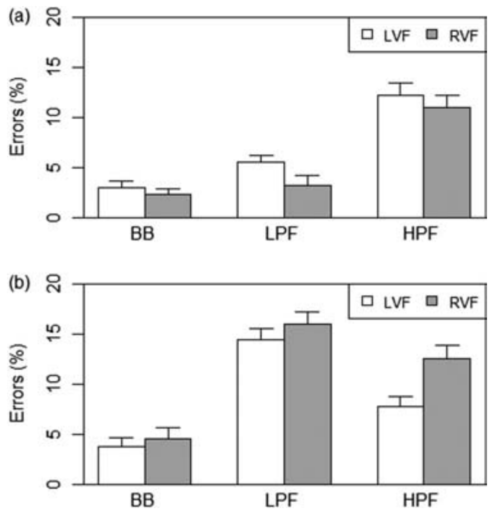

Figure 5. Errors for the identification of (a) happy and (b) sad expressions as a function of SF content and visual field in Experiment 2.

both the visual fields ($p < .00001$). More important, accuracy was better for HPF faces in the LVF, as compared with the RVF, $t(19) = 5.134$, $p < .05$. In addition, the accuracy for emotion identification was better for LPF faces than for the HPF faces in the RVF, $t(19) = 6.29$, $p < .01$. The interaction between the visual field and emotion was also significant $F(1, 19) = 10.339$, $MSE = 20.402$, $p < .01$. Post hoc comparisons showed a significant difference in performance between the identification of the happy and sad expressions in the RVF, $t(19) = 9.432$, $p < .0001$, but not in the LVF, $p = .19$. The identification of the sad emotion was significantly better in the LVF than the RVF, $t(19) = 4.059$, $p < .05$ but there was no asymmetry for happy emotion identification.

We also found a significant three-way interaction between visual field, spatial frequency and emotion $F(2, 19) = 3.326$, $MSE = 8.312$, $p < .05$. Post hoc comparisons for emotion identification between the presentations in the LVF and RVF for all the conditions showed a significant difference only for sad emotion identification with the HPF faces, $t(19) = 7.446$, $p < .001$. This clearly indicates the role of HPF in the hemispheric asymmetry for the identification of sad expression with better performance in the LVF/RH. This is consistent with the preference for sad emotions in the RH (right hemispheric bias).

The pattern of results with spatial frequency content and emotions were similar to that obtained in Experiment 1. Happy expression was identified better and faster than the sad expression. The results from Experiment 2 on the links between spatial frequency content and emotions indicate the importance of LSF for the identification of the happy expression and HSF for the identification of the sad expression.

The presentation of emotional faces in different visual fields in Experiment 2 show the presence of hemispheric asymmetries in emotion identification as a function of emotion as well as spatial frequency content. In terms of emotion identification and hemispheric asymmetry, the happy advantage was more in the RVF (LH) than the LVF (RH). In addition, hemispheric asymmetry was present for the identification of the sad expression with better performance in the LVF (RH) but not for the happy expression. This is consistent with findings that indicate hemispheric asymmetry for sad emotions with better performance in the RH (Alpers, 2008; Baijal & Srinivasan, 2011; Hartikainen et al., 2000; Simon–Thomas et al., 2005; Smith & Bulman–Fleming, 2005; van Strien & Morpugo, 1992). In terms of spatial frequency content, emotion identification was better with HPF faces in the LVF (RH) than the RVF (LH). There was a RVF (LH) advantage for LPF faces relative to the HPF faces, but this was not present in the LVF (RH). Unlike earlier studies (Kitterle et al., 1992; Sergent, 1994), there was no RH advantage for LSF. However, it should be noted that the task is emotion identification and the asymmetries for spatial frequency might be dependent on the nature of the task (Kitterle et al., 1992).

General Discussion

The current study investigated the link between identification of happy and sad emotions in faces and spatial frequency content in those emotional faces. Relatively fewer studies have explored the link between the spatial frequency content of a face and its effects on the processing of emotional information (Vuilleumier et al., 2003; Winston, Vuilleumier, & Dolan, 2003). These studies have mostly focused on fearful faces and have suggested the importance of LSF content in processing fearful faces. The current study has directly investigated the role of spatial frequency content in emotion identification, especially the identification of happy and sad expressions. The results from both experiments clearly indicate that spatial frequency does affect the identification of emotions with LSF content linked to identification of the happy expression, and HSF content linked to identification of the sad expression. In terms of laterality effects in emotion identification, RH was better in identifying the sad emotion, especially with HSF content.

Overall, the happy expression was identified faster than the sad expression. This result is in consistent with previous findings indicating an advantage for the identification of the happy, relative to the sad, expression (Alves et al., 2009; Eastwood et al., 2001; Hitenan & Leppanen, 2004; Kirita & Endo, 1995; Srivastava & Srinivasan, 2010). There are many possible potentially interlinked reasons for the advantage for the identification of happy expression. The preference for happy faces might be linked to different physiological systems used for processing the happy and sad facial expressions (Adolphs, 2002). Differences in attentional processes, and hence resources, with happy faces associated with broad scope of attention or less resources could be responsible for the faster identification of happy faces (Srivastava & Srinivasan, 2010).

The global–happy and local–sad links indicate that the advantage for global processing might be extended to the identification of the happy expression as well. This is also consistent with the dual-route model of emotion (LeDoux, 1996) in which the short quick route processes global stimulus features, and a longer slower route processes detailed information. In addition, the link between happy expression and LSF content could be another reason for the faster identification of happy expression. It has been shown that the response times for LSF are faster than that for HSF stimuli. The faster magnocellular pathway has a better sensitivity to LSF than to HSF. This behavioral study cannot determine whether the advantage for the happy expression is due to the subcortical route or the faster responding LSF channels in the magnocellular pathway that forms part of the cortical route. However, both possibilities are consistent with the faster identification of the happy expression.

The results of the study provide a possible early visual processing mechanism that could mediate the links between emotions and global–local processing. Srinivasan and Hanif (2010) showed that happy emotion identification is linked to global processing and sad emotion identification is linked to local processing. Srinivasan and Gupta (2011) have shown that global processing facilitates the identification of happy faces and local processing facilitates identification of sad faces. The link between happy emotions and global processing as well as sad emotions and local processing is also linked to differences in the scope of attention, with happy emotions associated with broad scope of attention and sad emotions associated with narrow scope of attention (Srinivasan & Gupta, 2010; Srivastava & Srinivasan, 2010). Earlier studies on global–local processing have indicated a link between LSF and global processing and HSF and local processing (Badcock et al., 1990; Lamb & Yund, 1993; Shulman & Wilson, 1987) with the global precedence effect dependent on the LSF present in the stimuli.

The results of the current study are important not only to understand the mechanisms involved in emotion identification, but also to understand the mechanisms involved in emotion–vision and emotion–attention interactions associated with sad and happy emotions. The processing of emotional faces and differences in processing due to different emotions could be attributed to differences in spatial frequencies associated with different visual pathways (magnocellular for LSF and parvocellular for HSF content; Vuilleumier et al., 2003; Bocanegra & Zeelenberg, 2009). In addition, differences in emotions as well as global–local processing could also be associated with differences in scope of attention or attentional "spotlight."

Some studies on face processing indicate dissociation between face recognition and facial expression identification (Calder & Young, 2005; Fox, Oruc, & Barton, 2008). The research on face identification indicates the importance of 8–32 cpf range in identifying faces (Goffaux & Rossion, 2006). Our study has investigated the importance of frequencies below 8 and above 32 in the identification of happy and sad expressions. The results show that a single band of spatial frequencies is not used for emotion identification. Different spatial frequencies might be important for the identification of different emotions. Some aspects of the dissociation in face and emotion identification might be due to the differences in spatial frequency processing associated with faces.

The experimental results regarding hemispherical asymmetry suggest a right-hemispheric bias for processing of sad facial expression. These results are consistent with the general findings that there is a right hemispheric advantage for processing of negative emotions (Ahern et al., 1991; Alpers, 2008; Baijal & Srinivasan, 2011; Hartikainen et al., 2000; Simon–Thomas et al., 2005; Smith & Bulman–Fleming, 2005). This right-hemispheric bias is especially significant for HPF, but not for LPF faces, indicating that the asymmetry observed for emotions is mediated by spatial frequency content of the emotional stimuli. Specifically, the right hemispheric bias observed for the sad emotion identification is mediated by HSF content.

Previous studies regarding asymmetries in spatial frequency processing have reported mixed findings. Many studies have suggested a right-hemispheric advantage for processing of LSF (Saunoriute–Kerbeliene et al., 2001), while other studies have suggested that spatial frequency asymmetry is task dependent (Kitterle et al., 1992; Sowden & Schyns, 2006). The results from our study indicate that LSF faces are processed faster and more accurately than HSF faces. This advantage for processing of LSF faces exists only for RVF (LH) and not for LVF (RH), suggesting a right-hemispheric advantage for HSF content. These results lend support to the idea that spatial frequency processing is dependent on the nature of task and the kind of stimuli used in the experiment, and may be affected by top-down control of spatial frequency processing (Kitterle et al., 1992; Sowden & Schyns, 2006).

The cutoffs that we used in our study were 8 cpf and 32 cpf for the low pass and high-pass filters respectively, which are the cutoffs that have been used in earlier face identification tasks. Vuilleumier et al. (2003) have used a cut-off pf 6 cpf and 24 cpf, for the low pass and high-pass filters, respectively, in their study on emotional expressions with fearful faces. Further studies are needed in order to identify the optimal spatial frequency ranges for emotion identification. We have investigated the identification of happy and sad expressions and it is important to investigate systematically the identification of all emotional expressions as a function of spatial frequency content.

In conclusion, the processing and identification of emotion in a face is mediated by the spatial frequency content, with LSFs facilitating identification of the happy expression and higher spatial frequencies facilitating identification of sad expression. Spatial frequency content is important and point a way for identifying the mechanisms involved in emotion identification, possibly mediated through different visual pathways. Spatial frequency content, more specifically higher spatial frequencies might mediate the hemispherical asymmetry associated with sad emotions.

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