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Face Emotion Processing in Depressed Children and Adolescents with and without Comorbid Conduct Disorder

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Abstract Studies of adults with depression point to characteristic neurocognitive deficits, including differences in processing facial expressions. Few studies have examined face processing in juvenile depression, or taken account of other comorbid disorders. Three groups were compared: depressed children and adolescents with conduct disorder (n=23), depressed children and adolescents without conduct disorder (n=29) and children and adolescents without disorder (n=37). A novel face emotion processing experiment presented faces with 'happy', 'sad', 'angry', or 'fearful' expressions of varying emotional intensity using morphed stimuli. Those with depression showed no overall or specific deficits in facial expression recognition accuracy. Instead, they showed biases affecting processing of low-intensity expressions, more often perceiving these as sad. In contrast, non-depressed controls more often misperceived low intensity negative emotions as happy. There were no differences between depressed children and adolescents with and without conduct disorder, or between children with comorbid depression/conduct disorder and controls. Face emotion processing biases rather than deficits appear to distinguish depressed from non-depressed children and adolescents.

Keywords Depression · Comorbidity · Neurocognitive · Face expressions · Emotion processing

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Introduction

Depression is one of the main contributors to the global burden of disease (Demyttenaere et al. 2004; Üstün et al. 2004), often starts in childhood or adolescence (Jaffee et al. 2002; Kim-Cohen et al. 2003), and shows strong continuities with adult affective disorder (Harrington et al. 1991; Fombonne et al. 2001a, b). Early onset depression is associated with a poorer prognosis and substantial functional impairment, including a heightened risk for suicide (Thapar et al. 2010). Evidence also highlights the importance of taking account of comorbid disorders in understanding links between adolescent and adult depression and long-term prognosis (Copeland et al. 2009).

There has been a substantial recent growth in research addressing neurocognitive correlates of depression (McClintock et al. 2010; Pine et al. 2004; Surguladze et al. 2004), including depressed individuals' patterns of face

processing, but there are still substantial knowledge gaps (Herba and Phillips 2004; McClintock et al. 2010). In particular, relatively few studies have focused on face expression processing in depressed children and adolescents, and almost none of these take account of comorbidity with other disorders. Studies of face emotion processing in juvenile depression are important because these provide insights both into patients' cognitive appraisal of the environment, and because facial expressions provide important cues that guide our social interactions. The ability to accurately and swiftly identify facial expressions is of great importance as faces contain vital cues about social interaction and other people's mental states (Ekman et al. 1969).

It is noteworthy that there are considerable individual differences in the perception and interpretation of facial expressions (Herba and Phillips 2004). Various psychiatric disorders have been linked with deficits and biases in face emotion processing (Herba and Phillips 2004; Pine et al. 2004). These can range from general impairments as found in individuals with autistic spectrum disorders (Herba and Phillips 2004) to specific impairments linked to particular emotions (e.g. disgust recognition in patients with Huntingdon's disease, Sprengelmeyer et al. 1996). In relation to depression, the research evidence suggests that depression is associated with subtle biases affecting attention to and interpretation of specific facial expressions rather than gross abnormality or inaccuracy in face processing. Studies of adults with depression have shown negative biases when judging facial affect, being more likely to misinterpret neutral faces as sad and happy faces as neutral (e.g. Nandi et al. 1982; Gur et al. 1992). Additionally, some studies have shown a positive bias amongst non-depressed controls when judging facial expressions that is lacking in adults with depression (Matthews and Antes 1992). Moreover, there is evidence of selective attention to sad faces among depressed adults and towards happy faces among non-depressed controls (Joormann and Gotlib 2007).

There are relatively few studies of face emotion processing in children and adolescents with depression, and these have focused more specifically on amygdala function and processing of fear-related stimuli. There is some evidence that encoding of fearful faces is impaired (Pine et al. 2004), and is possibly linked to variations in amygdala function (Monk et al. 2008). Given evidence of ongoing maturation and developmental change of face emotion processing into late adolescence (Guyer et al. 2008; Herba and Phillips 2004; Thomas et al. 2007), it is important to investigate whether patterns of face expression biases and deficits associated with adult depression also apply to juvenile depression.

Many children and adolescents with depression also exhibit conduct problems (Angold and Costello 1993). This subgroup appears to have a similar depressive symptom profile to depressed individuals without conduct disorder (Ezpeleta et al. 2006), but appears to differ in terms of adult outcomes, familial correlates (Harrington et al. 1991), and functional impairment (Ezpeleta et al. 2006). Less is understood about cognitive biases and social information processing deficits in this group (Quiggle et al. 1992), which is of great importance given its relevance to alternative treatment and prevention approaches.

Research on face expression processing by children and adolescents with conduct disorder is currently limited. Studies have shown links between psychopathy and impaired recognition of fear, possibly due to structural problems in the amygdala (Blair and Coles 2000; Blair et al. 2001). There is some evidence that fear processing deficits may also apply to other antisocial populations (Marsh and Blair 2008). At the same time, there is also evidence of heterogeneity of face processing impairments within antisocial samples, though this remains poorly understood. A recent study by Fairchild et al. (2009) examined whether conduct disorder was associated with deficits in facial expression recognition and whether these deficits differed for early-onset and adolescence-limited forms of CD. They found that recognition of anger, disgust, and happiness in facial expressions was impaired in participants with both sub-types of CD when compared to control participants, but that these impairments were more pronounced in children with early-onset CD; consistent with the view that early-onset conduct disorder is more strongly linked with neurocognitive impairment (Moffitt 1993). Critically, no study to date has examined the processing of facial expressions by children and adolescents with comorbid depression and conduct disorder.

There are two further issues affecting most previous studies of face emotion processing in depression. The first is that these have often only tested the processing of prototypical posed expressions (Ekman 1976). However, in real life situations faces show subtle variations in expression; people rarely display extremes of emotion. Most faces we encounter, especially ones we do not engage with (e.g. strangers on the bus), display relatively neutral expressions. How these faces are perceived (e.g. as happy or sad) may be especially informative about people's mental representation of others. Interactions with people also usually involve low intensity facial expressions, and biases in processing these may affect how we act and react in social interchanges. For example, if we perceive someone as relatively happy, we may engage more positively, which in turn may lead to similar reciprocal reactions by the other person. Furthermore, it is important to accurately perceive low intensity expressional cues in order to anticipate the likely progression of social interchanges at an early stage (e.g. Does someone look annoyed? Will they become angry?).

A second methodological issue concerns the distinction between accuracy and bias. According to signal detection theory, accuracy of identification of specific facial expression requires taking account of both correct identifications ('hits') and of misidentifications ('false alarms'). A commonly used approach is to use d-prime as a measure of discrimination accuracy (Miller 1996; Collishaw and Hole 2000). In addition to an overall assessment of face emotion processing accuracy, it is also of interest to examine biases in processing. Equivalent discrimination accuracy may result from high levels of hits and false alarms or from low levels of each, but different biases in processing would underlie these two patterns of performance. We hypothesise that separate analyses of hits and false alarms will reveal distinct biases for children with and without depression, in particular a greater tendency to label faces as sad and a reduced tendency to label them as happy.

This study extends prior research on facial emotional recognition in depression in three important ways. First, the study focuses on face processing in clinically depressed children and adolescents; most previous research has focused on adult depression. Second, the use of blended expressions allows the investigation of abnormalities of low intensity expression in a systematic manner, and thus provides new evidence on sensitivity to facial emotion. Third, the study assesses not only overall accuracy, but also decomposes performance into hits and false alarms. This provides evidence on two related but non-identical questions – to what extent is face processing ability impaired and to what extent is face processing biased in juvenile depression? A secondary aim is to test possible differences in face emotion processing between depressed children with and without comorbid conduct disorder.

Method

Participants

Participants in this study were 89 children and adolescents aged between 8 and 18 years. Twenty-nine suffered from depression (10 boys and 19 girls, mean age=15.7 years), and 23 suffered from depression and conduct disorder (8 boys and 15 girls, mean age=15.3 years). Thirty-seven non-affected children and adolescents were recruited for a control group (14 boys and 23 girls, mean age=15.0 years). Patients in the clinical groups were recruited at the point of referral to one of the seven South London clinics involved in the study and assessed by child psychiatrists using patients and their parents as informants. The depressed group included patients diagnosed with major depressive disorder, minor depression and/or dysthymia. The comorbid group included children and adolescents with major depression, minor depression and/or dysthymia and additional diagnosis of conduct disorder and/or oppositional defiant disorder. The study's exclusion criteria were presentation of psychotic disorder (such as bipolar depression), symptoms on the autistic spectrum, having a learning disability (IQ<70), or suffering from a serious and chronic medical condition. Depression and conduct disorder symptom screens (see below) were subsequently administered by the researcher to patients to test the validity of the clinical diagnoses. Two depressed individuals initially recruited without a formal diagnosis of CD/ODD had very high conduct screen scores (20+), had their case notes were reviewed by a child psychiatrist, and were reassigned to the comorbid group. One child in the comorbid group also had a diagnosis of ADHD. Information on anxiety diagnoses was not systematically available, but symptom scores (as assessed using the Revised Child Manifest Anxiety Scale) were elevated in both clinical groups relative to controls (see below). Participants in the control group were recruited from King's College London Dental Clinic, and by an email advertising the study at the University. The control group were broadly matched to the clinic groups to provide an overall comparable profile with respect to sex, age and ethnicity. Two children had been recruited as controls, scored above a clinical cut-off on the depression screen (30+) and were therefore excluded from the study. Ethical approval was obtained from the local hospital and academic ethical committees. The study sample sizes provided at least 80% power to detect moderate-large effect sizes (Cohen's d=0.5-0.8) in overall group comparisons, and for detecting large effect size differences (Cohen's d=0.8) for secondary comparisons of the two clinical subgroups.

Psychiatric Screens

The Mood and Feelings Questionnaire (MFQ, Angold et al. 1987) contains 34-items and assesses symptoms of depression in children and adolescents. Each item is rated as 'true', 'sometimes true' or 'not true' over the past 3 months (Wood et al. 1995). The MFQ has good diagnostic accuracy (AUC=0.82) judged against a diagnosis of MDD and high internal consistency (alpha=0.94; Wood et al. 1995; alpha=0.96 in the present study). The Olweus Aggression Inventory (Olweus 1977) consists of 32 items relating to aggression, non-aggressive delinquency and oppositionality. Participants were asked to rate each event as 'untrue', 'true, but not in last 3 months', or 'true, in last 3 months'. To generate a total score, recent events were given a score of '2' while past events were scored '1'. Scale reliability in this sample was good (alpha=0.88).

In addition, levels of anxiety were assessed to ensure that any difference in cognitive processing between the two

clinical groups was not due to the presence of comorbid anxiety symptoms rather than presence or absence of conduct disorder. The Revised Children's Manifest Anxiety Scale (RCMAS, Reynolds and Richmond 1978) contains 28 items assessing symptoms of anxiety over the past 3 months. Each item is rated 'yes' or 'no'. The scale showed good reliability in this sample (alpha=0.85).

The Face Emotion Task

Facial expressions were posed by four adult volunteers aged between 20 and 34 years. Two of the volunteers were female, and two were male. All faces were Caucasian. The four expressions (sad, happy, angry and fearful) were posed according to Ekman's (1976) description of facial expressions. In addition, a neutral photograph of each volunteer was taken. All faces were photographed from a full frontal view against a clear background, and were scaled to a standard size in Adobe Photoshop. The facial expressions of the 'prototypes' were validated in a pilot study, and all expressions were recognised at a 95% level of accuracy or better. To construct faces that varied in intensity of the four emotional expressions of interest, each of the four prototype expressions was blended with the neutral expression for each volunteer using the Ulead Morph Studio 1.0 software. Eighty facial expressions were created along four continua (happy-neutral; sad-neutral; fear-neutral; anger-neutral). Using a method similar to that used by Sprengelmeyer et al. (1996) prototypes were blended to create five 'morphed' faces along each continuum. For example, the happiness-neutral continuum consisted of faces that were: 90% happy, 70% happy, 50% happy, 30% happy, and 10% happy (See supplementary material for sample stimuli). Participants were tested at home. Printed photographs (A4 size) of eighty faces (4 expressions x 4 actors x 5 intensity levels) were presented one at a time in a random order by the interviewer for a maximum duration of five seconds each. After presentation of each face participants were required to rate the face as happy, sad, fearful or angry, and the interviewer recorded their response.

Statistical Analysis

Mean rates of correct identifications ("hits") were computed for each expression and for each level of intensity. Overall accuracy in expression processing is indexed by the average of these scores across the complete stimulus set. When examining performance for specific emotions, however, it is important to consider both hits and false alarms. False alarms (FA) were defined as the rate of misidentifications for faces at a particular level of intensity. For example, the FA rate for sad faces is given by the rate at which participants labelled 10% angry, 10% fearful, or 10% happy faces as sad. In accordance with signal detection theory, we used d-Prime scores (Miller 1996) as a measure of recognition accuracy taking account of both hits and false alarms. D-Prime scores were calculated by subtracting z-transformed false alarm rates from z-transformed hit rates, i.e. z(hits)-z(false alarm). In line with common practice (Miller 1996), where d-prime would otherwise be undefined (0% or 100% correct identifications or false alarms), values of 0% or 100% hits were replaced with 10% and 90%, and values of 0% or 100% false alarms were replaced with 4% and 96%. Higher d-prime scores indicate better performance, whilst chance level corresponds to a d-prime of 0 (i.e. d-prime=0 if the hit rate equals the false alarm rate). The maximum possible d-prime score for this task was 3.03, and scores ranged from −1.48 to 3.03. Hit and false alarm rates are presented separately for each emotion to allow a better understanding of the nature of face emotion processing biases across the three study groups.

First, a one-way analysis of variance was used to test the main effect of group on overall emotion recognition performance. Second, one sample t-tests were used to compare performance for each group and for every emotion at each intensity against chance level. The comparison value in these analyses was a d-prime of 0. For this set of analyses an alpha level of 0.01 was used to correct for the number of one-sample t-tests conducted. Third, mixed-design analyses of variance (with group as the between-subjects factor and intensity as the within-subjects factor) were used to assess effects on overall accuracy (d-prime), correct recognition rates (hits), and false alarm rates for each of the four emotions. Bonferroni post-hoc comparisons examined patterns of significant between-group differences.

Results

Demographic Background and Symptoms of Depression and Conduct Disorder by Clinical Status

The three groups did not differ in terms of sex, $\chi^2(2)=0.1$, $p=0.9$, age, $F(2, 86)=1.33$, $p=0.3$, ethnicity (around 15% in each group were from a non-white background), $\chi^2(2)=0.14$, $p=0.9$, family social class, $\chi^2(10)=11.0$, $p=0.3$, or parental education, $\chi^2(6)=10.7$, $p=0.10$. However, there was a significant difference in family composition, with 68% of depressed individuals with comorbid conduct disorder living in a single parent or step parent family, compared with 32% of those with depression only and 29% of controls, $\chi^2(2)=12.6$, $p=0.01$. The two clinical groups had elevated MFQ depression symptom scores, but did not differ from one another (Depressed $M=40.1$, $SD=12.6$, Comorbid $M=42.7$, $SD=13.2$, Control $M=13.0$, $SD=8.6$), $F(2, 86)=68.1$, $p<.001$. The comorbid group had higher

conduct problem scores than both the other groups, with no significant elevation in the pure depressed group (Depressed M=11.3, SD=7.1, Comorbid M=20.4, SD=9.4, Control M=8.5, SD=5.7), $F(2, 86)=20.0$, $p<.001$. Both clinical groups had higher levels of anxiety than the control group but did not differ from each other ($F(2, 86)=49.07$, $p<.001$; D, CM>C).

Overall Accuracy for Facial Expression Recognition

No significant differences were found between the groups in their general ability to identify facial emotions, $F(2, 86)=1.42$, $p=0.25$. The average rate of correct responses was 66.8% (SD=7.3) for the depressed group, 64.5% (SD=4.2) for the comorbid group, and 64.6% (SD=5.6) for the control group.

Accuracy for Specific Facial Expression – D-prime Analyses

First, the study sought to establish the minimum levels of intensity at which participants in the three groups could recognise each emotion at above chance level. Here, performance depends both on the correct identification rate for targets and the rate of false alarms, and is described using d-prime scores. One sample t-tests showed that d-prime scores exceeded chance level (i.e. d-prime=0) in almost every case for each intensity level and for each emotional expression. This was true for both depressed subgroups and for controls ($p\leq0.001$ for happy expressions; $p\leq0.01$ for sad expressions; $p\leq0.001$ for fearful expressions). The one exception was that lowest intensity angry expressions did not exceed chance level in the two depressed groups (correcting for multiple testing), depressed $t(28)=2.26$, $p=0.03$, comorbid $t(22)=2.31$, $p=0.03$.

Next, analyses examined whether there were group differences in recognition performance for the four types of facial expressions. Table 1 provides details of d-prime scores for each facial expression and intensity level. Figures 1, 2, 3 and 4 further illustrate a breakdown of the levels of hits and false alarms for each group. The figures display performance over the five levels of intensity for each expression.

Mixed-design analyses of variance of d-prime scores, taking account of performance over the five levels of emotion intensity, as expected, showed significant effects of intensity for each expression ($p<0.001$). Higher intensity expressions were identified more accurately (see Table 1). There were no significant main effects of group for sad faces, $F(2, 86)=1.75$, $p=0.18$, for angry faces, $F(2, 86)=0.39$, $p>0.6$, for fearful faces, $F(2, 86)=0.93$, $p>0.3$, or for happy faces, $F(2, 86)=1.89$, $p=0.16$. There was a significant interaction between group and intensity for fearful faces, $F(8, 344)=2.63$, $p=0.01$, with better discrimination of high intensity (90%) fear expressions from other high intensity expressions amongst controls than amongst depressed patients, $t(64)=2.25$, $p=.025$ (Table 1). Tests of the interaction between intensity level and group were not significant for sad faces, $F(8, 344)=0.56$, $p>0.8$, for angry faces, $F(8, 344)=1.77$, $p=0.08$, or for happy expressions, $F(8, 344)=0.91$, $p>0.5$.

Table 1 Recognition performance by expression intensity level and group (perfect performance d'=3.03; chance level performance d'=0)

	Depressed (N=29) mean d' (SD)	Comorbid (N=23) mean d' (SD)	Control (N=37) mean d' (SD)
Sad			
10%	0.76 (0.73)	0.63 (0.85)	0.53 (0.75)
30%	0.81 (0.81)	0.56 (0.59)	0.70 (0.66)
50%	1.86 (0.63)	1.83 (0.48)	1.71 (0.64)
70%	2.46 (0.56)	2.25 (0.58)	2.18 (0.56)
90%	2.50 (0.43)	2.36 (0.48)	2.51 (0.53)
Happy			
10%	0.93 (0.81)	0.71 (0.78)	0.62 (0.77)
30%	1.80 (0.69)	1.52 (0.57)	1.47 (0.78)
50%	2.70 (0.43)	2.66 (0.51)	2.57 (0.47)
70%	2.94 (0.37)	2.90 (0.19)	2.89 (0.33)
90%	2.95 (0.26)	2.98 (0.18)	2.97 (0.16)
Fear			
10%	0.47 (0.58)	0.59 (0.62)	0.47 (0.35)
30%	0.99 (0.65)	0.58 (0.63)	0.68 (0.49)
50%	2.21 (0.65)	1.98 (0.70)	2.18 (0.62)
70%	2.37 (0.71)	2.18 (0.71)	2.52 (0.41)
90%	2.21 (0.79)	2.47 (0.69)	2.58 (0.53)
Angry			
10%	0.29 (0.69)	0.39 (0.80)	0.29 (0.39)
30%	0.64 (0.39)	0.69 (0.43)	0.72 (0.48)
50%	1.76 (0.71)	1.44 (0.70)	1.29 (0.67)
70%	2.06 (0.75)	2.04 (0.46)	1.93 (0.67)
90%	2.36 (0.55)	2.35 (0.61)	2.51 (0.55)

Taken together these findings indicate no major differences in face expression recognition accuracy between depressed and non-depressed children and adolescents (see Table 1). To examine possible differences in processing bias, the next step was to separately examine rates of identifications and misidentifications of each expression, i.e. hits and false alarms.

Analyses of Hits and False Alarms

Mixed-design analyses of variance, taking account of performance over the five levels of emotion intensity, showed significant effects of intensity on number of correct hits for each expression ($p<0.001$), but no significant main effects of group for happy faces, $F(2, 86)=1.43$, $p=0.2$, for sad faces, $F(2, 86)=1.02$, $p=0.4$, or for fearful faces, $F(2, 86)=0.31$, $p=0.7$. However, there was a significant

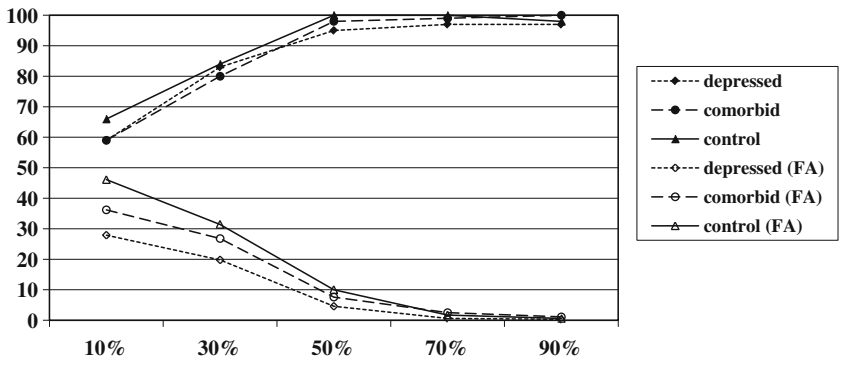

Fig. 1 Correct recognition rate for happy faces (hits), and proportion of faces at each intensity level misidentified as happy (false alarms, FA)

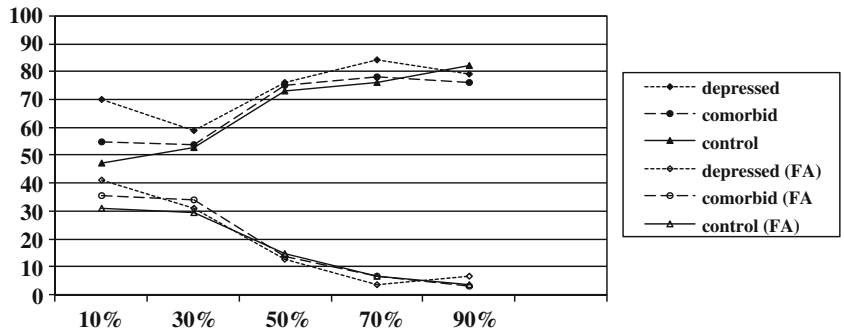

Fig. 2 Correct recognition rate for sad faces (hits), and proportion of faces at each intensity level misidentified as sad (false alarms, FA)

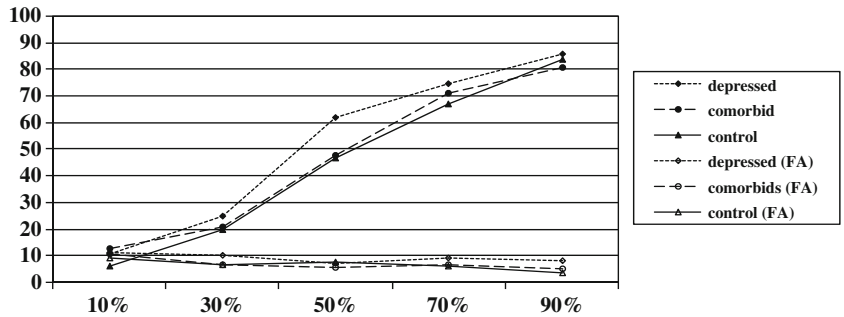

Fig. 3 Correct recognition rate for angry faces (hits), and proportion of faces at each intensity level misidentified as angry (false alarms, FA)

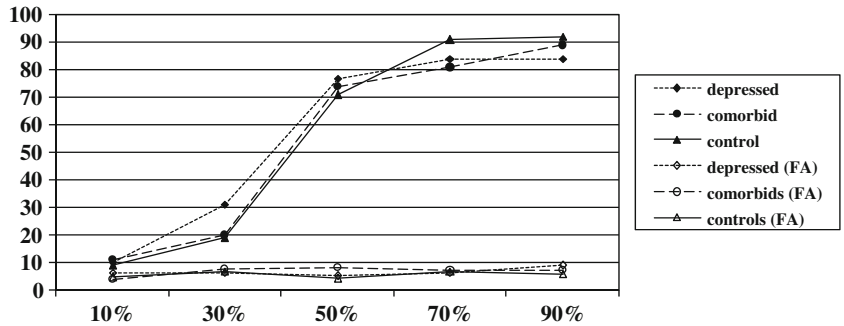

Fig. 4 Correct recognition rate for fearful faces (hits), and proportion of faces at each intensity level misidentified as fearful (false alarms, FA)

main effect of group for angry faces, $F(2, 86)=3.65$, $p=0.03$. As shown in Fig. 3, this reflects a higher identification rate amongst the depressed group as compared with the control group (posthoc comparisons: depressed vs. control, $p=.025$, other comparisons $p>0.4$). Tests of the interaction between intensity level and group were not significant for happy and angry faces, but statistically significant for sad faces, $F(8, 344)=2.02$, $p=0.04$, and for fearful faces, $F(8, 344)=2.04$, $p=0.04$. As shown in Figs. 2 and 4, depressed children and adolescents recognised low intensity sad and fearful faces better than controls, 10% sad faces: $t(64)=2.70$, $p=.009$; 30% fearful faces: $t(64)=2.09$, $p=.04$.

As shown in Figs. 1, 2, 3 and 4, false alarms were more common for low intensity than high intensity faces. Furthermore, facial expressions were much more commonly misidentified as happy or sad than as fearful or angry (compare Figs. 1 and 2 with Figs. 3 and 4). Four mixed-design analyses of variance were conducted, again taking account of performance over the five levels of emotion intensity. The dependent variables in these analyses were the rates at which participants misidentified faces as sad, happy, fearful or angry. There was a main effect of group on rates of misidentifying expressions as happy, $F(2, 86)=5.84$, $p<0.01$, as well as an interaction between intensity level and group, $F(8, 344)=3.93$, $p<0.01$. As shown in Fig. 1, and as confirmed by post-hoc tests, this reflected a significantly greater level of "happy false alarms" by controls than depressed children ($p=.003$), especially at lower levels of emotional intensity. Post-hoc comparisons showed no differences between the comorbid group and either of the other groups ($p>0.3$). For "sad false alarms", there was no significant main effect of group, $F(2, 86)=0.31$, $p>0.6$, but a significant interaction between expression intensity and group, $F(8, 344)=2.46$, $p=0.01$. As shown in Fig. 2, depressed participants made more false alarms than the controls at the lowest level of intensity, $t(64)=2.08$, $p=.04$. There were no significant group differences, or interactions between intensity and group, for angry or fearful faces ($p>0.2$).

Effect Sizes and Power to Detect Differences in Face Processing Between the Two Depressed Subgroups

Effect sizes were derived from estimated mean differences for each of the above analyses for comparisons of the two depressed subgroups. These ranged from d=.07 to d=.25 for discrimination accuracy (d-prime), from d=.11 to d=.21 for correct identifications (hits), and from d=.03 to d=.35 for false alarms. The average effect size was estimated at d=.17 across all comparisons. As noted above, none of these differences was statistically significant. Post-hoc power calculations showed that sample sizes of more than $N=500$ per group would be required to detect any small effect size of this magnitude.

Discussion

Main Findings

This study found several interesting results. First, depressed children and adolescents showed no overall deficit in recognising facial expressions. Overall accuracy did not differ across the groups. Like the non-disordered controls, those with depression identified high intensity facial expressions with a high degree of accuracy, and even the lowest intensity expressions were recognised at above chance level by all groups. Second, there were clear differences in the patterns of response biases affecting processing of specific facial expressions, especially at lower intensity levels. D-prime analyses showed better discrimination of low intensity happy faces by depressed participants compared to controls. Separate analyses of hits and false alarms showed that this finding reflected a bias in the control group for labelling other low intensity expressions as happy. For sad faces, analyses suggested a more general difference in response biases between the groups with higher rates of both correct identifications and misidentifications as sad by those with depression. It seems that impairments in face processing associated with depression are more marked by biases for ambiguous faces than by absolute impairment in emotion processing accuracy (Surguladze et al. 2004). Finally, this is the first study to compare face emotion processing between depressed children with and without comorbid conduct disorder. No clear differences were found between these two subgroups.

Depression and the Nature of Face Processing Biases

There were two main differences in the types of bias between the pure depressed and control groups.

Depressed children and adolescents labelled more low intensity faces as sad. This finding is in keeping with previous research, suggesting that depressed people are biased towards perceiving negative emotions in ambiguous faces (e.g. Bouhuys, Geerts and Gordijn 1999). Second, the finding that low intensity happy faces were more accurately discriminated from other facial expressions due to a lower rate of happy false alarms amongst those with depression is a novel and interesting finding. It suggests that there may be 'positive' information processing biases amongst non-depressed individuals, which are less marked or absent amongst depressed individuals. Although the possibility of

depressed people merely lacking other people's positive cognitive biases has been raised before (e.g. Alloy and Abramson 1979; Matthews and Antes 1992; Mezulis et al. 2004), this has been difficult to assess without objectively defined measures. The current findings based on an experimental task involving the perceptual processing of facial expressions provide important support. The results are also consistent with studies of adults. Joormann and Gotlib (2007) used a dot-probe task to provide evidence of attentional biases involving selective attention to sad faces among depressed adults, and selective avoidance of sad faces in healthy controls. Interestingly, Tranter et al. (2009) found that anti-depressant medication improved recognition of happy faces, and reduced recognition of negative emotions.

Previous research has made a number of predictions about the processing of fearful faces. For example, it has been shown that depression is associated with differences in amygdala activation, which in turn is associated with the processing of fearful expressions (Herba and Phillips 2004; Monk et al. 2008). Pine et al. (2004) also found that depression is associated with impaired encoding of fearful expressions. The present study, however, found no evidence of any deficit or bias affecting the perception and identification of fearful faces in depressed children regardless of comordity with conduct disorder. Accuracy of processing was good at higher intensity levels for all three groups, and depressed individuals actually showed marginally better recognition of fearful expressions at low intensity compared with the control group. A recent meta-analysis suggests that there is also a reliable fear-specific face processing deficit linked with amygdala dysfunction in antisocial individuals (Marsh and Blair 2008). However, this review excluded individuals with other axis-I psychiatric disorders such as depression, and half the studies focused on psychopathic samples. Our study did not assess psychopathy, but it is possible that fear processing deficits are more pronounced in antisocial individuals with psychopathic tendencies than in those with comorbid depression.

Finally, in relation to the processing of anger, there were no group differences in overall recognition accuracy: the identification of angry faces was good at high intensity levels, and there were few false alarms at any intensity level. This stands in contrast to some previous research demonstrating differences in anger recognition in children with, or at risk for, psychopathology. However, prior research is not clear-cut, showing marked heterogeneity in patterns of performance. Distinct clinical or developmental subtypes of disorder may in part explain inconsistencies in findings across studies. For example, adolescents with conduct disorder have been shown to have impaired anger recognition, but this is more apparent in those with early onset conduct disorder (Fairchild et al. 2009, 2010). Information on age at onset of disorder was not available in the current study, so could not be addressed here. In contrast, physically maltreated children (a group at higher risk for both conduct disorder and depression) have been shown to demonstrate enhanced sensitivity to angry facial expressions (Pollak and Tolley-Schell 2003). Further research is needed to clarify patterns of development of anger recognition for different clinically relevant subtypes of depression and conduct disorder.

Furthermore, methodological factors are also likely to be important, and these should be taken into account when making comparisons with other studies. Group differences here only became apparent with increasing task difficulty. By examining patterns of hits and false alarms (and not just overall accuracy) we were also able to demonstrate that differences in face processing between depressed and non-depressed children largely reflected biases rather than overall accuracy in judging facial affect for low-intensity expressions. There are other factors which were impossible to examine within the constraints of the present design. These include temporal factors involved in face processing. Thus we did not vary the presentation time of facial stimuli, nor assess children's reaction speeds.

Limitations

There are a number of limitations. Mean levels of facial emotion recognition accuracy for the comorbid group fell between those of the pure depressed and control groups. Comparisons of the two clinical groups revealed no significant differences in face processing, but the study was only adequately powered to detect large effects. Type II errors cannot be ruled out, although estimated effect sizes for comparisons of depressed and comorbid samples were all small. Considerably larger samples would be required to adequately test any such subtle differences in emotion recognition that might distinguish these subgroups of depression, although this is likely to be hard to achieve using clinically defined samples such as those studied here. Second, the faces used were a novel set of stimuli developed for this study, the number of actors used was small, and face-specific effects cannot be ruled out altogether. The constraints of the study meant it was not possible to include a larger stimulus set which would also have allowed investigation of differences in emotion processing according to actor age, gender or ethnicity, and improved the ecological validity of the study. However, the universality of face expression recognition means that effects of actor characteristics on expression recognition would be expected to be small (Ekman et al. 1969). Indeed, pilot data demonstrated good validity, with all prototypes used here identified with a high degree of accuracy. Third,

we only focused on a subset of possible facial expressions. Recent research suggests that disgust recognition may be impaired among adolescents with conduct disorder (Fairchild et al. 2009, 2010; but see also Marsh and Blair 2008), and it would be interesting to examine processing of this expression in those with comorbid depression and conduct disorder. Fourth, the study focused on emotion perception and identification, and complementary designs focusing on attentional mechanisms and memory would be useful for future work in these groups. Fifth, the study included a broad age range of children and adolescents (average age of 15 years). However, it was not feasible to look at developmental processes here; larger and ideally longitudinal sample designs would be required. Finally, study groups were based on diagnoses made by child psychiatrists. This has advantages for the generalisation of research findings to clinical practice, and validity of diagnoses was supported by findings from the symptom screens later administered as part of the study. Nevertheless, it would have been preferable if diagnoses were separately confirmed by structured research interviews.

Implications

The results have important implications. First, juvenile depression does not appear to involve any gross inaccuracy in face processing ability. This stands in contrast to patterns of face processing impairment in other disorders such as autism (Baron-Cohen, Spitz and Cross 1993), psychopathy (Blair 2003) or Huntington's disease (Sprengelmeyer et al. 1996). Rather, depressed children and adolescents differed in the processing of ambiguous faces from non-depressed children. The results show that even at the basic perceptual level involved in looking at other people's faces, the world is filtered in a less positive way for depressed children. Findings showed a reduced 'happy bias' and enhanced 'sad bias' for low-intensity emotion faces in those with depression. As already noted, low intensity facial expression processing may be more relevant to everyday life, as this underlies common everyday social interaction. Perceiving people as happier is likely to have consequences for our interactions with other people, and in turn their interactions with us.

The current study raises several ideas for further research. It would be interesting to look at evidence for a lack of optimism bias in other spheres of functioning. A second issue is whether and how differences in expression recognition relate to young people's inter-personal functioning. For example, are those with the most negative interpretations of others' facial expressions those with the most interpersonal problems? Could problems in social relationships mediate the associations between expression processing and depressive relapse as previously suggested (Bouhuys et al. 1999)?

A different important area of potential research concerns the ways in which facial expression recognition develops – both typically and atypically. Face expression processing is to some extent hard-wired (Ekman et al. 1969), but is also influenced by individual experience (Pollak and Sinha 2002). Long-term longitudinal studies tracking the development of individual differences in face emotion processing are largely absent at present. It is also unclear whether there are gender-specific patterns of development of emotion processing, and how these relate to the steep increase in risk for depression in females during adolescence. A crucial question from a prevention perspective is whether face expression processing predicts either risk for new onset or recurrence of depression in future. One implication of the current study is that new larger-scale prospective research should focus not just on prototypical face expressions but use more detailed assessments of face processing across a range of emotion intensities, and that assessment of face processing biases may be as informative as assessment of overall discrimination accuracy.

Neuroimaging studies have identified key brain regions involved in processing facial expressions, and highlighted possible neural substrates for differences between depressed and non-depressed individuals (Herba and Phillips 2004; Monk et al. 2008), but none have addressed these issues in comparisons of depressed children with and without other comorbid disorders. Finally, studies of face processing in conduct disorder also highlight differences by age at onset with early onset and adolescent onset conduct disorder associated with different patterns of expression recognition deficits (Fairchild et al. 2009). Studies of larger samples of depressed patients with comorbid conduct disorder will be required to take account of this heterogeneity in future research.

To conclude, the present study found that juvenile depression is not marked by any gross impairment affecting ability to discriminate facial expressions. Young people with clinical depression do, however, exhibit distinct patterns of face emotion processing biases relative to non-depressed controls. Specifically, low intensity facial expressions are more often perceived as sad and less often as happy. Further research is needed to clarify whether or not face processing biases pre-date the development of depressive disorder, and whether they contribute to functional impairments that often accompany depression.

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