Author(s): Ashok Jansari, Paul Rodway and Salvador Goncalves
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Identifying facial emotions: Valence Specific Effects and an exploration of the effects of viewer gender

Ashok Jansari[1], Paul Rodway[2], and Salvador Goncalves[1]

[1] School of Psychology, University of East London, London, UK
[2] Department of Psychology, University of Chester, UK

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Address for correspondence:
Dr Ashok Jansari
School of Psychology
University of East London
Romford Rd
London E15 4LZ
UK
Tel: +44 (0)20 8223 4943
Fax: +44 (0)20 8223 4937
Email: a.jansari@uel.ac.uk

Abstract

The valence hypothesis suggests that the right hemisphere is specialised for negative emotions and the left hemisphere is specialised for positive emotions (Silberman & Weingartner, 1986). It is unclear to what extent valence-specific effects in facial emotion perception depend upon the gender of the perceiver. To explore this question 46 participants completed a free view lateralised emotion perception task which involved judging which of two faces expressed a particular emotion. Eye fixations of 24 of the participants were recorded using an eye tracker. A significant valence-specific laterality effect was obtained, with positive emotions more accurately identified when presented to the right of centre, and negative emotions more accurately identified when presented to the left of centre. The valence-specific laterality effect did not depend on the gender of the perceiver. Analysis of the eye tracking data showed that males made more fixations while recognising the emotions and that the left-eye was fixated substantially more than the right-eye during emotion perception. Finally, in a control condition where both faces were identical, but expressed a faint emotion, the participants were significantly more likely to select the right side when the emotion label was positive. This finding adds to evidence suggesting that valence effects in facial emotion perception are not only caused by the perception of the emotion but by other processes.

Keywords: Sex differences; Hemispheric asymmetry; Face recognition; Response bias.

Introduction

The valence hypothesis suggests that each hemisphere is differently specialised for processing emotion according to the valence of the emotion, with the right hemisphere (RH) specialised for negative emotions and the left hemisphere (LH) specialised for positive emotions (Ahern and Schwartz, 1985; Davidson & Hugdahl, 1995; Silberman & Weingartner, 1986; Jansari, Tranel & Adolphs, 2000; Adolphs, Jansari & Tranel, 2001). Support for the valence hypothesis comes from the finding that experiencing positive emotions results in greater activation of the LH, whereas experiencing negative emotions results in greater activation of the RH (Davidson, 1992, 1993, 2004; Davidson & Fox, 1982; Jones & Fox, 1992). Similarly, for emotional expression, the RH appears to control the expression of negative emotions and the LH the expression of positive emotions (Ross, Homan & Buck, 1994).

For the perception of facial emotion, however, similar hemispheric valence effects have been less consistently found, with the majority of evidence pointing to a RH specialisation for facial emotion perception (Alves, Aznar-Casanova & Fukusima, 2009; Borod, Andelman, Obler, Tweedy & Welkowitz 1992; Borod, Zgaljardic, Tabert & Koff, 2001; Christman & Hackworth, 1993). Despite this, an increasing number of other studies have obtained valence-specific laterality effects for the perception of facial emotion, with the LH more accurate at perceiving positive emotional expressions and the RH more accurate at identifying negative emotional expressions (Jansari, Tranel & Adolphs, 2000; McLaren & Bryson, 1987; Reuters-Lorenz & Davidson, 1981; Rodway, Wright & Hardie, 2003; Natale, Gur & Gur, 1983; van Strien & van Beek, 2000; for reviews see Borod, 1993; Davidson, 1984; Killgore & Yurgelun-Todd, 2007).

Various accounts have been proposed to explain the emergence of valence-specific effects in facial emotion perception (see Alves, et al. 2009; Borod, 1993; Bourne, 2010; Davidson, 1984; Fusar-Poli, Placentino, Carletti et al., 2009; Killgore & Yurgelun-Todd, 2007; Rodway & Schepman, 2007). In general it is suggested that valence effects emerge because of additional factors, other than the perception of emotion, that are involved in emotion discrimination. These include, for example, the activation of prefrontal cortical regions that are differently lateralised for emotional experience (Borod, 1993; Davidson, 1984; Gur, Skolnic & Gur, 1994), or approach-withdrawal processing (Davidson, 1993; Davidson, 2004; Davidson & Irwin, 1999; see also Demaree, Everhart, Youngstrom & Harrison, 2005). For example, Killgore & Yurgelun-Todd (2007) suggest valence effects are a product of frontal regions that are required for elaborative processing of facial stimuli, to enable discrimination of the emotions, and that the posterior RH is specialised for all facial emotion perception, but more so for negative emotion.

The aim of the present study was to examine whether valence specific effects in facial emotion perception depend upon the gender of the perceiver. Of the studies that have obtained valence effects in facial emotion perception, the majority have obtained the effect for female participants but not male participants (e.g. Burton & Levy, 1989; Rodway et al., 2003; van Strien & van Beek, 2000). In contrast, Jansari et al. (2000) obtained valence specific effects in both males and females and it remains unclear why some studies have obtained the effect only in females. One possibility appears to be that males and females use different perceptual strategies to complete facial emotion discrimination tasks, causing males to be less likely to show valence effects.

Neuroimaging studies have found that males and females use different frontal and sub-cortical regions when perceiving facial expressions of emotion. For example, gender differences in amygdala activation appear to depend on the valence of the emotion, with males showing greater right amygdala activation when perceiving happy expressions and both genders showing increased activation in the left amygdala for sad expressions (Killgore & Yurgelun-Todd, 2001). This suggests that males may be more lateralised in the amygdala than females when perceiving emotions (see also Wager, Phan, Liberzon & Taylor’s, 2003 meta analysis).

Gender differences in levels of hemispheric activation during facial emotion perception have also been found to depend on the valence of the expressed emotion (e.g. Kesler-West, et al. 2001; Lee, et al. 2002). These gender differences are influenced by a number of factors, including the gender of the face expressing the emotion (Fischer, Sandblom, Herlitz, Fransson, Wright, & Blackman, 2004), and the type of emotion task used. For example, Derntl, Finkelmeyer, and Eickhoff et al.,

(2010) found that females showed stronger activation of the right angular gyrus and the left superior frontal gyrus when completing a facial emotion recognition task, whilst for an emotional empathy task, females activated the left inferior frontal region but males activated the middle temporal region. Derntl et al. (2010) suggest that females appeared to use brain regions involved in experiencing an emotion to complete the emotion perception tasks, whereas males used other brain regions possibly involving a more cognitive strategy.

It is therefore apparent, from brain imaging findings, that males and females may show different valence specific effects because of the different neural regions (and strategies) used to perceive emotions. The possibility that females use brain regions involved in emotional experience and empathy, whereas males use a more cognitive strategy, is important because it provides an explanation of why males may be less likely to show valence effects. As suggested by Jansari et al. (2000, p.351), to complete the task used in their study, participants may rely on the ability to empathise "with the emotion depicted in the stimulus", so that lateralised valence effects, in facial emotion perception, may partly derive from the emotional experience subjects generate to identify the emotion. An implication is that if males do not use the brain regions involved in emotional empathy, while perceiving emotional expressions, they may be less likely to show valence effects.

Behavioural studies provide further evidence for gender differences in emotion perception, with females performing better than males when recognising facial emotion (McClure, 2000; Rahman, Wilson & Abrahams 2004), vocal emotion (Voyer & Rodgers, 2002) and non-emotional faces (McBain, Norton & Chen, 2009). Females appear to excel at facial emotion recognition when face identification and discrimination is more difficult (McBain et al. 2009) and the emotions are faint and subtle (Hoffmannlow, Kesslera, Eppela, Rukavinaa & Trauea, 2010). Evidence also suggests that males and females use different perceptual strategies when identifying emotional expressions. For example, Vassallo, Cooper, and Douglas (2009) found that males and females showed different scanning patterns when discriminating facial emotions, with both genders fixating the eye region most often but with males also making more fixations on the nose and mouth. Vassallo et al. suggest that the extra time spent by males fixating non-salient regions such as the nose may cause them to be less efficient at recognising emotional expressions compared to females. However, as it has been found that the nose and mouth are important for recognising "disgust" and "happy" expressions, respectively, and the eyes are particularly important in the recognition of fear (Schyns, Petro, & Smith, 2007), Vassallo et al.'s results also indicate that males spend longer scanning additional facial regions that are important for the identification of particular expressions. Based on these findings a further aim of this study was to examine whether similar gender differences in perceptual strategy emerged when participants completed a lateralised emotion recognition task.

The free viewing task developed by Jansari et al. (2000) which has reliably obtained valence-specific laterality effects was used in this experiment. This task presents two faces until a response is made (rather than brief tachistoscopic presentation), and therefore it was possible to measure eye fixations in males and females as they completed the lateralised emotion recognition task. It was expected that, if gender differences in perceptual strategy underlie gender differences in valence effects, then this would be reflected in the eye fixation data. Based on Vassallo et al.' results it was predicted that males would scan the faces more extensively, making more fixations on a wider range of facial regions.

A final aim of the study was to investigate bias effects that occur when there is no difference between the two facial stimuli presented; this allowed the exploration of possible non-perceptual processes that could be at play. Earlier work has indicated a bias to perceive emotional faces (Davidson, Mednick, Moss, Saron, & Schaffer, 1987; Natale, et al. 1983), cartoons (Dimond, Farrington, & Johnson, 1976), and pictures (Drake, 1987), presented in the right visual field as positive and items in the left visual field as negative (see also Casasanto, 2009). To test this possibility Rodway et al. (2003) presented two identical neutral faces to participants, along with an emotional label (e.g. happy), and required them to select the face they thought best represented the labelled emotion. Although the faces were neutral, a valence specific laterality effect was obtained, with faces presented to the left of centre rated negatively and those presented to the right of centre rated positively. As this finding is relevant to the understanding of valence specific effects in emotion perception (Rodway & Schepman, 2007), an additional aim of the experiment was to extend this finding by including two conditions in which the two faces were identical, but participants had to choose which face matched a given emotional label.

Method

Participants

Forty six right handed participants took part in the study. The sample consisted of 23 males (mean age = 31 ± 12.6) and 23 females (mean age = 34 ± 14.8). The Edinburgh handedness questionnaire (Oldfield, 1971) was used to measure hand preference. Participants had to demonstrate a strong right hand preference to be included in the study; this was defined as use of the right hand at least 75% of the time for the activities listed in the handedness questionnaire. Twenty four participants were recruited from the University of East London and a further 22 from the general population. All subjects gave informed consent to participate in the study. Ethical approval was given by the University of East London Ethics committee. We complied with the Ethical Code of Conduct of the British Psychological Society.

Stimuli

Ekman and Friesen’s (1976) pictures of facial affect were used as stimuli. The faces presented in the experiment were J.J. (male) and P.F. (female). Using the software ‘SmartMorph” (MeeSopht, 2003) six morphs of each face were created by combining the neutral expression with an emotional expression. Two of the emotional expressions were positive (happiness, surprise) and four were negative (fear, sadness, disgust, and anger). For each of the six emotional expressions, three different levels of morphing were used (5%, 10%, and 15%), as more intense facial expressions had been found to produce ceiling effects in discrimination tasks (Jansari et al., 2000).

The 3 morphs for each of the 6 emotional expressions gave a set of 18 morphed expressions for each face (J.J. and P.F.), giving 36 in total. Each expression was presented once on the left of the neutral face and once on the right of the neutral face, giving 72 stimuli. A further 12 slides consisting of two identical double neutral faces and 12 slides with two identical 15% morphed faces were created. For the identical 15% morphed faces the emotion label presented above the faces matched the emotion depicted in the morphed expression.

For one set of stimuli J.J and P.F. had hair, neck and ears, and in a second set these features were excluded so that only facial features were included (see Figure 1). The same morphing and slide production was used for both hair and no hair stimuli. Therefore two different sets of 96 slides were used (192 in total). Each slide image was controlled for size and brightness.

<Figure 1 about here>

Procedure

An IBM compatible computer with a 15 inch coloured screen and standard keyboard was used to present the face stimuli and measure accuracy. The two sets of 96 slides (hair, no hair) were presented in a random order to each participant.

On each trial participants were presented with two faces. The faces were presented side by side, and the participants sat approximately 60 cm from the screen. On the screen, directly above the mid-point between the two faces, a label indicating one of the six emotions was presented simultaneously with the faces. The participants were instructed to select the face which best depicted the emotion corresponding to the emotion label. They were instructed to press ‘Z’ if they thought the emotion face was on the left, and press ‘M’ if they thought it was on the right. These keys were clearly labelled ‘left’ and ‘right’ using a yellow sticker on the keyboard. The faces were presented until participants made a response, after which the stimuli were removed from the screen and then there was an inter-trial interval of 1000 ms. There were 192 trials (92 with hair and 92 without), of which there were 168 experimental trials and 24 control trials (12 double neutral, 12 identical but with a 15% morph corresponding to the label). For the control condition, even though the faces did not differ, the participants were required to select the face which they thought best depicted the emotion label. Participants were instructed to guess if they were unsure.

Eye tracking measure

An eye tracker (ASL EYE-TRAC 5000 with ASI software) was used to record the eye movements of 24 of the participants as they completed the emotion discrimination task. The sample consisted of 12 males (mean age = 31.7) and 12 females (mean age = 27.4) all of whom had normal vision.

Eye fixations in six areas of interest (AOI) were measured. The areas of interest were the hair, forehead, eyes (left-eye and right-eye), nose, and mouth. These were chosen because research has demonstrated the importance of the eyes, nose, and mouth (Schyns et al., 2007; Blais, Jack, Scheepers, Fiset, & Caldara, 2008; Vassallo et al., 2009) and forehead (Knoll, Attkiss, & Persing, 2008) in the perception of emotional expressions. The hair was also included to examine whether participants (and males in particular) had a tendency to fixate a region which was not informative for the perception of facial emotion. Because there were two faces in each slide, 12 areas of interest were measured. Fixations were defined as 0.5 of a second continuous look (or longer) at an area of interest. A fixation ended when three sequential data samples (equivalent to 60 ms) were more than one degree from an initial fixation position. We adopted the 0.5 second criterion to provide an unambiguous measure of the regions of the face that participants examined in detail when identify an emotional expression. We believed this criterion enabled the exclusion of relatively brief fixations at an AOI that were made as participants scanned from one face to the other face (or between areas of interest) and that may not have been involved in analysing facial emotion (e.g. brief fixations while planning a saccade). This criterion was also adopted because research suggests that fixations at AOI during facial emotion identification tasks are, on average, substantially longer than 500 ms. For example, in Vassallo et al.'s study, which used unambiguous emotional expressions presented centrally, the average duration of fixations at AOI ranged from 1000 ms to over 2000 ms. As the emotional expressions used in the free view task were extremely subtle, and fixation duration increases with task demands (Jacob & Karn, 2003) and varies according to task (e.g. Guo, Mahmoodi, Robertson, & Young, 2006), we expected average fixation duration at AOI to be longer than those obtained by Vassallo et al. The mean fixation score for each participant was averaged across the three morph levels and calculated according to emotion (positive, negative) and whether the emotional face was on the right side or on the left side.

Results

An initial analysis including hair vs. no hair conditions found that there was no difference in accuracy of emotion identification for stimuli with hair and stimuli without hair (stimuli with hair 65.1%, without hair 64.9%). The presence or absence of hair did not interact with any other factor and therefore the data from the hair/no-hair conditions was pooled and dropped as a factor in subsequent analyses. The mean accuracy data (averaged across the three levels of morphing) for the male and female participants as a function of valence, side of presentation of correct face (hereafter referred to as 'side'), and facial region, is presented in Table 1.

<Table 1 about here>

A 2 X 2 X 2 [participant-gender (male, female), valence (positive, negative), side (left, right)] ANOVA was performed on participants' mean accuracy scores. Participant-gender was between-subject factor while valence and side were within-subject factors.

The analysis produced a significant main effect for valence, F(1, 44) = 5.61, p < .02, $\eta 2$ =.113, with positive faces more accurately identified than negative faces (66% vs. 61%). There was no main effect of side, F(1,44) = 1.29, p = .26, $\eta 2$ =.029.

A significant two-way interaction was obtained between valence and side, F(2, 44) = 15.22, p < 0.0001, $\eta 2$ = .26, with participants more accurately identifying negative emotions when presented on the left (mean = 65%) than on the right (mean = 58%) and more accurately identifying positive emotions presented on the right (mean = 72%) than on the left (mean = 60%) (see Figure 2). Further analyses for valence revealed that for positive emotions the effect of side was significant, F(1,44) = 15.08,

$p < .003$, $\eta 2 = .25$, with greater accuracy at identifying positive emotions on the right than on the left. Similarly, for negative emotions, the effect of side was significant, $F(1,44) = 4.87$, $p < .033$, $\eta 2 = .1$, with greater accuracy at identifying negative emotions when on the left than on the right. Thus, the two-way interaction was due to significantly more accurate detection of positive emotions on the right side than on the left side, and significantly more accurate detection of negative emotions when on the left side than the right side (see Figure 2).

<Figure 2 about here>

Control task

Two separate, 2 x 2 (participant-gender x valence of label) mixed ANOVAs were carried out, one on the double neutral and one on the double-15% pairs, on the tendency to select the right or left side in the presence of positive and negative emotion labels. There was no effect of emotion label for the double neutral condition, $F(1, 44) = .01$, $p = .93$, $\eta 2 = .0001$, with the participants' tendency to select the right or left face uninfluenced by the emotion label (right side selected 50.5% when the label was positive and 50% when label was negative). However, for the double 15% condition there was a significant effect of the emotion label, $F(1, 44) = 7.41$ $p < .01$, $\eta 2 = .144$, with participants selecting the right side more than the left side when the label was positive (right 63%, left 37%). When the label was negative, however, there was no greater tendency to select the left side than the right side (right 49%, left 51%: see Figure 4). The interaction between valence of label and participant-gender did not reach significance $F(1, 44) = 3.5$, $p > .05$, $\eta 2 = .073$.

<Figure 3 about here>

Eye-tracker analysis

The mean fixation data (averaged across the three levels of morphing) for the male and female participants, as a function of valence, side of presentation, and facial region, is presented in Table 2.

<Table 2 about here>

A 2 X 2 X 2 X 6 [participant-gender (male, female), valence (positive, negative), side presented (left, right), region (hair, nose, left-eye, right-eye, nose, lips, forehead)] mixed ANOVA was conducted on the mean fixation data. Participant-gender was a between-subjects factor and all other factors were within-subjects.

This revealed a significant main effect of participant-gender, F(1, 22) = 5.6, $p < .05$, η2 = .20, with male participants making more fixations than female participants (male = .52. female = .32). This indicates that the males looked longer while identifying the emotions. There was also a main effect of side, F(1, 22) = 66, $p < .001$, η2 = .75, with more fixations made to faces on the left side than on the right side. It is possible that the participants examined the left face for longer than the right face, because they tracked from left to right as they completed the task, or because the RH is specialised for emotion perception (see Figure 4); this issue is explored further in the Discussion. There was also a significant interaction between side and participant-gender, F(1,22) = 7.28, $p < .013$, η2 = .25. Both the females, F(1,11) = 25.47, $p < .0003$, η2 = .70, and the males, F(1,11) = 40.22, $p < .0005$, η2 = .78, made more fixations to the face on the left side than the face on the right side, but the males did this to a greater extent than the females.

<Figure 4 about here>

A significant main effect of region was also obtained, F(1, 22) = 8.7, $p < .01$, η2 =.26. Bonferroni-corrected pair-wise comparisons showed that significantly fewer fixations were made to the hair than to the left-eye, right-eye, nose and forehead ($p = .01$) and that the left-eye was significantly more fixated than the right-eye ($p = .025$) (see Figure 5). The greater number of fixations on the eyes replicates previous findings and demonstrates the importance of the eyes in enabling emotion identification. The greater time spent on the left-eye might indicate a tracking strategy from left to right.

<Figure 5 about here>

There was a significant 2-way interaction between side and region, $F(1, 22) = 4.8$, $p < .01$, $\eta 2 = .18$. For the left side (with Bonferonni correction) the number of fixations on the hair was significantly less than the number of fixations for the left-eye ($p = .003$), right-eye ($p = .001$), nose ($p = .007$), and forehead ($p = .004$). Therefore when looking at the face on the left side the participants were looking at several regions but spending little time looking at the hair (see Figure 5). This reiterates the lack of importance of head hair in emotion identification demonstrated in the accuracy data. In contrast, for the right side, there were significantly more fixations for the left-eye compared to the right-eye ($p = .006$) and hair ($p = .006$), and the nose had significantly more fixations than the right-eye ($p = .039$). It appears that after making more fixations on the left face participants became more selective as they fixated the right face, concentrating predominantly on the left-eye and, to a lesser extent, the nose.

A two-way interaction between valence and participant-gender was obtained, $F(1, 22) = 5.7$, $p < .025$, $\eta 2 = .21$. For positive emotions, there was a significant effect of participant-gender, $F(1, 22) = 7.67$, $p < .05$, $\eta 2 = .26$, with males making more fixations than females (.56 vs .29). For negative emotions, however, the effect of participant-gender did not reach significance, $F(1, 22) = 2.65$, $p = 0.12$, $\eta 2 = .11$, with females making fewer fixations than the males (males =.49, females = .36) but not significantly so.

Discussion

This study investigated the effects of gender of perceiver on the valence-specific laterality effect in facial emotion perception. The main finding was, as predicted, a valence specific laterality effect, with the accuracy of identifying positive and negative facial emotions influenced by the side of presentation. The valence-specific laterality effect did not depend upon the gender of perceiver. Finally, positive emotions were also more accurately identified than negative emotions, replicating the findings of previous studies (Hugdahl, Iverson & Johnsen, 1993; Jansari et al. 2000; Rodway et al. 2003; see Leppanen and Hietanen, 2004, for a discussion of this effect).

The results replicate Jansari et al.'s (2000) findings, but only partly replicate those of Rodway et al. (2003), where a valence specific effect was obtained in female participants but not male participants. Other studies have also obtained valence effects for females and not males (Burton & Levy, 1989; van Strien & van Beek, 2000). Therefore, while the effect of gender has been inconsistent, the valence effect has been obtained in three studies using the free viewing task and three different stimulus sets. Based on these findings it appears that the effect is reasonably robust, is present in males and females, but it is unclear why gender differences in valence laterality effects have emerged across studies.

A reason why gender differences in valence effects may have emerged is suggested by the eye fixation data. Males made significantly more fixations than the females, particularly for the positive emotions, which supports the view that males and females may use different perceptual strategies when completing the emotion discrimination task. These results correspond with those of Vassallo et al. (2009) who found that males made significantly longer fixations than females when identifying facial emotions. However, as the criterion for a fixation was set at a 0.5 second continuous look at an area of interest in our experiment, it remains possible that females made more brief fixations than males as they scanned the faces more extensively. This cannot be discounted, but is perhaps unlikely given the average duration of fixations obtained in Vassallo et al.'s study ranged from 1000 ms (nose region) to 2000 ms (eye region), and that study used expressions of facial emotion that were unambiguous. It is possible that the average fixation duration, for the very subtle expressions used in our experiment, was even greater than those obtained by Vassallo et al. and that the females may not have made significantly more brief fixations.

It is clear that the greater number of fixations made by males for positive emotions, was not due to the positive emotions being harder to identify in general, and that some other factor must be causing this effect. It can be speculated that if positive emotions elicit a stronger emotional experience in the viewer than negative emotions (Wild, Erb & Bartels, 2001), and females use this emotional experience when identifying facial emotions as an additional source of information (e.g. Derntl et al. 2010), then females may need fewer (or briefer) fixations than males to identify the face that expresses the faint positive emotion.

The results of this study show that less frequent valence effects in males are not caused by a female superiority (at least in terms of accuracy) in face perception. Males and females have shown similar levels of accuracy across three studies even though females have more consistently shown the effect. It is interesting to note, however, that while males and females did not differ in accuracy on the free viewing task, they show differences in performance when completing other facial emotion discrimination tasks (e.g. McBain, et al. 2009) which have often measured RT in addition to accuracy. We did not measure RT in this study because it was designed to be purely a free view task, emphasising accuracy and not RT. However, it is possible that differences in performance would emerge if RT and accuracy were both measured, and that males might be maintaining an equivalent level of accuracy by taking longer to make the discrimination. Indirect evidence for this is provided by the fact that the males made more fixations, suggesting that they took longer to identify the face expressing the emotion. Therefore, it would be useful for future studies to measure both RT and accuracy so that levels of performance in males and females can be examined, and also whether a speed-accuracy trade-off has contributed to some studies obtaining valence-specific effects in females but not males.

The eye tracking data showed that participants spent more time fixating the face on the left, than the face on the right, indicating that for a greater proportion of time the RH was receiving the facial information. Whether this bias to look to the face on the left is determined by a tendency to track from left to right, or the greater specialisation of the RH in facial perception, is unclear. The data suggest that in the free viewing task the two hemispheres are not being used equally to discriminate the emotions. When given the choice of two faces to examine, the participants favour using the RH to examine the emotional content of the face on the left. To some extent, therefore, the results produced by the free viewing task might be a product of the natural tendency to use a particular hemisphere (the right) for facial perception, rather than an absolute measure of each hemisphere's perceptual abilities.

The eye tracking data also suggest the importance of the eye region for emotion discrimination, which concurs with other work (Keating & Keating, 1982). However, because a control condition consisting of a neutral face was not used in the present study it is possible that similar fixations on the eye region might have been present with neutral faces. Therefore, while these results correspond to other studies that have examined eye tracking during emotion discrimination (e.g. Vassallo et al., 2009), and the results show the regions the participants fixate while completing the emotion discrimination task, it is possible that these fixation patterns are not specific to discriminating emotions.

Research has shown that different facial regions vary in the extent to which they contribute to the identification of specific emotions (Schyns et al., 2007; see also Calvo & Nummenmaa, 2008), and when identifying emotions people start by examining the eyes and move down the face to the nose and mouth (Schyns et al., 2007). The greater number of fixations on the eye region found in this study might be a product of the tendency to start with the eyes. It was also found that participants became more selective and tended to focus on fewer regions, such as the eyes and nose, when they looked at the face on the right. This might have been due to participants reaching a decision by primarily looking at the face on the left, and then looking at specific regions of the face on the right, when they needed additional information to identify a particular emotion.

The greater time spent fixating the left-eye is of particular interest, with the left-eye receiving most fixations and the left-eye in the right face fixated as often as the right-eye in the left face (see also Butler & Harvey, 2006; Alpers, 2008). If this left-eye preference was due solely to a left to right tracking strategy it might be expected that the right-eye in the left face would receive more fixations than the left-eye in the right face. This pattern was not present in our data. As the left-eye preference was present for the face on the right it shows, for the first time, that it reflects a consistent tendency to look at the left-eye irrespective of a face's location. Finally, as Gilbert and Bakan (1973) found that Hebrew speakers (who read from right to left) still exhibited a left-sided bias on judgements of facial identity, it seems possible that the left side preference obtained in this study reflects lateralised facial perception processes, rather than habitual scanning strategies.

The bias toward the left-eye extends other research showing that there is a tendency to look at the left side of the face when judging facial expressions (Burt & Perrett, 1997). Several studies have also shown that a bias to look at the left side of a face is not specific to judgements of facial emotion, and generalises to a wide range of face perception tasks, including gender discrimination (Burt & Perrett, 1997), identity perception (Gilbert & Bakan, 1973), and judgements of age and attractiveness (see Alpers 2008; Guo, Meints, Hall, Hall & Mills, 2009). Moreover, other species such as rhesus monkeys look to the left side of a face when looking at upright human faces (Guo et al., 2009). The perceptual bias toward the left side of a face might be relevant to some of the conflicting findings in the literature. Facial emotion studies that have used the Chimeric Faces Test (where one half of the face expresses an emotion and the other half is neutral) have consistently shown that emotion perception is more influenced by the left side than the right side of a face. These results have been interpreted as demonstrating a RH dominance in the perception of all emotions (Bourne, 2008). If the left side of a face is examined when perceiving facial emotion, it could mean that there will be a RH advantage for the perception of all facial emotions, because the facial information is being directed to the RH because of the left-face bias. In contrast, in tachistoscopic experiments (e.g. Reuter-Lorenz & Davidson, 1981) and the free view task, the facial information may be more likely to go to the LH (for a greater proportion of the time) when presented in the right visual field, enabling differences in each hemisphere's role in valence perception to emerge. While this is speculative, it is a potential reason why a RH superiority in facial emotion perception has been obtained using the Chimeric Faces Test (e.g. Bourne, 2010), but tachistoscopic studies and the free view task have obtained evidence of valence-specific hemispheric differences in emotion perception.

An interesting finding of the present study is that for the control condition, when both faces had a neutral expression, there was no response bias, but when the identical faces possessed a faint (15% morphed) emotion, the participants selected the right side when the label was positive and were unbiased when the label was negative. This raises the possibility that lateralised valence effects in emotion perception are not necessarily solely caused by the lateralised perception of different emotions, but instead by a response bias, because in this case the two faces were perceptually identical (Rodway et al. 2003).

There are several possible causes of this response bias (see Rodway et al. 2003 for a discussion). For example, Casasanto's (2009) body specific hypothesis proposes that from interacting with the world, people form particular associations between their bodies and spatial choices they make in their environment. Casasanto suggests that because right-handers respond more to their environment with their dominant right hand they learn to associate the right side of space with positive attributes. In support of this hypothesis Casasanto found, using a two location forced choice task, that right handers were more likely to place items with positive attributes (e.g. a good animal) in a box on the right, and items with negative attributes in a box on the left. It is therefore possible that such an association could underlie the response bias obtained in this experiment. However, if a pre-learned association caused the response bias it would be expected to be present in both the double neutral, and double 15% conditions, which was not the case in the present experiment. As the response bias was only obtained in the 15% morph it indicates that it might originate from the faint emotion activating the hemisphere that is specialised for that particular emotion (e.g. RH for negative, and LH for positive emotion).

The modified valence hypothesis (Borod, 1993; Davidson, 1984), suggests that posterior regions of the RH are specialised for the perception of all emotions, but that regions of the prefrontal cortex are asymmetrically specialised according to valence to deal with emotional expression and experience. If valence-specific prefrontal regions are activated by the faint emotion expressed by the two 15% morphs, perhaps by a contagion effect (e.g. Wild et al. 2001), or because subjective experiences of an emotion are generated in the prefrontal cortex during emotion perception (e.g.

Heberlein, Padon, Gillihan, Farah & Fellows, 2008), then it could cause the response bias. For example, two faint positive faces might activate left frontal regions more than right frontal regions, because of the left frontal region's specialization in positive emotion. As hemispheric activation is believed to cause attention to be directed towards the contralateral visual field (Kinsbourne, 1970), this activation could then make the choice of a face on the right side more likely when the faces are expressing a positive emotion. By the same process, activation of prefrontal right regions could make a left side choice more likely in response to two faces expressing a negative emotion.

To summarise, the current study replicated valence specific effects obtained in previous work. It was found that valence effects emerge irrespective of the gender of the participant. However, the eye tracking data indicate that studies should measure RT in addition to accuracy because males and females may use different strategies when making the emotional discrimination. The eye tracking data also suggest the importance of the eye region, and the left-eye in particular, in enabling facial emotion discrimination. Finally, the modified valence hypothesis (Borod, 1993; Davidson, 1984) could explain the response bias obtained in this study by suggesting that a faint emotion can asymmetrically activate valence-specific prefrontal regions involved in an emotional experience (e.g. Heberlein et al. 2008). This activation could then bias attention toward the side of space contralateral to the activated hemisphere, making a right-side choice more likely following LH activation, and a left-side choice more likely after RH activation. An important issue left unanswered is why the response bias in the current study occurred only when the label was positive. A hypothesis worthy of future investigation is that, when emotions are faintly expressed, it is due to positive emotions being more contagious than negative emotions[1]. It is therefore clear that the robust valence effect has got a number of dimensions to it which can help elucidate how the brain processes facial emotions.

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