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RUNNING HEAD: Lateralization & emotion discrimination

Sex differences in the relationship between children's emotional expression discrimination and their developing hemispheric lateralization

Dawn Watling

And

Victoria J. Bourne

Royal Holloway, University of London

Correspondence should be addressed to Dawn Watling, Department of Psychology, Royal Holloway, University of London, Egham Hill, Egham, Surrey, TW20 0EX, UK. Email: *Dawn.Watling@rhul.ac.uk,* Telephone: +44 (0) 1784 443706, Fax: +44 (0) 1784 434347.

Abstract

Strength of lateralization for processing facial emotion becomes more right hemisphere lateralized throughout childhood, but sex differences in this development are not currently understood. This study examines patterns of lateralization for emotion discrimination in 185 6-10 year olds. Strength of right hemisphere lateralization was stronger in the older children, and right hemisphere dominance emerged at around age 8. Children who were more strongly lateralized performed with greater accuracy on a behavioral test of emotion discrimination and this relationship was significant for boys but not girls, demonstrating that there is a relationship between lateralization and performance (particularly, the discrimination of emotions).

KEYWORDS: hemispheric lateralization, emotion recognition, chimeric faces, sex differences

1. Introduction

An individual's ability to quickly recognize and understand the emotions of others is an important tool in developing and maintaining positive social interactions. Facial expressions are one tool which individuals often will use to judge the attitude and/or feelings of another (Cunningham & Odom, 1986) and to guide one's behavior (Gao & Maurer, 2009). Researchers have traditionally used static images (2 dimensional posed) and have demonstrated that infants are able to discriminate between emotions and children from a young age are able to recognize facial expressions of emotion (see Herba & Phillips, 2004, for a review). Additionally, researchers have found that there is a right hemisphere advantage in emotional processing (e.g., de Haan, Nelson, Gunnar, & Tout, 1998; Saxby & Bryden, 1985) which develops during childhood (Workman, Chilvers, Yeomans, & Taylor, 2006). There is currently little understanding of the relationship between the ability to process facial emotion and the neuropsychology underlying these processes and whether there are individual differences in this relationship (for a review of this area, see Watling, Workman, & Bourne, 2012). This research examines the development of this relationship and whether there are sex differences.

Children's ability to recognize the 'basic' facial emotions (i.e., happiness, sadness, anger, fear, disgust, and surprise) has been widely explored. Research has demonstrated that emotion recognition accuracy differs for each emotion and with age. One of the earliest emotions recognized is happiness. In fact, Reinenbach and Masters (1983) found that children as young as 4 years old were fairly accurate at identifying happiness (85%), while identification of sadness and anger were much lower (62% and 56%, respectively). More recent work by Durand, Gallay, Seingeuric, Robichon, and Baudouin (2007) has found that children are able to accurately discriminate, at a level similar to adults, happiness and sadness by around 5 to 6 years old, while fear was at 7 years old, anger was at 9 years old, and disgust was at 11 years old. Therefore, researchers tend to consistently find that children first recognize happy facial expressions earliest, followed by sad or angry facial expressions, then surprise or fear facial expressions, and disgust.

Researchers have attempted to explain the development of emotion processing in different ways and have particularly focused on individual differences in children's social experiences, such as exposure to emotional displays (Gordon, 1989) and levels of expressivity in the home (e.g., Camras et al., 1990). However, recent research has examined the maturation of the brain. One such line of investigation has focused on the development of brain lateralization for emotion processing; specifically, research with adult participants has explored how emotion is processed in the brain. Some researchers found evidence that emotions are processed using both hemispheres (e.g., Adolphs, Jansari, & Tranel, 2001; Davidson, Shackman, & Maxwell, 2004); however, the majority of evidence suggests that the right hemisphere is dominant for emotion processing (e.g., Ashwin, Wheelwright, Baron-Cohen, 2005; Bourne, 2005).

One widely used behavioral test of lateralization is the chimeric faces test (CFT; Bourne, 2010; Levy, Heller, Banich, & Burton, 1983). Much of the research using chimeric faces has explored the processing of happiness. Kucharska-Pietura and David (2003) validated the CFT with patients, who had unilateral brain lesions. Emotional chimeric faces are formed from an emotive half face and a neutral half face. Two versions are created that are mirror images of each other with the emotive half presented in either the left or the right half face. When presented with these face pairs participants are asked to judge which of the two chimeric faces looks more emotive (e.g., happier). Findings show a strong bias towards the face with emotion in the left visual field (LVF) indicating a right hemisphere bias. They found that both non-clinical and left hemisphere lesion patients viewed images as more emotional when the emotion was portrayed in the LVF of the chimera, indicating a right hemisphere processing dominance for emotion. However, the right hemisphere lesion patients were significantly less likely to show this LVF bias. These findings have been replicated by Bava, Ballantyne, May, and Trauner (2005) with children who have congenital unilateral brain damage.

Hemispheric lateralization is expected to emerge during childhood, with two competing views to explain when it occurs: the invariant viewpoint and the progressive viewpoint (see Boles, Barth, & Merrill, 2008). In brief, according to the invariant viewpoint hemispheric lateralization is well-established by 2 years old with later developments occurring only due to plasticity of the brain, while according to the progressive viewpoint hemispheric lateralization occurs throughout the period of childhood. Research exploring the development of laterality for processing emotions tends to support the progressive viewpoint. Researchers have used the CFT to explore children's lateralization for emotion processing from 4 years old (e.g., Bava et al., 2005; Levine & Levy, 1986; Watling & Bourne, 2007; Workman et al., 2006). Studies demonstrate that while younger children are weakly lateralized for emotion processing, between 4 and 10 years children become increasingly lateralized to the right hemisphere, and lateralization at 10 years old does not significantly differ from that of adults (Levine & Levy, 1986). Workman et al. (2006) further demonstrated that the developmental trajectory for emotion processing differed for the six basic emotions between 5 and 11 years old, with happiness and sadness lateralized for emotion processing earliest.

While it is clear that the lateralization of emotion processing develops through childhood, it is not clear if there is a relationship between the neuropsychological (strength of lateralization) processing of emotions and the ability to recognize or discriminate between emotions. Given that the same developmental trends have been found for the neuropsychological and the behavioral recognition of emotions, it seems likely that they are associated. To date, the relationship between laterality for emotion processing and the ability to discriminate between emotions has not been explicitly examined, however two studies have examined if there is a relationship between the development of lateralization for emotion processing and social-emotional understanding. Workman et al. (2006) found significant positive relationships between children's (5- to 11-year-olds) right hemisphere processing of emotions and their ability to judge what emotion is depicted in a set of eyes, as well as their ability to judge what emotion a protagonist would be feeling after being given situational information. This was particularly true for the 5- to 6-year-olds. Furthermore, Watling and Bourne (2007) found that 10-year-olds ability to recognize that a protagonist would hide his/her actual feelings for self-presentational reasons from his/her audience was positively related to their right hemisphere laterality for processing emotions; no such relationship was found with the 6- and 8-year-olds. These studies indicate that there are relationships between children's hemispheric processing of emotions and their social-emotion understanding and that these links change with age.

In addition to examining the developmental trajectories for the strength of lateralization for emotion processing and the ability to discriminate between emotions, we will also consider possible sex differences in these relationships as sex differences in adults have been reported for both aspects. Hampson, van Anders, and Mullin (2006) showed adult males and females photographs of emotionally expressive faces and found that females were faster than males for processing facial emotion. A more recent study also found that females are more accurate for processing facial emotion, but this was only for more subtle emotional expressions (Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010). Although the adult evidence suggests that females are better than males at processing emotional faces, the evidence from children is rather more mixed. In a meta-analysis of 58 studies that explored the processing of facial emotion in infants, children, and adolescents, girls were found to be better at recognizing emotions (McClure, 2000). However, other researchers have found the female advantage for emotion recognition in children to be either minimal (Herba, Landau, Russel, Ecker, & Phillips, 2006) or no sex difference at all (De Sonneville, Verschoor, Njiokiktjien, Op het Veld, Toorenaar, Vranken, 2002).

There is evidence supporting sex differences in various aspects of the strength of lateralization for emotion processing in adults. Research using the chimeric faces test has found that males are more strongly lateralized than females (Bourne, 2005, 2008) and that this stronger pattern of lateralization is exaggerated in males who are highly masculine (Bourne and Maxwell, 2010). This sex difference in lateralization has also been found using alternative methodologies and emotion processing tasks. Studies recording event related potentials have also found that males are more strongly lateralized to the right hemisphere than females (females were bilateral in their neurophysiological responses; e.g., Proverbio Brignone, Matarazzo, Del Zotto, & Zani, 2006).

The finding that males are more strongly lateralized than females is relatively well established in adults but this relationship has not yet been replicated in children (e.g., Levine & Levy, 1986; Watling & Bourne, 2007; Workman et al., 2006). In the present study, sex differences in lateralization for processing emotion and the ability to discriminate between emotions will both be examined. More importantly, the possible sex difference in the relationship between lateralization and emotion discrimination will be considered. In summary, while previous research has suggested a relationship between the development of socio-emotional skills and emotion lateralization, none has examined the development of the relationship between emotion recognition and emotional lateralization. In this research we expect that children who are more lateralized to the right hemisphere for emotion processing will have greater accuracy in recognizing positive (happy) emotions across different age groups through childhood. Additionally, as males tend to have a stronger strength of lateralization for emotion processing, we expect that the aforementioned finding will be present for boys but not girls, where boys' strength of lateralization of emotion processing will be related to performance and girls will not.

2. Methods

2.1 Participants

One-hundred and eighty-five children from three British urban primary schools in Southeast England participated in this study. There were fifty-seven 5- to 6-year-olds (M(SD) = 6.25 (.33), range = 5.25 – 6.83, 29 females), sixty-one 7- to 8-year-olds (M(SD) = 8.31 (.27), range = 7.85 – 8.82, 31 females), and sixty-seven 9- to 10-year-olds (M(SD) = 10.27 (.29), range = 9.73 – 10.79, 40 females). This study was approved by the Department of Psychology Ethics Committee prior to data collection beginning. Parents received information about the study and were able to opt for their child not to participate. Participants were also verbally told about the project and assented to participate and were ensured all their responses were confidential. All participation was voluntary and participants were advised they could stop or withdraw at any time during the data collection.[1]

2.2 Materials

Two tasks (see below) were presented to children in the form of a multimedia presentation using Runtime Revolution software on a laptop computer, which included the simultaneous presentation of the task instructions both verbally (through headphones) and in written format. Children used the mouse to register their responses.

2.2.1. Chimeric faces task. The chimeras used in this task were developed by Workman et al. (2006). The chimeric faces were created from grayscale Ekman pictures of males and females with neutral or happy facial expressions. The pictures were split down the middle and an emotional expression picture would be merged with a neutral expression picture. Two faces are presented simultaneously, one above the other. One face when merged has the positive expression in the viewer's left visual field (LVF) and a neutral expression in the right visual field (RVF), while the second face when merged is the mirror image of the first (i.e., has the positive expression in the RVF and the neutral expression in the LVF). Each face subtended approximately 7.65° horizontally and 11.40° vertically. The distance between the two faces was 0.35°. There were eight trials and presentation was randomized within each emotion block. Children were asked to concentrate on the faces that were to be presented and to decide which face looked happier. Children responded by clicking on the picture that they have chosen. Placement of the pictures was in the centre of the computer screen, with the cursor placed in the middle of the two pictures so that any upward movement would allow the children to click on the top face and any downward movement would allow them to click on the bottom face. The pictures stayed on the screen until the children responded. Laterality quotients were calculated that ranged from -1 (always choosing the face with the happy expression in the RVF indicating left hemisphere dominance) to +1 (always choosing the face with the happy expression in the LVF indicating right hemisphere dominance).

2.2.2. Emotion discrimination task. Using Ekman faces (the same stimuli used for the chimeric faces task), children were presented with a full face expressing one of four emotions (happy, sad, angry, and fear). Four full faces were chosen to represent each emotion. Faces were presented in the centre of the screen. Each child would see the four target images (happy faces) and two non-target images for each of the three negative emotions (sadness, fear, anger; randomly selected by the computer program). In total there were 10 items (four target items and six distracter non-target items).

Before each trail an 'X' fixation point appeared prior to the image in the location which corresponded to the bridge of the nose. The 'X' remained for 500 ms then disappeared. The image (either a target or non-target image) then appeared and remained on screen for 1500 ms. After the image disappeared from the screen two buttons became visible showing "Happy" and "Not Happy". Children clicked on the response button to indicate their choice and then the next trial began.

2.3. Design and Procedure

Children were seen in groups of 1 – 5, each seated in front of a laptop computer with their individual set of headphones on in a quiet room. The experimenter ensured that the children were not able to view the screen of any other child (e.g., may be sitting in a circle, backs to each other). The computer program randomized the presentation order of the two tasks.

3. Results

3.1. Analysis of emotion discrimination scores

Emotion discrimination scores, measured as proportion of happy faces accurately discriminated, were analyzed using a 3 (age group: 6-, 8- or 10-year-olds) x 2 (sex: male, female) independent measures design ANOVA. Neither the main effect of sex, F (1, 179) = 1.6, p = .208, partial η^2 = .009, nor the interaction between sex and age group, F (2, 179) = 0.5, p = .511, partial η^2 = .007, were significant. There was a significant main effect of age group, F (2, 179) = 4.5, p = .013, partial η^2 = .048. Helmert contrasts showed that the youngest age group was significantly less accurate (see Table 1) than the 8- and 10-year-old children, p = .003, whereas there was no significant difference in accuracy between the two older groups of children, p = .933. The significant difference between 6- and 8-year-olds suggests an improvement in the ability to discriminate happiness from other (negative) emotions between these ages.

3.2. Analysis of emotion laterality quotient

One-sample t tests were used to compare laterality quotients to 0 (i.e., no laterality bias; see Table 1). Overall the mean laterality quotient was 0.128 (SD = 0.47) showing a significant right hemisphere bias for processing facial emotion, t (184) = 3.7, p < .001. This significant right hemisphere bias was found for both boys, t (84) = 2.1, p = .042, and girls, t (99) = 3.1, p = .002. There was no significant laterality bias for the 6-year-olds, t (56) = 0.2, p = .810, but there was a significant right hemisphere bias for both 8-year-olds, t (60) = 2.8, p = .008, and 10-year-olds, t (66) = 3.6, p = .001.

Table 1. Descriptive statistics summarizing emotion discrimination and emotion laterality quotients for each age group and by sex.

			Emotion discrimination		Emotion lateralization	
		N	Mean	SD	Mean	SD
Boys	6 year olds	28	.830	.24	-.018	.42
	8 year olds	30	.950	.12	.108	.42
	10 year olds	27	.926	.19	.213	.48
Girls	6 year olds	29	.897	.24	-.009	.41
	8 year olds	31	.944	.12	.234	.54
	10 year olds	40	.962	.09	.206	.49
All participants		185	.922	.17	.128	.47

Laterality quotients for processing faces expressing happiness were analyzed using a 3 (age group: 6-, 8- or 10-year-olds) x 2 (sex: male, female) independent measures design ANOVA. Neither the main effect of sex, F (1, 179) = 0.4, p = .537, partial η^2 = .002, nor the interaction between sex and age group, F (2, 179) = 0.4, p = .691, partial η^2 = .004, were significant. There was a significant main effect of age group, F (2, 179) = 3.9, p = .002, partial η^2 = .042. Helmert contrasts showed that the 6-year-old children were significantly less lateralized (see Table 1) than the 8- and 10-year-old children, p = .007, whereas there was no significant different in accuracy between the two older groups of children, p = .644. The significant difference between 6- and 8-year-olds suggests development of right hemisphere dominance between these ages.

3.3. Analysis of the relationship between emotion discrimination and emotion lateralization

A hierarchical regression analysis was run with accuracy for discriminating happy faces as the outcome variable. In the first block, age group and sex were entered as predictor variables. In the second block laterality quotient, the interaction between laterality quotient and age group, the interaction between laterality quotient and sex, the interaction between age group and sex, and the interaction between laterality quotient, sex, and age group were entered as predictors of emotion discrimination. See Table 2 for full statistical details.

The first block, containing age group and sex as predictors, was significant and explained 4.4% of the variability in happiness discrimination. Age group was a significant predictor with older children discriminating happiness from other emotions with greater accuracy. Sex was not a significant predictor. The second block, containing lateralization and the interactive predictors, was also significant explaining a further 10.8% of the variability in emotion processing. Consequently, the overall model explained 15.2% of the variability in the ability to discriminate happiness from other emotions.

Table 2. Regression analysis summary predicting emotion discrimination.

		Predictor statistics			Block change statistics	
		β	t	p	Significance	R^2
Block 1	Age group	.020	2.54	.012	F (2, 182) = 4.17, p = .017	.044
	Sex	.030	1.17	.243		
Block 2	Age group	.033	1.30	.195	F (4, 177) = 4.52, p = .001	.108
	Sex	.060	0.91	.366		
	LQ	.712	3.70	< .001		
	LQ * Sex	-.318	-2.66	.009		
	LQ * Age group	-.155	-2.89	.004		
	Sex * Age group	-.013	-0.44	.664		
	LQ * Sex * Age group	.064	1.93	.055		

LQ = Laterality quotient

In the final model, age group becomes not a significant predictor of happiness discrimination and sex remains not a significant predictor. Strength of lateralization was a significant predictor, showing a positive relationship between the two variables whereby children who are more strongly lateralized are more accurate at the emotion discrimination task. Both of the interactive predictors involving laterality quotients were significant. The interaction between age group and sex was not significant. The interaction between laterality quotient, sex, and age group was approaching significance. The significant 2 way interactions were broken down by examining the zero order correlations between emotion discrimination and emotion lateralization for each group and statistically comparing these correlations, either comparing males and females, or comparing across the three age groups to break down the interaction with age.

For the interaction between lateralization and age of the child, there was a significant positive correlation for the 6-year-olds, r (57) = .384, p = .001, but no significant correlation for the 8-year-olds, r (61) = -.106, p = .207, or the 10-year-olds, r (67) = -.102, p = .207. The correlation for the 6-year-olds was significantly larger than for the 8-year-olds, p = .003, and the 10-year-olds, p = .003. There was no difference in the correlations between the 8-year-olds and the 10-year-olds, p = .509. For the interaction between lateralization and sex, there was a significant positive correlation for the boys, r (85) = .277, p = .005, but not for the girls, r (100) = -.023, p = .411. There was a significant difference between these two correlations, p = .020.

4. Discussion

Our findings replicate previous research (e.g., Levine & Levy, 1986; Workman et al., 2006), whereby there are differences in the strength of lateralization between 6, 8, and 10-year-olds, with the older age groups being more strongly right hemisphere dominant in emotion processing. Importantly, the key novel finding of this research demonstrated that there is an association between children's ability to discriminate happiness from other emotions and the strength of lateralization for processing happiness. Specifically, 6-year-olds who were more strongly lateralized to the right hemisphere for processing happy emotions were more accurate in their recognition of happy emotions. A sex difference was also identified in this relationship with the correlation being evident only for males.

One of the primary aims of this work was to explore how children's developing lateralization for emotion processing was related to their ability to accurately recognize facial emotions. We found that once laterality measures were introduced into the model, age group was no longer a significant predictor or happiness discrimination ability. Children's strength of lateralization for happy emotion processing significantly predicted their accuracy on the task; although, it was only for the youngest children that this was the case. This may indicate that it is only as recognition is developing towards adult-like levels that the degree of brain lateralization is important. Consistent with this proposal, Baron-Cohen, Wheelwright, Spong, Scahill, and Lawson (2001) found that between 6 and 8 years old most children pass the Emotion in the Eyes Test (a test where children must infer what the individual is thinking or feeling from pictures of eyes) above chance levels, and children become more proficient at this task between 8 and 12 years old. Importantly, Workman and colleagues (2006) found that 5- to 6-year-olds ability to correctly judge which emotion state the person was feeling from a set of eyes (using the Eyes Test) was significantly related to the strength of right hemisphere lateralization for emotion processing, yet this was not the case for the older children (7- to 8-year-olds and 10- to 11-year-olds). Taken together, the findings in this study and those of Workman and colleagues, suggest that when children are initially developing an ability to accurately recognize emotions (from whole faces or eyes only) neuropsychological processes, specifically strength of lateralization for emotion processing, is important.

Overall, it was found that there was no significant difference in strength of lateralization for boys and girls. This goes against some research conducted with adult participants, which has typically found that males are more strongly lateralized than females (e.g., Bourne, 2005, 2008; Bourne and Maxwell, 2010). However, research examining emotion lateralization in children has tended not to find significant sex differences (Watling and Bourne, 2007). While there was no overall sex difference, sex was found to interact with strength of lateralization when predicting the ability to process facial expressions of happiness. This difference for boys and girls in the relationship with laterality for emotion processing and happiness discrimination indicates that this relationship is only significant for the males. Boys who were more strongly lateralized to the right hemisphere for emotion processing were more accurate at discriminating happiness from other emotions. This is not necessarily a surprising effect as it has been reported in a number of studies conducted with adult participants. For example, for males but not for females, relationships have been reported between lateralization and handedness (Bourne, 2008), masculinity (Bourne and Maxwell, 2010), trait and social anxiety (Bourne and Vladeanu, 2011) and emotional intelligence (Castro-Schilo and Kee, 2010). Interestingly, the laterality for emotion processing, sex, and age interaction was approaching significance as a predictor. In examining the mean laterality quotients it is possible that the sex difference in emotion processing may be related to boys lateralization patterns differing from those of the girls across the age groups; for instance, with the girls lateralization at 8 and 10 years appears similar, while for the boys it appears that the 10 year olds are more right hemisphere dominant in emotion processing than the 8 year olds. This could indicate that the predictive ability of laterality for emotion processing for boys only may be that they are delayed in their laterality and if the patterns of laterality for boys and girls were more similar there may not be a sex difference. This warrants further investigation.

Two key explanations have been proposed to account for these reported sex differences: the role of hormones and fluctuating asymmetry across the menstrual cycle in adult women and sex differences in interhemispheric transfer. Given that our participants were aged 6 to 10 years old, fluctuating asymmetry is unlikely to provide a valid explanation of the sex difference found. However, the influence of hormones prior to the onset of puberty may account for some of the variability depending on the sex of the child. One of the most examined sources of hormonal variability is prenatal testosterone exposure, whereby higher levels of testosterone are associated with stronger patterns of lateralization (e.g., Geshwind and Galaburda, 1985; Bourne and Gray, 2009; Cohen-Bendahan, Buitelaar, van Goozen, & Cohen-Kettenis, 2004). Consequently, prenatal hormonal exposure may explain, at least to some extent, the differing developmental trajectories for males and females. The interhemispheric explanation may provide a more reasonable account. Fagard, Hardy-Leger, Kervella, and Marks (2001) found that the speed of interhemispheric transfer becomes faster through childhood; however, they did not examine possible sex differences. It is also possible that these two explanations are not necessarily mutually exclusive given that a recent study (Lust, Geuze, Van de Beek, Cohen-Kettenis, Groothuis, & Bouma, 2010) showed that higher levels of prenatal testosterone were associated with stronger patterns of lateralization in girls, but reduced interhemispheric transfer in boys. Evidently the source of the sex difference in lateralization, across the lifespan, requires further examination.

While we have shown a clear relationship between the ability to discriminate emotions and the strength of lateralization for emotion processing for happy facial emotion, the causal direction of this relationship is unclear. One possibility is that increased experience and interactions with emotional faces lead to the development of lateralized processing mechanisms. Alternatively, it may be that the development of right hemisphere emotion processing enables enhanced processing of emotional faces. It is only really possible to address this question in a longitudinal design to see whether the shift to right hemisphere processing of facial emotion occurs before or after the ability to effectively recognize facial emotion develops. Additionally, this research explored children's discrimination of happy emotional faces from negative emotional faces. It is possible that children were using different strategies to detect if a face was happy or not happy (e.g., looking at the upward turn of mouth). While this may explain some of the variability in emotion discrimination, it seems unlikely to provide a complete explanation of the findings However, it would be important to explore emotion discrimination for all emotions in future work to assess if the same or different patterns exist.

This research is the first to directly explore how children's discrimination of emotion may be predicted from their strength of lateralization of emotion processing. We have seen that when children are first becoming accurate at recognizing happiness, those who are more right hemisphere dominant in the processing of happy emotions are more accurate. This is not the case for older children resulting in clear implications for the role of experience in later judgments. The relationship is also far more apparent in male children than in females.

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Footnote

1. Handedness was recorded in terms of whether each child used their left or right hand for writing, throwing a ball, brushing their teeth and using a mouse. This was used to calculate a handedness score ranging from 0 (all left) to 4 (all right). This gave a mean handedness score of 3.5 (range: 0-4, SD = 1.2). This measure was not correlated with either of the emotion tasks (discrimination: $r = .11$, $p = .369$; lateralization: $r = .02$, $p = .858$). Consequently, handedness was not included as a factor in any subsequent analyses.