Neuropsychologia 48 (2010) 1289–1294

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Examining the sex difference in lateralisation for processing facial emotion: Does biological sex or psychological gender identity matter?

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ARTICLE INFO

Article history:
Received 22 September 2009
Received in revised form
15 December 2009
Accepted 17 December 2009
Available online 29 December 2009

Keywords:
Emotion lateralisation
Chimeric faces test
Biological sex
Psychological gender identity
Hormonal exposure

ABSTRACT

The research examining sex differences in functional lateralisation has shown varying results. While some provide evidence for males being more strongly lateralised than females, a number have shown either no relationship or the opposite pattern of findings. In this study we consider whether psychological gender identity might clarify some of the conflicting results in this area of research. Eight five participants (39 males) aged from 18 to 49 years old were tested. We found that psychological masculinity was associated with stronger patterns of lateralisation for the processing of a range of emotional expressions. We also found an interaction between biological sex and psychological gender identity, with a positive relationship between psychological masculinity and lateralisation found for males, but a negative relationship found for females. The possible role of hormonal exposure in this relationship is discussed.

1. Introduction

The issue of whether there are sex differences in lateralisation for cognitive processes is currently a hotly debated topic. While evidence in support of a difference tends to show that males are more strongly lateralised than females (e.g., Bourne, 2005, 2008), a large amount of evidence has shown no sex difference (e.g., Sommer, Aleman, Bouma, & Kahn, 2004; Sommer, Aleman, Somers, Boks, & Kahn, 2008) and some research has even shown the opposite sex difference with females being more strongly lateralised than males (e.g., Obleser, Eulitz, Lahiri, & Elbert, 2001). In this paper we revisit this issue by examining strength of lateralisation for processing facial emotion across all six of the basic emotional expressions. Specifically, we consider sex differences both in terms of a person's biologically determined biological sex, and their psychological gender identity, in terms of their more psychological masculinity and femininity.

Probably the most extensively examined lateralised cognitive process, certainly in terms of the sex differences literature, is language processing. Additionally, this is also the area in which there are the most conflicting sources of evidence. Studies using varying methodologies have supported the idea that males are more strongly lateralised to the left hemisphere than females for language processing. Divided visual field studies have found that males are more strongly lateralised on a phoneme detection task (Cousin, Perrone, & Baciu, 2009) and a lexical decision task with semantic priming (Van Dyke et al., 2009). This has also been shown in an event related potential (ERP) study of word reading (Hill, Ott, Herbert, & Weisbrod, 2006) and in functional magnetic neuroimaging (fMRI) studies (e.g., Kansaku, Yamaura, & Kitazawa, 2000).

The opposite pattern of sex differences has also been reported, with females being more strongly lateralised than males. This was found in a magnetoencephelography (MEG) study of vowel processing (Obleser et al., 2001). However, a divided visual field study of both phonological and semantic processing skills found that females were only more strongly lateralised within left handed participants (Tremblay, Ansado, Walter, & Joanette, 2007). In spite of this evidence for sex differences in lateralisation for language processing, a great number of studies have failed to find such differences. Chiarello et al. (2009) found no sex differences in the anatomical size of the regions of the brain involved in language and only very little evidence for small behavioural laterality effects. Meta-analyses have also failed to find sex differences in both fMRI (Sommer et al., 2004, 2008) and dichotic listening studies (Sommer et al., 2008).

Clements et al. (2006) conducted an fMRI study of both phonological and visuospatial processing to consider whether possible sex differences in lateralisation might be consistent across different cognitive abilities. For the phonological processing task they found that males were more strongly lateralised to the left hemisphere than females, supporting the typical sex difference in lateralisation. However, for visuospatial processing the opposite pattern

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doi:10.1016/j.neuropsychologia.2009.12.032

was found with females being more strongly lateralised to the right hemisphere than males. Njemanze (2007) also found that the sex difference in lateralisation varies across different cognitive functions. In a study measuring cerebral blood flow using functional transcranial Doppler spectroscopy (fTCDS) they found that males were lateralised to the right hemisphere for face processing, whereas females were lateralised to the left hemisphere. When processing objects, men were lateralised to the right hemisphere, but there was no hemispheric bias for the women. Again though, not all studies have found sex differences. In an fMRI study of both language and face processing, Haut and Barch (2006) found no sex differences. Boles (2005) examined a wide range of cognitive functions using the divided visual field methodology and found little evidence for sex differences in lateralisation. On average Boles found that sex could only account for 0.09% of the variability in lateralisation and that at best it was able to account for 0.9% of variability.

Studies of sex differences in cognitive functions lateralised to the right hemisphere, such as visuospatial and face processing have tended to provide somewhat more convincing evidence. Rilea, Roskos-Ewoldsen, and Boles (2004) and Rilea (2008b) found that males were more strongly lateralised than females on a mental rotation task. However in another study Rilea (2008a) showed that females were more strongly lateralised for mental rotation of alphanumeric stimuli. Georgopoulos et al. (2001) also found opposite patterns of lateralisation in an fMRI study using an object construction task with males having more activation in the right hemisphere and females having more activation in the left hemisphere. The same pattern was found for activation in the amygdala during both emotional memory (Cahill, Uncapher, Kilpatrick, Alkire, & Turner, 2004) spatial memory (Frings et al., 2006) tasks. Frings et al. attributed this difference to women using more verbal, left hemisphere, strategies to help them achieve the task. This suggestion fits well with previous work also suggesting that sex differences in lateralisation may be explained in terms of sex differences in cognitive strategies (Welsh & Elliott, 2001).

Sex differences have also been examined in lateralisation for face processing. Although the evidence is weak for the processing of facial identity (e.g., Kampf, Nachson, & Babkoff, 2002; Voyer, 1996), rather more convincing evidence has been presented for the processing of facial emotion. Using the chimeric faces test, we have previously shown that males are more strongly lateralised to the right hemisphere than females for processing positive facial emotion (Bourne, 2005, 2008; Bourne & Todd, 2004). This finding has also been supported by ERP studies of the processing of facial emotion (Proverbio, Brignone, Matarazzo, Del Zotto, & Zani, 2006) and emotional stories (Gasbarri et al., 2006). However, Gasbarri et al. (2007) found that the P300 ERP response to negative emotional images was larger in the right hemisphere in men and larger in the left hemisphere in women.

While there is some convincing evidence for there being sex differences in lateralisation, particularly with males being more strongly lateralised than females, there is also equally convincing evidence against it. In this study we re-examine whether there might be sex differences in lateralisation for processing emotion and expand on our previous work in two ways. First, in our previous work we only looked at lateralisation for processing positive facial emotion (i.e., happiness). There are currently two competing theories regarding the lateralisation of emotion processing: the right hemisphere hypothesis (Borod, 1992), which proposes that the processing of all emotion is lateralised to the right hemisphere, and the valence hypothesis (Davidson, 1992), which proposes that the processing of positive emotion is lateralised to the left hemisphere and the processing of negative emotion is lateralised to the right hemisphere (see Bourne, in press). To address this limitation, in the current study we measured strength of lateralisation for the processing of all six of the basic emotions: anger, disgust, fear, happiness, sadness and surprise.

Second, in this experiment we have expanded our consideration of sex difference by examining both biological sex (i.e., male vs. female) and psychological gender identity (i.e., psychological masculinity vs. psychological femininity). Previous work looking at various cognitive processes has shown interactions between biological sex and psychological gender identity in terms of performance. For example, Ritter (2004) found that psychologically feminine men performed better than psychologically masculine men on a verbal processing task, on which women generally outperform men. In this study the Bem Sex Role Inventory (Bem, 1974) will be used to assess psychological masculinity and femininity. This is one of the most frequently used psychometric measures of psychological gender identity and has been used in a large number of psychological studies. It is possible that psychological gender identity might be a mediating factor in the biological sex difference in lateralisation for face processing. It is predicted that the biological sex difference in lateralisation will be become more apparent by taking into account psychological gender identity. Specifically, it is predicted that people who have higher psychological masculinity will be more strongly lateralised than those who are psychologically feminine.

The main aim of this paper is to understand the variability in lateralisation reported in previous work. While biological sex has been considered, the role of psychological gender identity has not. Of particular importance is to understand the relationship between these two variables. While biological sex differences have been reported in lateralisation (e.g., Bourne, 2005, 2008), there is still a fair amount of variability in lateralisation that remains to be explained. One possibility is that this additional variance may be explained, at least to some extent, in terms of psychological gender identity. Alternatively, the biological sex difference itself might be better explained in terms of psychological gender identity, the two factors might interact with each other or they may each explain variability in lateralisation in varying and distinct ways. For example, Weekes, Zaidel, and Zaidel (1995) and Weekes, Capetillo-Cunliffe, Rayman, Iacoboni, and Zaidel (1999) found different relationships with lateralisation on a dichotic listening task for biological sex and psychological gender identity. The data will be analysed using regression modelling to test for the different possible relationships between lateralisation, biological sex and psychological gender identity. Biological sex and psychological gender identity will be simultaneously entered into the model; consequently the variable which best explains the variability in lateralisation will be most significant. The interaction between biological sex and psychological gender identity will also be entered into the model.

2. Methods

2.1. Participants

There were 85 participants (39 males) with a mean age of 25 years (SD = 7.4, range 18–49). The participants were undergraduate psychology students who were recruited through a experimental participation scheme. All participants were right handed by self-report and this was confirmed with a handedness questionnaire (adapted from Dorthe, Blumenthal, Jason, & Lantz, 1995). None reported any previous neurological damage or psychiatric diagnosis. This study was given approval by the Ethics Committee of the School of Psychology, University of Dundee.

2.2. Chimeric faces test

In this study we used six versions of the chimeric faces test to test for strength of lateralisation across the basic emotions: anger, disgust, fear, happiness, sadness and surprise. There were 24 trials for each emotion. These were presented in blocks and block order was randomised across participants. The experiment was run on a computer using Superlab version 4.1. Participants were seated centrally in front of the computer monitor and a chin rest was used to ensure that the stimuli were presented in the centre of the participant's visual field and to maintain a viewing distance of 52 cm.

Table 1
Descriptive statistics, for all participants and for males and females separately, and one-sample *t*-tests (across all participants) for the six versions of the chimeric faces test.

	Males (N = 39)		Females (N = 46)		All participants (N = 85)		
	Mean	SD	Mean	SD	Mean	SD	
Anger	.19	.48	.11	.55	.15	.52	2.6*
Disgust	.23	.54	.08	.53	.15	.54	2.6*
Fear	.34	.50	.17	.60	.25	.56	4.1**
Happiness	.29	.60	.17	.57	.23	.59	3.6*
Sadness	.23	.38	.23	.35	.23	.36	5.9**
Surprise	.37	.59	.16	.59	.25	.60	3.9**

* $p < .010$.
** $p < .001$.

The stimuli were those used by Workman, Chilvers, Yeomans, and Taylor (2006) made from the original Ekman emotive faces (Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). One male face and one female face were used and stimuli were presented in greyscale on a white background. The chimeric faces comprised vertically split half faces in which one half was neutral and the other half emotive. These faces were presented in pairs, one above the other, with one face showing emotion in the viewer's left visual field and the other face showing emotion in the viewer's right visual field. Each face subtended approximately 4.5° horizontally and 7° vertically at a viewing distance of 52 cm.

Pairs of chimeric faces were presented to participants. In half of the trials the face expressing emotion in the viewer's left visual field was presented as the higher stimulus and in the other half it was presented as the lower stimulus. This presentation was randomised across participants. For each trial participants had to select either decide which face they thought looked more emotive (i.e., angrier on the angry block of trials) by pressing either the upper button on a response pad for the upper face or the lower button on a response pad for the lower face. The faces remained on screen until a response was made and participants were encouraged to respond as instinctively as possible.

Laterality quotients were calculated for each emotion on the basis of the responses made by participants (for full details on this calculation see Bourne, 2008). Laterality quotients ranged from −1 through to +1. A score of −1 indicated always choosing the face with the emotion expressed in the viewer's right visual field, and therefore a left hemisphere bias. A score of +1 indicated always choosing the face with the emotion expressed in the viewer's left visual field, and therefore a right hemisphere bias.

2.3. Psychological gender identity

Psychological masculinity and femininity were measured using the Bem Sex Role Inventory (Bem, 1974). This is a sixty item questionnaire in which participants are asked to rate the extent to which particular character traits described themselves on a 7-point Likert scale ranging from 1 (never or almost never true) to 7 (always or almost always true). There were twenty masculine items, twenty feminine items and twenty neutral items. Scores for the masculine and feminine items were averaged for each scale separately giving each participant a psychological masculinity and psychological femininity score. For both scales, higher scores indicated being more masculine or feminine.

2.4. Statistical analyses

Initial analyses examined biological sex differences in psychological gender identity using independent *t*-tests. One-sample *t*-tests were then used to examine lateralised biases on the chimeric faces test by comparing laterality quotients to 0 (i.e., no bias). It is predicted that scores will be significantly higher than 0, indicating a right hemisphere bias. The main analyses used multiple regression.

Table 3
Summary of the regression analyses for all six versions of the chimeric faces test. R^2 is given as the percentage of variance explained by the overall model.

	Anger	Disgust	Fear	Happy	Sad	Surprise
Overall model						
R^2	8.1	7.4	11.9	13.6	13.9	18.0
F	1.4	1.3	2.1	2.5	2.5	3.5
p	.236	.285	.070	.039	.035	.007
Biological sex						
β	3.0	2.0	2.0	3.9	2.7	4.5
t	2.1	1.4	1.4	2.5	2.9	2.9
p	.036	.177	.180	.014	.006	.008
Psychological masculinity						
β	0.6	0.7	0.9	1.1	0.6	1.0
t	1.9	2.1	2.6	3.0	2.6	2.7
p	.068	.044	.012	.004	.011	.008
Psychological femininity						
β	0.6	0.1	0.1	0.5	0.4	0.7
t	1.5	0.4	0.1	1.3	1.7	1.8
p	.141	.728	.970	.207	.091	.068
Biological sex × psychological masculinity						
β	−0.4	−0.5	−0.6	−0.7	−0.4	−0.7
t	−2.0	−2.1	−2.7	−3.0	−2.9	−3.1
p	.053	.040	.009	.004	.004	.003
Biological sex × psychological femininity						
β	−0.3	−0.1	0.1	−0.2	−0.2	−0.3
t	−1.1	−0.1	0.5	−0.8	−1.2	−1.3
p	.258	.962	.642	.462	.237	.183

Biological sex, psychological masculinity, psychological femininity, the interaction between biological sex and psychological masculinity and the interaction between biological sex and psychological femininity were entered as predictors of laterality quotient. Six separate regressions were conducted, one for each analysis. Significant interactive predictors were broken down by statistically comparing the correlation between laterality quotient and psychological gender identity measure for males and females.

3. Results

There was a significant biological sex difference in psychological masculinity scores ($t(83) = 5.6$, $p < .001$) with higher scores for males ($M = 5.0$, SD = .6) than females ($M = 4.3$, SD = .6). There was also a significant biological sex difference in psychological femininity scores ($t(83) = 1.7$, $p = .050$) with higher scores for females ($M = 4.8$, SD = .5) than males ($M = 4.6$, SD = .5). These analyses confirm the expected biological sex differences in psychological gender identity with males tending to be more psychologically masculine and females tending to be more psychologically feminine. One-sample *t*-tests found that all six versions of the chimeric faces test showed a significant left visual field bias, indicating right hemisphere dominance for processing facial emotion (see Table 1).

Zero-order correlations are given in Table 2 and a summary of the regression analyses are given in Table 3. The overall model statistics were not significant for anger and disgust, was approach-

Table 2
Zero-order correlations showing the relationship between gender identity and laterality quotients for all participants and for males and females separately.

	All participants (N = 85)		Males (N = 39)		Females (N = 46)	
	Psychological masculinity	Psychological femininity	Psychological masculinity	Psychological femininity	Psychological masculinity	Psychological femininity
Anger	.022	.077	.203	.271*	−.193	−.028
Disgust	.094	.037	.254	.078	−.168	.051
Fear	.100	.080	.333*	.080	−.197	.133
Happiness	.093	.113	.346*	.225	−.216	.060
Sadness	−.061	.120	.217	.288*	−.347**	−.016
Surprise	.010	.078	.223	.314*	−.367**	−.043

* $p < .050$.
** $p < .010$.

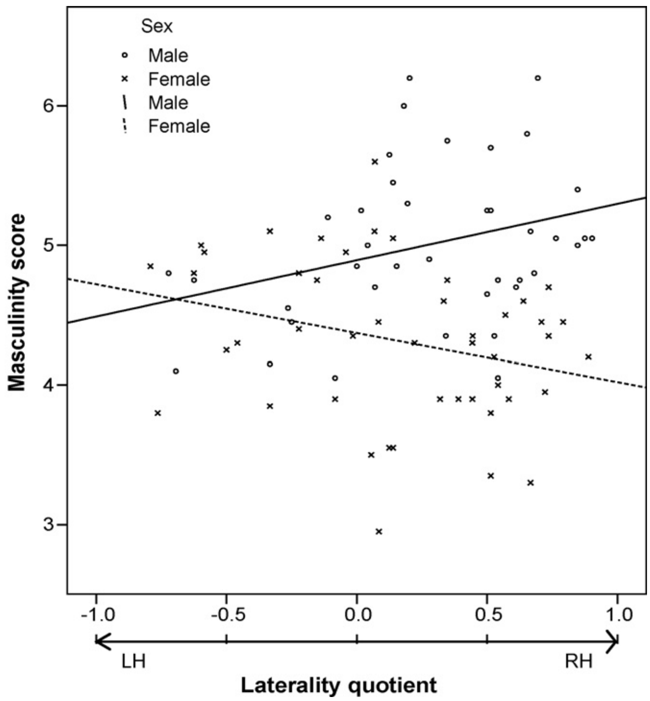

Fig. 1. Scatterplot showing the relationship between laterality quotient (averaged across all six emotions) and psychological masculinity for males and females separately.

ing significance for fear and was significant for happiness, sadness and surprise (see Table 3).

The full statistics for the individual predictors and interactions are given in Table 3. Biological sex was a significant predictor of strength of lateralisation for anger, happiness, sadness and surprise. For all, males were more strongly lateralised than females. This trend was also apparent for disgust and fear although the result was not significant. Psychological masculinity was a significant predictor of lateralisation for all six emotions, although for anger the result was only approaching significance. The same relationship between psychological masculinity and strength of lateralisation was found for all six emotions: the higher the psychological masculinity score, the stronger the right hemisphere bias for processing facial emotion. Psychological femininity was not a significant predictor of lateralisation.

The interaction between biological sex and psychological masculinity was a significant predictor of lateralisation for all six emotions (see Table 3); however the interaction between biological sex and psychological femininity was not. Inspection of the zero-order correlations in Table 2 shows a clear difference in the relationship between lateralisation and psychological masculinity for males and females. For the males this relationship is always positive, and significant for fear and happiness. This indicates that, for males, the more psychologically masculine you are the more strongly lateralised you are for processing facial emotion. For the females the relationship is always negative, and significant for sadness and surprise. This indicates that, for females, the more psychologically masculine you are the less strongly lateralised you are for processing facial emotion. A statistical comparison of the correlations for males and females showed that they were significantly different for all six emotions: anger ($z = 1.8$, $p = .038$), disgust ($z = 1.9$, $p = .029$), fear ($z = 2.4$, $p = .008$), happiness ($z = 2.6$, $p = .005$), sadness ($z = 2.6$, $p = .005$), and surprise ($z = 2.7$, $p = .003$). Given that the relationship was the same across all six emotions, this is shown in a scatterplot (see Fig. 1) showing the mean laterality quotient against psychological masculinity scores for males and females separately.

4. Discussion

The main finding of this study is that people who are more psychologically masculine are more strongly lateralised for the processing of both positive and negative emotions. This fits well with the previous research showing that males are more strongly lateralised than females (e.g., Bourne, 2005, 2008), a result that we also replicated within this study. It therefore seems that both being chromosomally male and being psychologically masculine are associated with being more strongly lateralised. In order to explain this finding it is important to consider the possible explanations for why there is variability, and particularly sex differences, in brain organisation.

Geschwind and Galaburda (1985) proposed that sex differences in lateralisation occurred due to the differential hormonal exposure in males and females. They suggested that testosterone is implicated in the development of cerebral lateralisation and that the higher levels of testosterone in males can explain their stronger patterns of lateralisation. The possible effects of prenatal testosterone exposure have also been examined using 2D:4D ratio as an estimator of levels of prenatal testosterone. Lower 2D:4D ratios are associated with higher levels of prenatal testosterone exposure (Manning, Scutt, Wilson, & Lewis-Jones, 1998) and this relationship has been shown in both humans (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004) and rats (McMechan, O'Leary-Moore, Morrison, & Hannigan, 2004; Talarovičová, Krskova, & Blazekova, 2009). Given the relationship between testosterone exposure and 2D:4D ratios, it is perhaps unsurprising that a large number of studies have found that males tend to have lower 2D:4D ratios than females (e.g., Manning, Churchill, & Peters, 2007; Putz, Gaulin, Sporter, & McBurney, 2004). 2D:4D ratio has been associated with asymmetry of hand skill (Fink, Manning, Neave, & Tan, 2004) and have also been found to predict stronger patterns of lateralisation in women using the chimeric faces test (Bourne & Gray, 2009). This finding provides strong support for higher levels of prenatal testosterone exposure being associated with stronger patterns of lateralisation, even in women.

Levels of testosterone have also been associated with psychological gender identity, typically with higher levels of testosterone being correlated with higher levels of psychological masculinity. For example, children have been found to prefer more psychologically masculine stereotyped forms of play if they have lower 2D:4D ratios (Alexander, 2006; Honekopp & Thierfelder, 2009). The same finding has been reported for girls with congenital adrenal hyperplasia (Auyeung et al., 2009) and women with polycystic ovary syndrome (Manlove, Guillermo, & Gray, 2008), who have increased levels of testosterone. Associations between 2D:4D and cognitive skills have also been shown. Both men and women with more masculine 2D:4D ratios are better at visuospatial processing, which usually shows a male advantage (Collaer, Reimers, & Manning, 2007). Males who have more feminine 2D:4D ratios tending to have higher scores on cognitive abilities that typically show a female advantage (e.g., location memory, spatial working memory and anxiety; Evardone & Alexander, 2009). Hormonal exposure, and particularly higher levels of prenatal testosterone exposure, has been associated with both stronger patterns of functional lateralisation and higher levels of psychological masculinity. It is possible though that there is not a direct relationship between psychological gender identity and strength of lateralisation, but rather that hormonal exposure is a causal factor for both. In order to fully test this possibility all four factors, hormonal exposure (2D:4D), psychological gender identity, biological sex and lateralisation would need to be examined within the same study.

Although we found a main effect of a relationship between psychological masculinity and lateralisation, we also found a biological sex difference in this relationship. For males, high levels of psychological masculinity were associated with stronger patterns of lateralisation. However, for females, the opposite pattern was found with high levels of psychological masculinity being associated with weaker lateralisation, or even lateralisation to the left hemisphere for the processing of facial emotion. Our finding of a biological sex difference in psychological gender identity effects has also been shown in other studies of cognitive processing. For example, Evardone and Alexander (2009) only found a relationship between psychological "gender" (as measured by 2D:4D ratio) and cognitive style in males. It is clear that possible interactions between psychological gender identity and biological sex require further examination, both in terms of lateralisation and more general cognitive processing.

One interesting way of interpreting the interaction between biological sex and psychological masculinity is that there might be a congruency effect. That is, when biological sex and psychological gender identity are congruent (i.e., psychologically masculine males and psychologically un-masculine females), strong lateralisation to the right hemisphere is found. However, when biological sex and psychological gender identity are incongruent (i.e., psychologically un- masculine males and psychologically masculine females), atypical lateralisation is found. It would be particularly interesting to examine this possible congruency effect in more detail, especially in light of the research on cognitive abilities and functional lateralisation in individuals with psychological gender identity disorders.

In this study we primarily found a relationship between psychological masculinity and lateralisation. However there was some evidence of a relationship between psychological femininity and lateralisation within the analyses. Inspection of the zero-order correlations presented in Table 2 shows significant positive correlations between psychological femininity and lateralisation for processing anger, sadness and surprise in males only. This shows that males who are more psychologically feminine are more strongly lateralised for processing these emotions. Again, this finding is difficult to reconcile with the idea that psychological masculinity is associated with stronger patterns of lateralisation and requires further examination.

Two points can also be raised in relation to the tests of lateralisation that we used in this study. First, for all six emotions we found a significant right hemisphere bias. This finding supports the right hemisphere theory of emotion lateralisation, rather than the valence hypothesis (see Bourne, in press). We also found that males were more strongly lateralised than females across all six of the emotions, although this effect did not reach significance for disgust and fear. However, our finding of biological sex differences across a range of both positive and negative facial expressions of emotion replicates our previous work in this area showing biological sex differences in lateralisation for positive facial emotion (Bourne, 2005, 2008) and expands upon it to show the sex difference for a range of negative facial emotions too. Second, although we used a range of emotive faces, all six versions of the test showed right hemisphere dominance. It is not possible to tell from this study whether the interaction between biological sex and psychological gender identity is specific to functional lateralisation for processing facial emotion, more generally associated with right hemisphere function, or whether it would be replicated for left hemisphere functions, or even tests of interhemispheric transfer.

It is also important to consider the implications of our measurement of psychological gender identity using the Bem Sex Role Inventory (Bem, 1974). One of the key criticisms of this measure is that gender roles have changed since its original inception and consequently that some of the items no longer effectively discriminate between masculine and feminine traits (see Colley, Mulhern, Maltby, & Wood, 2009; Holt, 1998; Wilcox & Francis, 1997). However, the Bem Sex Role Inventory is one of the most frequently used measures of psychological gender, and within our sample the expected biological sex differences in masculinity and femininity were found. There are alternatives that may have been used. Examination of 2D:4D ratio is sometimes used as a measure of gender identity, with low 2D:4D ratios indicating masculinity and we have previously reported a relationship between 2D:4D ratio and lateralisation (Bourne & Gray, 2009). Measurement of hormonal levels may also have provided an alternative measure of gender identity, with higher levels of testosterone indicating masculinity. Alternatively, lateralisation could have been contrasted in participants of differing sexual orientations (Rahman, Cockburn, & Govier, 2008). It is quite likely that all four possible measures (psychological gender identity, sexual orientation, prenatal and current hormonal levels) would be highly correlated and it may be preferential to include multiple measures in future studies.

This study provides the first evidence for a relationship between psychological gender identity and lateralisation for processing facial emotion, further to this it also shows an interaction between biological sex and psychological gender identity. In the discussion of this finding we have suggested that hormonal exposure is likely to provide a strong causal explanation for this relationship. The interaction between biological sex, psychological gender identity, lateralisation and hormonal exposure requires further research in order to try to decompose these interrelationships.

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