Changing choices: a neurocognitive examination of decision-making during adolescence

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CHAPTER

Do you see what I see? Sex differences in the discrimination of facial emotions during adolescence

Nikki C. Lee[1], Lydia Krabbendam[1], Thomas White[2], Martijn Meeter[3], IMAGEN Consortium, Gunther Schumann[4] & Sukhi S. Shergill[2]

1. Department of Educational Neuroscience, VU University Amsterdam, Amsterdam, The Netherlands
2. Department of Psychosis Studies, Institute of Psychiatry, King's College London, United Kingdom
3. Department of Cognitive Psychology, VU University Amsterdam, Amsterdam, The Netherlands
4. Social, Genetic and Developmental Psychiatry Centre, Institute of Psychiatry, King's College London, United Kingdom

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ABSTRACT

During adolescence social relationships become increasingly important. Establishing and maintaining these relationships requires understanding of emotional stimuli, such as facial emotions. The current study examined sex differences in emotional face processing during adolescence. Participants were *N* = 1951 adolescents with a target age of 14, who completed a forced-choice emotion discrimination task. The stimuli used comprised morphed faces that contained a blend of two emotions in varying intensities (11 stimuli per set of emotions). Adolescent girls showed faster and more sensitive perception of facial emotions than boys. However, both adolescent boys and girls were most sensitive to variations in emotion intensity in faces combining happiness and sadness, and least sensitive to changes in faces comprising fear and anger. Furthermore, both sexes overidentified happiness and anger. However, the overidentification of happiness was stronger in boys. These findings were not influenced by individual differences in the level of pubertal maturation. These results indicate that male and female adolescents differ in their ability to identify emotions in morphed faces containing emotional blends. Adolescent girls show more sensitive and faster emotional face processing than boys. The findings provide information for clinical studies examining if sex differences in emotional processing are related to sex differences in the prevalence of psychiatric disorders within this age group.

INTRODUCTION

Interacting with others in social situations is dependent on the capacity to recognise social and emotional stimuli, especially facial expressions. Accurate emotion recognition enables us to understand the feelings of others and respond accordingly. During adolescence, as social relationships become more important, adolescents must become increasingly adept at reading emotional cues as well as modulating emotional responses. This is reflected in age-related improvements on tasks measuring facial emotion processing (Herba, Landau, Russell, Ecker, & Phillips, 2006; Thomas, De Bellis, Graham, & LaBar, 2007). A failure to adequately recognise emotions is associated with a range of psychopathologies that are prevalent during adolescence, such as conduct disorder, anxiety and mood disorders (Paus, Keshavan, & Giedd, 2008). Understanding normal developmental trajectories of emotion recognition during adolescence may enable earlier identification of these disorders. Furthermore, an increased understanding of sex differences in emotional development could help to explain clinically relevant questions about sex differences in the vulnerability to these disorders, which emerge during adolescence and continue into adulthood.

Emotional face processing is an important skill, and therefore takes many years to develop. Much of the literature has focused on infancy and early childhood (Boyatzis, Chazan, & Ting, 1993; see McClure, 2000 for a review; Tremblay, Kirouac, & Dore, 2001; Walden & Field, 1982; Walker-Andrews, 1997). Development during adolescence has received less attention, with some initial studies suggesting that few changes in facial emotion recognition occur after childhood (Harrigan, 1984; Tremblay, Kirouac, & Dore, 1987). However, recent work using more sensitive measures, has found differences in performance when comparing adolescents to children and adults. For example, a recent study using morphed faces made of emotional blends, found that children (ages 7-13) and adolescents (ages 14-18) were less sensitive than adults to negative emotions such as fear and anger (Thomas, et al., 2007). A second study, using faces differing in the intensity of emotion expressed, found that sensitivity to happy and fearful expressions increased between 4 and 15 years of age. No changes were found for expressions of sadness, anger or disgust (Herba, et al., 2008). These findings suggest continued refinement of emotional face recognition throughout the adolescent period and into adulthood.

This assumption of continued improvement has been strengthened by structural and functional MRI studies showing continued maturation during adolescence of the networks in the brain involved in emotion processing (Baird, et al., 1999; Gogtay, et al., 2004; Monk, et al., 2003; Somerville, Fani, & McClure-Tone, 2011; Yurgelun-Todd & Killgore, 2006). These areas include the fusiform gyrus, amygdala and prefrontal cortex (PFC). The fusiform gyrus is selectively involved in the processing of faces (Kanwisher, McDermott, & Chun, 1997), and becomes increasingly specialised in this task during development (Aylward, et al., 2005). Other studies have concentrated on the amygdala, which is known to be a key structure in emotion processing, especially the evaluation of emotional faces (Adolphs, 2010). Adolescents display greater amygdala activation during processing of various facial emotions than children and adults, suggesting an increased sensitivity to emotional stimuli (Guyer, et al., 2008; Hare, et al., 2008; Killgore, Oki, & Yurgelun-Todd, 2001). They also show reduced amygdala connectivity to prefrontal regions compared to adults, possibly causing a weaker integration of emotion processing with higher cognitive processes such as cognitive control (Guyer, et al., 2008). The continued development during adolescence of the PFC and the amygdala-PFC circuitry increases this control over emotional responses with age (Gogtay, et al., 2004; Luna, Padmanabhan, & O'Hearn, 2010; Monk, et al., 2003).

Adolescent neuroimaging literature has also shown that the development of emotion processing networks, as well as other regions of the brain, differs between boys and girls (Lenroot, et al., 2007). For example, the left amygdala shows significantly greater growth in adolescent males than females (Giedd, et al., 2006). Functional differences have also been observed, such as differing patterns of lateralisation of amygdala activation between boys and girls when viewing angry faces (Schneider, et al., 2011). Killgore, et al. (2001) studied a group of children and adolescents and found that only females showed an increase with age in left prefrontal relative to amygdala activation when viewing fearful faces.

Previous behavioural studies of sex differences in emotional face processing have produced mixed findings. Results of a meta-analysis suggested that generally adult females outperform males in processing emotional expressions (Hall, 1984). A second meta-analysis also showed a female advantage in facial emotion processing from childhood to adulthood, though only a few of the studies included examined differences during adolescence (McClure, 2000). However, various individual studies have not reported sex effects in wither child or adolescent samples (De Sonneville, et al., 2002; Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000). For example, Herba and colleagues (2006) found no sex differences in adolescents on an emotion-matching task using faces displaying anger, sadness, happiness, disgust and fear with varying intensities. Thomas et al. (2007) asked participants to identify morphed faces combining fear, anger and neutral expressions and were also unable to find differences between male and female adolescents.

This lack of sex differences in performance seems to be at odds with the results of neuroimaging studies. However, a number of factors may have contributed to the inability of previous behavioural studies to find these differences. Firstly, previous studies have often recruited small numbers of participants. However, sex differences in cognitive abilities are often modest, suggesting that powerful designs and large samples are needed to detect effects (McCarthy & Konkle, 2005). Secondly, to our knowledge, no study has combined examination of sex differences in adolescent emotional face recognition with measures of pubertal maturation; this despite findings showing that sex differences in adolescent brain structure and function are strongly influenced by the responsiveness of the brain to sex-specific fluctuations in hormone levels during puberty (Neufang, et al., 2009). For example, gray matter volume in frontal and parietal lobes peaks at an earlier age in girls (around age 11) than in boys (around age 12), and corresponds to the sexually dimorphic ages of puberty onset (Giedd, et al., 1999). This gray and white matter development has been directly linked to pubertal endrocrinological changes, such increases in sex steroids (Peper, et al., 2009). Furthermore, pubertal development has been shown to influence processing of emotional stimuli, such as emotional faces (Moore, et al., 2012; Silk, et al., 2009). Pubertal changes in hormone levels have also been related to sex differences in the prevalence of several classes of psychiatric disorders during adolescence related to emotional processing. The incidence of depression, anxiety and panic disorders is equal between prepubertal boys and girls, but shifts to a 2:1 overrepresentation of girls after puberty (Paus, et al., 2008). As sex and pubertal status are correlated during adolescence, sex differences in performance need to be evaluated in light of the known differences in pubertal status.

The primary goal of this study was to investigate differences between male and female adolescents in recognition of blends of anger, fear, sadness and happiness expressed in faces. A single age group was used, comprising adolescents differing in pubertal status, hereby enabling us to control for the contribution of pubertal hormones separate from age-related behavioural changes. Participants performed a facial identification task that required them to identify emotions in faces that had been morphed to contain a blend of two emotions in varying intensities. This method increases the sensitivity of the task, as it requires the participant to distinguish between nuances in facial expressions. Moreover, the task is indicative of everyday life, as faces of mixed emotional valence are encountered on a daily basis (Depaulo, 1992), and with age mixed emotions are increasingly experienced in emotionally complex situations (Larsen, To, & Fireman, 2007). We hypothesised that the valence of the emotions would influence identification. Furthermore, we expected that, after controlling for puberty, adolescent girls would be more sensitive to differences between emotions then adolescent boys.

METHOD

PARTICIPANTS

Participants were taken from the IMAGEN sample, a large European multicentre study aimed at examining the genetic and neurobiological basis of individual variability in impulsivity, reinforcement sensitivity and emotional reactivity. Participants in the IMAGEN study are typically developing adolescents with a target age of 14 (M = 14.43, SD = .39, range = 13.07-15.85). The present study used data from 2010 adolescents who completed a morphed faces task as part of the IMAGEN test protocol. Of this group, 15 were excluded from the sample prior to data analysis due to incomplete data and 41 participants were excluded due to irregularities during task administration, such as the participant rushing through the task or being

Table 1 - *Participant characteristics*

	BOYS (*N* = 956)	GIRLS (*N* = 998)	TOTAL (*N* = 1954)
AGE *(M (SD))*	14.42 (.39)	14.43 (.40)	14.43 (.39)
PDS STAGE *(M (SD))*	3.99 (.68)	3.25 (.45)	3.63 (.68)

disturbed during task completion. Participant characteristics are displayed in Table 1.

Details of the study, recruitment procedures and further characteristics of the sample have been described elsewhere (Schumann et al, 2010). Local ethics boards at participating sites approved the study protocol. Parents and adolescents provided written informed consent prior to participation. Participants received monetary compensation for their participation in the study.

STIMULI

Two faces (03 and 24) were selected from the MacBrain stimuli set. These images were used to create four series of morphed continua per face: Anger-Sadness, Anger-Fear, Happiness-Fear and Happiness-Sadness. Each continuum consisted of 11 morphed images, which each differed by 10% in pixel intensity. For example, in the Anger-Sadness continuum, the first morph increment was 100% angry-0% sad, the second morph increment was 90% angry-10% sad, the third morph increment was 80% angry-20% sad etc. The middle face in each set of morph blends was a 50% blend of the emotions.

PUBERTAL DEVELOPMENT SCALE

The self-report Pubertal Development Scale is a non-invasive index of pubertal development based on the Tanner staging categories (Tanner, 1962). The questionnaire was designed by Carskadon and Acebo (1993) as an adaptation of the interview-based puberty rating scale devised by Peterson, Crockett, Richards and Boxer (1988). Self-ratings of Tanner stages have been shown to be a useful and accurate measurement of pubertal status when compared to both endocrine measures of hormone concentrations (Rapkin, Tsao, Turk, Anderson, & Zeltzer, 2006) and pictorial representations (Bond, et al., 2006). The scale comprises a male and female version and contains questions indexing physical development and separates individuals into five stages of pubertal development (prepubertal, early pubertal, midpubertal, late pubertal, post pubertal).

PROCEDURE

The created morphed faces were used in an emotion identification task based on Pollak and Kistler (2002). Trials began with a blank screen, followed by a display of the face border and response buttons for 250 ms.. This was followed by one of the morphed face stimuli, which remained in view until a response was recorded. Participants were asked to identify which of the two blended emotions it resembled most. Responses were made by using the mouse to click on one of two response buttons underneath the face stimulus on the screen. For each of the two faces the 11 points in the 4 morph continua were shown twice, with exception of the 3 central morph points, which were shown 4 times. This resulted in a total of 224 trials. Trial order was randomly determined so that the participants were not aware of the continua being examined. Both the morphed faces task and the Pubertal Development Scale were administered as part of a larger home-assessment battery. Participants completed each of the 10 tasks in battery in their own time using the web-based platform PsyTools (Delosis, London, UK).

DATA ANALYSIS

To derive simple measures of performance, we followed a procedure similar to that employed by Pollak & Kistler (2002). For each participant, and for each continuum, we fitted a logistic function to the proportion of "emotion A" responses, where emotion A was one of the two sides of the continuum (e.g., anger in the Anger-Sadness continuum). This function is given by:

$$P('A')= \frac{1}{1+e^{-a(x-b)}}$$

Here, *P ('A')* is the likelihood of a response 'emotion A' to a certain image, and *x* is the percentage of emotion A blended into the image (varying between 0 and 100). The two resulting parameters *a* and *b* can be interpreted as sensitivity and bias, respectively. Parameter *b* denotes the category boundary, the point where 50% of responses are 'emotion A'. A value of 50 denotes perfectly calibrated performance; lower values indicate a tendency to identify a mixture with less than 50% 'A' in it as emotion A, while a value above 50 indicates a bias away from emotion A. Parameter *a* indices the sensitivity of the participant to changes in the mixture; a high value indicates strong sensitivity, a low value weak sensitivity. Two further parameters introduced by Pollak and Kistler (2002) were left out, since the two-parameter function introduced above fit most participants as well as their four-parameter version.

A repeated measures ANOVA was used to examine differences in sensitivity and bias related to sex and pubertal status for each of the four morph types. Both analyses included sex as a between-group variable and puberty as a covariate. Significant main effects were followed up by Bonferroni-corrected independent samples t-tests. As initial examination of the data showed that the distribution of values of *a* were skewed, a logarithmic transformation was performed to normalise the data prior to analysis. Speed accuracy trade-offs were also examined using a repeated measures ANOVA, with the mean reaction time per morph type as a dependent variable and sex pubertal status the between-subjects factor.

RESULTS

SENSITIVITY

Mauchly's test indicated that the assumption of sphericity had been violated (χ^2 (5) = 204.61, $p < .05$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .94$). There was a significant main effect of condition, due to participants' sensitivity to the emotions displayed differing between morph types, F (2.82, 5491.09) = 133.80, $p < .001$, partial $\eta^2 = .06$. Participants were most sensitive to differences between emotions in Happiness-Sadness morphs (M = .88, SD = 3.23), followed by Happiness-Fear (M = .73, SD = 2.53) and Anger-Sadness (M = .37, SD = 1.57). They were least sensitive to differences between emotions within the Anger-Fear morph continuum (M = .28, SD =1.20). Tests of between-subjects effects revealed a main effect of sex, F (1, 1949) = 11.54, p = .001, partial η^2 = .01, and revealed that adolescent girls showed a higher sensitivity in processing of emotional facial expressions across all morph types compared to adolescent boys (see Figure 1). No significant influences of pubertal status were found, F (3, 1949) = 1.029, p = .379.

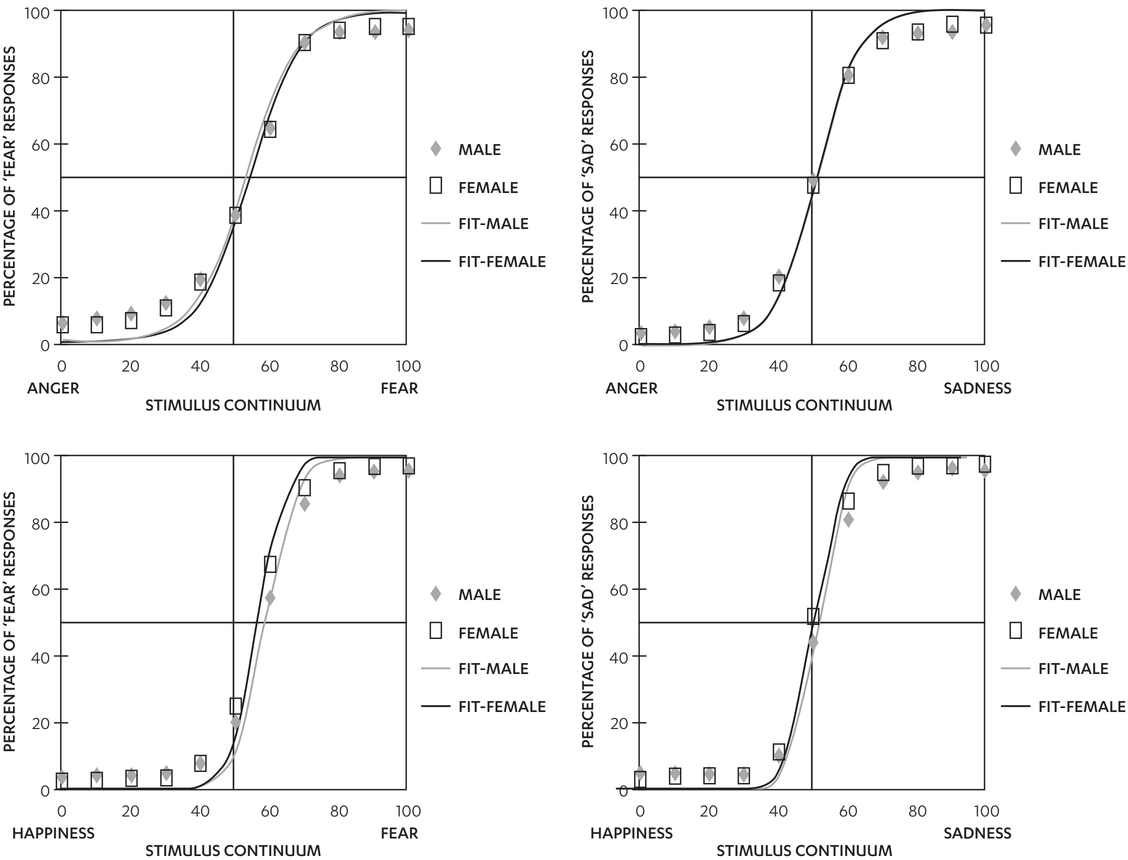

Figure 1 - *Data from the emotion identification task for each morph type. Continuous curves were produced with the logistic function, using as parameter values the median of values fitted on individual data. Such values do not fit average data perfectly (due to the nonlinearity of the logistic function), but give an impression of performance of individual participants. The x-axis shows the 11 morph increments, with labels reflecting the relative percentage of the second emotion within the stimulus. For example, for the Anger-Fear morph continuum, 20 = morph comprising 20% fear and 80% anger. The y-axis represents the percentage of trials the participant matched the viewed facial emotion to the second emotion in the pair, relative to the first emotion.*

CATEGORY BOUNDARIES

According to Mauchly's test, the sphericity assumption was violated (χ^2 (5) = 532.24, p < .05) and Greenhouse-Geisser estimates of sphericity were used (ε = .87). The repeated measures ANOVA analysis showed a main effect of condition, F (2.60, 5061.64) = 85.18, p < .001, partial η^2 = .04, due to a difference between the four morph continua in the shift of category boundaries from the midpoint (see Table 2). A bias in the recognition of emotions was observed for all morph types. Data from the Anger-Fear and Anger-Sadness conditions suggest that participants overidentified anger, while data from the Happiness-Fear and Happiness-Sadness continua suggested an overidentification of happiness. A main effect of sex was also found, F (1, 1949) = 8.49, p = .004, partial η^2 = .01, as well as a condition x sex interaction, F (2.60, 5061.64) = 5.89, p = .001. Post-hoc tests showed that for the Happiness-Fear continuum, adolescent boys showed a larger shift in the boundary between happiness and fear than adolescent girls, t (1958) = 4.71, p < .001. This was the result of a greater bias in boys towards labeling the faces in the continuum as happy. A similar effect was found for the Happiness-Sadness continuum, with adolescent boys again showing a larger bias towards labeling faces as happy compared to adolescent girls, t (1886.36) = 5.88, p < .001. No significant effects of pubertal status were found, F (3,1949) = .51, p = .679.

Table 2 - *Category boundary parameter values (mean and SD) per morph type. A value of 50 denotes an unbiased boundary. A value below 50 reflects a bias towards the first emotion in the diad, a value above 50 towards the second emotion. Differences between males and females were significant for the Happy-Fear and Happy-Sad continua.*

MORPH TYPE	MALE	FEMALE	TOTAL
ANGER-FEAR	52.88 (11.71)	52.98 (12.60)	52.94 (12.17)
ANGER-SADNESS	50.21 (11.40)	50.36 (9.84)	50.29 (10.63)
HAPPINESS-FEAR	58.17 (12.04)	56.11 (6.85)	57.12 (9.79)
HAPPINESS-SADNESS	51.84 (7.18)	50.06 (6.16)	50.93 (6.74)

REACTION TIME

Mauchly's test indicated that the assumption of sphericity had been violated (χ^2 (5) = 35.36, p < .05). Therefore, Greenhouse-Geisser estimates of sphericity were used (ε =

.99). Reaction times differed significantly between morph continua, F (2.96, 5776.41) = 44.01, $p < .001$, partial $\eta^2 = .02$. Mean reaction times are shown in Table 3. All participants showed the fastest reaction times for faces within the Happiness-Sadness morph continuum, followed by Happiness-Fear and Angry-Sadness morphs. Finally, the slowest reaction times were recorded for discrimination between anger and fear. Girls were faster than boys across all morph continua, F (1, 1949) = 10.17, $p = .001$, partial $\eta^2 = .01$. No significant differences were found between pubertal status groups, F (3, 1949) = .477, $p = .698$.

Table 3 - *Reaction times in milliseconds (mean and SD) per morph type. Females were significantly faster than males across all morph continua.*

MORPH TYPE	MALE	FEMALE	TOTAL
ANGER-FEAR	2568.24 (1209.35)	2451.46 (909.84)	2508.59 (1068.25)
ANGER-SADNESS	2392.38 (942.08)	2281.18 (1122.25)	2335.59 (1039.24)
HAPPINESS-FEAR	2284.53 (1098.13)	2122.37 (713.88)	2201.71 (925.42)
HAPPINESS-SADNESS	2190.30 (1022.36)	2049.47 (788.00)	2118.37 (912.72)

DISCUSSION

The current study examined sex differences in the perception of emotion during adolescence. A large sample of mid-adolescents completed an emotion recognition task comprising morphed facial expressions across four morph continua: Anger-Fear, Anger-Sadness, Happiness-Fear and Happiness-Sadness. Though there is wealth of literature describing functional and structural changes in the brain regions involved in emotion processing during adolescence (Giedd, et al., 2006; Killgore, et al., 2001; Schneider, et al., 2011; Yurgelun-Todd & Killgore, 2006), behavioural studies have previously produced mixed results (Herba, et al., 2006; Thomas, et al., 2007). The primary finding of this study was that male and female adolescents differed in their ability to identify emotions in morphed faces containing emotional blends. These differences were not caused by faster pubertal maturation of girls, since controlling for the level of pubertal maturation of individuals did not change results.

Valence of the emotions contained within the morph progression influenced sensitivity to the target emotion. Both adolescent boys and girls were most sensitive to small changes in emotional facial expressions within the Happiness-Sadness morph continuum, followed by the Happiness-Fear and Anger-Sadness continua and least sensitive to differences within the Anger-Fear continuum. However, across all morph continua, sensitivity differed between the sexes and was higher in girls than in boys. Furthermore, participants showed the fastest reaction times for the morph progressions in which they were most sensitive to differences between the emotions. Fastest reaction times were recorded for the Happiness-Sadness blends, followed by the Happiness-Fear and Anger-Sadness blends. The slowest reaction times were recorded for Anger-Fear blends. Finally, participants showed a bias towards one of the two emotions for each of the morph progressions. This indicated a shift in the category boundaries between the emotions, with results suggesting that both sexes overidentified happiness and anger. However, the overidentification of happiness was stronger in boys.

These findings of increased sensitivity to happiness, and the accompanying faster identification, are in line with previous studies, which have reported that positive emotions are often recognised faster and more accurately then negative emotions (McClure, Pope, Hoberman, Pine, & Leibenluft, 2003; Paus, et al., 2008). Developmental studies have shown that during childhood, sensitivity to happiness develops faster than sensitivity to other emotional facial expressions (Gao & Maurer, 2010). A study by Hare and colleagues using an emotional go/nogo task in adults (Hare, Tottenham, Davidson, Glover, & Casey, 2005) reported that participants found it difficult to inhibit responses to happy faces and were slower to respond to go-trials involving negative faces. A subsequent study showed similar results in adolescents (Hare, et al., 2008). Another study found that adolescents showed enhanced ventral striatum activity in response to happy faces, suggesting that these stimuli have inherent reward properties, which increase their appetitive value for adolescents (Somerville, Hare, & Casey, 2011). Herba and colleagues (2008) showed that the minimum intensity of happiness needed to recognise this facial expression decreased during adolescence. If adolescents are able to recognise happiness at lower intensities than other emotions, and find happy faces more rewarding than other emotional facial expressions, this may explain the overidentification of happiness among participants in this sample.

Results in the Anger-Fear and Anger-Sadness conditions suggest an overidentification of anger among participants. Angry faces are unambiguously viewed as threat signals, while other negative emotions are considered ambiguous, as they do not directly convey threat to the person viewing the expression (Whalen, et al., 2001). Therefore, of the three emotions used in the present task, anger is the most negative and the least accepted emotion in social interactions, due to the high interpersonal negative connotations (Depaulo, 1992). During adolescence, friendships with peers become more intense and concern about social status increases. As a result, peer acceptance becomes a powerful motivator for adolescents to conform to patterns of behaviour that receive approval from their peer group (Allen, Porter, McFarland, Marsh, & McElhaney, 2005). Given that anger is the emotion that signals annoyance and rejection, it may be an emotion that adolescents avoid displaying in order to maintain their increasingly important social relationships. Studies have shown that expression of anger is more controlled in the presence of peers than in the presence of others such as parents (Zeman & Garber, 1996). If adolescents actively regulate their displays of anger in particular contexts, this may increase their sensitivity to this emotion.

The present study also demonstrated differences in emotion recognition between the sexes. Adolescent girls were more sensitive to differences between emotional facial expressions than boys. These disparities were not due to differences in pubertal development between the sexes, as this was controlled for within the study design. Recent models have suggested that an interplay of biological, social and experiential factors influences the development of sex differences (McClure, 2000). A possible biological explanation may be what has been described as a lag in cortical maturation in adolescent boys compared to girls (De Bellis, et al., 2001; Lenroot, et al., 2007). If development of the areas involved in emotion processing is slower in boys than in girls, adolescent girls may have more a mature capacity for processing social information and therefore be more capable of encoding, processing and responding to social stimuli. However, these abilities may not just develop faster in girls, but may also develop to a higher level, leading to the well-documented advantages in accurately judging the emotions displayed in facial expressions found in adult females compared to males (e.g. Hall & Matsumoto, 2004; Montagne, Kessels, Frigerio, de Haan, & Perrett, 2005; Thayer & Johnsen, 2000). Future studies using a longitudinal design could further elucidate if the differences found are due to increased maturity in females or a higher level of functioning.

Differences between the sexes may also be due to social factors and learned patterns of behaviour. Studies have shown that both sexes are rewarded by parents and peers for showing gender appropriate behaviour (Bennett, Farrington, & Huesmann, 2005; Garner, Robertson, & Smith, 1997). Socialisation practices and display rules may make it easier for girls to display emotional expressions than boys (Herba & Phillips, 2004). Girls have a larger network of friends and are encouraged to value intimacy in their friendships, while boys are socialised to value achievement and assertiveness (Berndt, 1982; Feiring & Lewis, 1991). These socialisation effects mean that girls are more exposed to emotional expressions, and thus may make girls more skilled at identifying emotions.

This study also found evidence of faster emotion recognition in adolescent girls than boys. Sex differences in reaction time and speed of information processing in favour of girls have previously been noted on various cognitive tasks (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001). The finding of faster emotional processing in girls compared to boys suggests that adolescent females may recruit more efficient emotion perception strategies than males. Based on research in adults, Hall and colleagues (2004) suggested that females process emotions at the primary level, through innate and automatised responses of the limbic system. Males on the other hand process emotional stimuli at a secondary level. Their emotional responses are modulated by prefrontal areas, and as a result their responses are influenced by utilising information gained through learning and previous experiences. This would allow females to respond fast and instinctively when encountering emotional stimuli. In males this processing is more analytic and therefore potentially slower. The results of the current study suggest that these differences may already be present during adolescence.

Certain limitations need to be taken into account when interpreting the data. Firstly, happiness was the only positive target emotion used in this study, while the other three emotions were negative. Studies of categorical perception have shown that perception of differences between categories is easier then perception of incremental differences within a category (Pollak & Kistler, 2002). The faster reaction times and increased sensitivity to happiness within the Happiness-Fear and Happiness-Sadness blends compared to Anger-Fear and Anger-Sadness may therefore have been confounded by categorical differences between the stimuli. Further research with tasks including multiple positive and negative emotions is needed to examine this effect. Secondly, participants in the study were recruited within a narrow age range. As adolescence is a period of continued cognitive and emotional development (Casey, Getz, & Galvan, 2008), the results cannot be generalised across the entire adolescent period.

In sum, by employing a large sample within a narrow age range and controlling for developmental differences in pubertal maturation, the present study contributes to current knowledge of sex differences in emotional face processing during adolescence. The results suggest that adolescent girls show more sensitive and faster emotional face perception than adolescent boys. The findings of this study may provide information for further clinical studies examining if these sex differences in emotional processing are related to sex differences in the prevalence of psychiatric disorders within this age group.

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