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The development of emotion recognition from facial expressions and non-linguistic vocalizations during childhood

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Sensitivity to facial and vocal emotion is fundamental to children's social competence. Previous research has focused on children's facial emotion recognition, and few studies have investigated non-linguistic vocal emotion processing in childhood. We compared facial and vocal emotion recognition and processing biases in 4- to 11-year-olds and adults. Eighty-eight 4- to 11-year-olds and 21 adults participated. Participants viewed/listened to faces and voices (angry, happy, and sad) at three intensity levels (50%, 75%, and 100%). Non-linguistic tones were used. For each modality, participants completed an emotion identification task. Accuracy and bias for each emotion and modality were compared across 4- to 5-, 6- to 9- and 10- to 11-year-olds and adults. The results showed that children's emotion recognition improved with age; preschoolers were less accurate than other groups. Facial emotion recognition reached adult levels by 11 years, whereas vocal emotion recognition continued to develop in late childhood. Response bias decreased with age. For both modalities, sadness recognition was delayed across development relative to anger and happiness. The results demonstrate that developmental trajectories of emotion processing differ as a function of emotion type and stimulus modality. In addition, vocal emotion processing showed a more protracted developmental trajectory, compared to facial emotion processing. The results have important implications for programmes aiming to improve children's socio-emotional competence.

Understanding emotions from facial cues plays a fundamental role in the development of children's social competence. Children better able to understand facial emotional cues in social interactions have been found to form positive interpersonal relationships over time

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(Denham, 1998). The ability to discriminate facial expressions of emotion develops early in infancy. At 4 months of age, infants discriminate anger and happiness (Barrera & Maurer, 1981) and show a preference for looking at positive (happy faces with toothy smiles) versus negative (sad) faces (Oster, 1981). In the first year of life, infants recognize emotion from faces and can adjust their social behaviour to the emotional message conveyed facial expressions (Hertenstein & Campos, 2004). At the beginning of the second year of life, more abstract concepts of emotion begin to emerge as shown by infant's understanding of the congruence of other people's facial emotions and actions (Hepach & Westermann, 2013). Studies on infants' perception of vocal expressions of emotion have also shown that soon after birth, infants can discriminate among vocal expressions (Grossman *et al.*, 2010) and reliably detect vocal changes from sad to happy and happy to sad by 5 months of age (Walker-Andrews & Lennon, 1991). At 7 months of age, infants recognize congruence between the emotional message conveyed by facial and vocal expressions, as reflected by a larger centro-parietal positive component (~600 ms) in response to face–voice pairs conveying congruent (i.e., happy) compared to incongruent (i.e., happy, angry) emotional information (Grossmann, Striano, & Friederici, 2006). This cross-modal matching has been argued to reflect the development of a more stable representation of emotions that is evident across facial and vocal modalities (Walker-Andrews, 1997).

While basic emotion recognition is evident in infants, early childhood is argued to represent a key period for the development of emotional understanding (Denham *et al.*, 2003). Facial emotion processing continues to develop from the preschool years through to middle childhood and adolescence (Herba, Landau, Russell, Ecker, & Phillips, 2006). Research using dynamic facial expressions has found within age group differences in emotion recognition with sadness and anger being the least accurately recognized among happiness, fear, anger, sadness and disgust in 4- to 16-year-olds (Montirosso, Peverelli, Frigerio, Crespi, & Borgatti, 2010). Similarly, Gao and Maurer (2009) showed significantly higher misidentification rates for sad faces in 10-year-olds compared to adults. Accuracy of recognizing sad faces improved with age at a lower rate compared to happiness, fear and disgust in 4- to 15-year-olds (Herba *et al.*, 2006). Children under 11 years made more errors when asked to recognize facial emotional expressions compared with those in early adolescence (Tonks, Williams, Frampton, Yates, & Slater, 2007). Similarly, research has shown that the neural substrates involved in facial emotion processing are not adult-like until early adolescence (Batty & Taylor, 2006).

Despite advances in our understanding of the development of visual emotion processing, much less is known about the development of vocal emotion processing. In adults, emotions can be communicated accurately through speech (Scherer, Banse, & Wallbott, 2001) and emotional intonation can be processed independently of the linguistic aspects of speech (Pell, 1998). Adults show a good understanding of emotion from non-linguistic vocalizations with accuracy rates of 70% (Maurage, Joassin, Philippot, & Campanella, 2007). Considering children's understanding of emotions from non-verbal vocalizations, a recent study asked 5- to 10-year-old children to match simple (e.g., anger, sadness) and complex (e.g., surprise, contentment) vocal expressions to pictures (photographs of people). The results showed that age significantly predicted recognition accuracy for surprise, but no other emotions, from non-verbal vocalizations (Sauter, Panattoni, & Happé, 2013). However, this study did not directly compare different emotions and modalities (i.e., face, voice) in different age groups to allow an exploration of children's understanding of emotion to be distinguished across development.

Studies examining the development of vocal emotion recognition have mainly relied on linguistic stimuli (Baum & Nowicki, 1998; Hortacsu & Ekinci, 1992). While there is some evidence that preschoolers can recognize the speaker's angry, happy, and neutral emotional state (Hortacsu & Ekinci, 1992), further research has found that 4- and 5-year-old children make more errors when asked to recognize sentences with angry, happy, and sad tone of voice compared to 9- and 10-year-old children (McClanahan, 1996; Mitchell, 1995), suggesting that recognition accuracy improves from the preschool years to middle childhood. It has further been suggested that pre-adolescence marks another important developmental stage for the recognition of emotion from speech. Sensitivity to emotional speech continued to develop and reached adult-like levels at about 10 years of age (Baum & Nowicki, 1998). No improvement with age in the perception of emotional speech (angry, happy, sad, and neutral) across a number of tasks was found for 9- to 15-year-olds (Tonks *et al.*, 2007).

Studies that directly compare vocal and facial emotion processing have shown that for both adults and children, facial (vs. vocal) emotion cues are easier to recognize. For example, studies using linguistic stimuli in preschoolers (Nelson & Russell, 2011) and primary school-aged children (Nowicki & Duke, 1994) found increased recognition accuracy for facial compared to vocal emotions, suggesting that vocal emotion processing lags behind visual emotion processing. Researchers have argued that facial cues provide more discriminable emotion information compared to speech vocal cues (Pell, 2002).

Further research studies using linguistic stimuli have developed methodologies using two different intensities to measure emotion recognition (Baum & Nowicki, 1998). This approach is argued to represent a more ecologically valid and sensitive method of detecting developmental and individual differences in emotion expression discrimination (Montagne, Kessels, De Haan, & Perrett, 2007). In addition, it provides some indication of the extent to which children and adults show common or different misattributions of emotion or a bias to respond with particular emotions. Moreover, response biases are often used to understand misinterpretation of emotions in typical development and are also important in understanding atypical social behaviour in children (i.e., anger biases in aggression).

This study extends previous research to identify age-related changes in the processing of emotion from both visual and auditory modalities from preschool to 11 years of age. In contrast to previous research, which has typically used linguistic stimuli, we utilized non-linguistic stimuli. This manipulation is important because the linguistic content of speech can influence children's judgment of the emotional tone of the speakers (Morton & Trehub, 2001) and previous research has shown that language processing can have a distracting effect on children's vocal emotion processing (Morton & Trehub, 2007). Moreover, in real-life situations, vocal emotions are most of the time expressed using non-speech prosody (Belin, Fecteau, & Bédard, 2004; Wildgruber, Ackermann, Kreifelts, & Ethofer, 2006). This study represents the first attempt to study the development of processing emotional prosody independently of linguistic content at different intensities. We included three intensities to allow an assessment of sensitivity to discriminate an emotional expression and to help optimize task sensitivity to explore developmental and modality-specific effects. A recent study (Sauter *et al.*, 2013) in children's understanding of emotions from non-verbal vocalizations has not compared different intensities and modalities in different age groups.

We extended previous research by including response bias as well as recognition accuracy to measure emotion processing. While a large body of literature has focused on response bias in relation to facial emotion processing (Barth & Bastiani, 1997; van Beek &

Dubas, 2008; Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007), there is little developmental research looking at patterns of response bias in emotional prosody processing. The study of response bias is important because it reveals the pattern of misattribution errors and decision criteria underlying recognition (Scherer, 2003; Wagner, 1993). This study can make important contributions in addressing theoretical issues on the nature of socio-cognitive development and informing clinical and educational practices that aim to improve children's emotional and social competence.

Based on the existing literature, we hypothesized that recognition accuracy would improve with age and that children would be more accurate to recognize angry and happy compared to sad expressions, faces compared to voices and high compared to low-intensity expressions. We also hypothesized that recognition for sadness, voices, and low-intensity expressions would follow a slower developmental trajectory. *A priori* hypothesis for bias was not made due to the lack of prior knowledge in this area.

Methods

Participants

From 195 participants initially approached, 109 individuals (88 children and 21 adults) participated in the study. Children were recruited from primary schools and were selected from three age groups (see Table 1) based on the boundaries of UK classroom ages and previous developmental research (Batty & Taylor, 2006). Child assent and adult informed consent were obtained prior to participation. Data were also collected from healthy adults recruited from University undergraduates. The study was approved by the Psychology Ethics Committee.

Materials

We used facial and vocal expressions across three intensity levels.

Facial stimuli

Facial stimuli consisted of 10 expressions from a female model and included three emotions (angry, happy, and sad) across three intensity levels (mild – 50%, moderate – 75%, and high – 100%) and one neutral expression. The faces were selected from the Facial Expression of Emotion Face Set (Ekman & Friesen, 1976; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002) – A standardized stimulus set used widely with children and adolescents (Durand *et al.*, 2007). A main advantage of this stimulus set is that validated intensity data exist for it (see Young *et al.*, 2002 for details). In this study, we selected facial expressions from one female model based on high percentage recognition rates (angry: 89.50%, happy: 99.10%, and sad: 89.70%; Young *et al.*, 2002).

Table 1. Participant characteristics

Age groups	Age range	Mean	*SD*	*N*
Preschoolers	3.50–5.50	4.46	0.44	23 (11 males)
Young children	6.00–9.00	7.42	1.02	44 (24 males)
Older children	10.00–11.00	10.13	0.35	21 (8 males)
Adults	21.67–45.83	27.83	5.33	21 (11 males)

Vocal stimuli

Non-word vocal stimuli (interjection 'ah') were derived from a battery of vocal emotional expressions (Maurage *et al.*, 2007) and were normalized and standardized regarding acoustic properties including 700-ms duration, 16000 Hz recording frequency, and 70 dB intensity. These intense – nominally 100% – vocal stimuli have already been validated in adults (Maurage *et al.*, 2007). Mild – nominally 50% and moderate – nominally 75% intensity stimuli were created by manipulating the acoustic parameters of full intensity – 100% stimuli. A standard morphing procedure was performed by calculating a continuum between neutral and emotional vocal stimuli, with neutral being the 0% step and the full emotional stimulus being the 100%. This was achieved using STRAIGHT (Kawahara & Matsui, 2003, see Data S1).

Validation of vocal stimuli

The stimuli morphed for this study consisted of angry, happy, and sad expressions of both mild – 50% and moderate – 75% intensity and a neutral expression from five actresses. These stimuli were validated in a separate sample of 40 participants: 22 adults (mean age = 31.54, *SD* = 9.36, 14 girls) and 18 children (mean age = 6.60, *SD* = 0.70, 7 girls). These children were recruited via schools and were not included in the main study. Adults listened to each item and rated whether it was '*angry*', '*happy*', '*sad*', or '*neutral*' before reporting the perceived intensity on a 1–4 scale presented visually (e.g., 'not at all angry' to 'extremely angry'). Children listened to each item and were asked to classify the expression by selecting one of four response options read out to them by the experimenter (labels counterbalanced in order). Subsequently, children were asked to indicate how intense the emotion they had selected was by pointing to one of four varying schematic face drawings that increased in intensity (see Figure S1). These drawings have been validated in previous research (Voyer, Bowes, & Soraggi, 2009).

Accuracy for each expression was significantly greater than chance (25% given four response options). Mean percentage agreement among participants on the identification of a particular emotion was as follows: mild – 50%: angry: 52%, happy: 41.50%, and sad: 42.50%, moderate – 75%: angry: 68.50%, happy: 50.50%, sad: 54%, and neutral: 48%. When entering percentage agreement scores into a mixed design ANOVA with emotion (angry, happy, sad) and intensity (mild – 50%, moderate – 75%) as within-subject factors, we found significant main effects of emotion ($F(2, 39) = 5.36$, $p < .01$, $\eta_p^2 = .12$) and intensity ($F(1, 39) = 27.30$ $p < .001$, $\eta_p^2 = .41$), but no significant emotion × intensity interaction ($F(2, 39) = .90$, $p = .40$, $\eta_p^2 = .02$). *Post-hoc* pairwise comparisons showed that participants were significantly more accurate to discriminate angry compared to sad expressions ($p < .05$) and moderate – 75% intensity compared to mild – 50% intensity expressions ($p < .001$). The main study included all three intensity levels (mild – 50%, moderate – 75%, and high – 100%). One item per emotion × intensity condition (plus neutral) was selected for the main study, resulting in a set of 10 vocal expressions. Item selection was based on a high percentage of interjudge agreement because our main goal was to select stimuli that would be recognized by most participants as communicating a particular emotion. This empirical–normative approach has been adopted in established batteries of vocal emotion recognition (Nowicki & Duke, 1994) and optimizes the capture of emotional expressions as they occur in real-life situations. Mean percentage agreement for the selected stimuli was as follows: mild – 50%: angry: 50%, happy: 40%, and sad: 40%, moderate – 75%: angry: 77.50%, happy: 72.50%, sad: 72.50%, and neutral: 60%.

Item-by-item percentage (%) agreement on vocal stimuli used in the validation study is provided in Table S1.

Experimental paradigm

Facial and vocal stimuli were presented in two separate tasks and counterbalanced order across participants. Participants were instructed to classify each expression as either 'angry', 'happy', 'sad', or 'neutral'. Facial and vocal expressions were presented across 3 emotions (angry, happy, and sad) × 3 intensities (mild – 50%, moderate – 75%, and high – 100%) plus one neutral expression resulting to a total of 10 conditions. For each task (face and voice), the practice block consisted of 10 practice trials (1 per stimulus type), while the main task consisted of 12 presentations of each of the 10 conditions resulting to a total of 120 trials. Each trial began with the presentation of a central fixation cross (500 ms) followed by the presentation of the stimulus (1000 ms for faces; 700 ms for voices) and then a blank screen until the participants responded, and there was a 1,000-ms interval before the onset of the next trial. Adult and child participants responded by keyboard button press representing four possible response choices. Stimuli were presented, and responses were logged in via Inquisit software (www.millisecond.com).

Procedure

Participants were tested individually in a quiet room. The task was introduced to the children as a game. They were told, 'Children can tell how adults feel by looking at their faces and listening to their voice. Today we are going to play a game about feelings. Feelings are like when you feel angry or happy. Do you know what these words mean? Do you ever feel angry? What makes you angry?' This was repeated for all emotions used in the study. If the child did not respond, the experimenter went on to the other emotions and then returned to the emotion to which the child had not responded. Three preschoolers whose performance was not perfect on all emotions were not tested in this study. For all the remainder children, performance was perfect on all emotions. This method ensured that children understood the meaning of all emotion labels before taking part in the study. In addition, after this introduction to emotions, children participated in ten practice trials before the main task and all children could recognize the emotions in the practice trials. This approach was to make sure that children could understand and perform the task well before taking part in the main experimental block. Feedback was not provided after each practice trial.

The following instructions were given to all participants prior to the practice and the main task: 'You are going to see some faces/hear some voices. You need to identify the emotion in the face/voice and press one of the four keyboard buttons with the labels "angry", "happy", "sad" or "okay" to indicate your response'. [For preschoolers: 'You need to tell me if the face/voice is angry, happy, sad or okay']. Because the attention span of preschool children is typically limited, we tried to keep the task as simple as possible to obtain reliable data. As not all preschoolers were competent readers of emotion words on response buttons, immediately after presentation of the stimulus, the experimenter asked the child, 'Is this person angry, happy, sad, or okay?' The experimenter read out the emotion words in counterbalanced order across trials. This method was facilitated by the use of 24 script cards (six possible combinations of emotion words × four emotions). The same experimenter read out the response words to all preschoolers in a neutral tone of voice and did not provide any prompts or other cues to the answer. The total testing time was about 20 min (10 min for each task). Halfway through each task, children were given the opportunity to have a short break. Children were reminded to pay attention throughout the task and were given a sticker at the end of each 5-min block. The task was administered by an experienced researcher and children engaged in the task well. At the end of the study, children were given a certificate as a small 'thank you' gift.

Data processing

Raw data were transformed into measures of accuracy and bias according to the two high-threshold models (Corwin, 1994). This approach has been used in previous studies examining emotion recognition accuracy in children (Chronaki *et al.*, 2013) and adults (Surguladze *et al.*, 2004).

Discrimination accuracy (Pr) is defined as sensitivity to discriminate an emotional expression and is given by the following equation: Pr = ((number of hits + 0.5)/(number of targets + 1)) – ((number of false alarms + 0.5)/(number of distractors + 1)) (Corwin, 1994). Pr scores take values which tend to 1, 0, and −1 for accuracy at better than chance, close to chance, and worse than chance, respectively. Note that transformations are added in the above formulae (i.e., +0.5) to prevent divisions by zero. For example, in our task with 12 trials of each of the 10 conditions: Angry, happy, and sad at three intensity levels per emotion (e.g., 50%, 75%, 100%) plus one neutral condition, if a child classified 10 angry faces as angry but he/she also classified as angry 3 neutral faces, 4 happy 50% faces, 3 happy 75% faces, 4 sad 50% faces, 5 sad 75% faces, and 0 for all other happy/sad expressions, then his/her accuracy for angry faces would be as follows: ((10 + 0.5)/(12 + 1)) – ((3 + 4 + 3 + 4 + 5 + 0 + 0 + 0.5)/(84 + 1)) = 0.58, suggesting that accuracy is better than chance.

Response bias (Br) was defined as a participant's propensity to erroneously classify emotional expressions as angry, happy, or sad irrespective of intensity. This reflects participants' tendency to 'mislabel' an emotion. Response bias was computed according to the following formula: Br = ((number of false alarms + 0.5)/(number of distractors + 1))/(1−Pr). Values that tend to 1 indicate the presence of a systematic bias, whereas values that tend to zero (0) indicate the absence of a systematic bias. For example, in our task with 12 trials of each of the 10 conditions, angry, happy, and sad at three intensity levels per emotion plus one neutral condition, if a child had an accuracy score (Pr) of 0.58 for angry faces (combined Pr scores for angry 50%, 75%, 100%) and also classified as angry 3 neutral faces, 4 happy 50% faces, 3 happy 75% faces, 4 sad 50% faces, 5 sad 75% faces, and 0 for all other happy/sad expressions, then his/her response bias score for angry faces would be as follows: ((3 + 4 + 3 + 4 + 5 + 0 + 0 + 0.5)/(84 + 1))/(1–0.58) = 0.55, suggesting an elevated bias to anger.

Data analysis

Preliminary analyses

Kolmogorov–Smirnov tests confirmed that data met assumptions for parametric analysis. Discrimination accuracy for faces and voices was significantly different from chance, $t(108) > 11.20, p < .001$, across all emotion types. Results did not change when repeating the analyses for each emotion × intensity condition. Independent-samples *t*-tests confirmed that there were no statistically significant differences between boys and girls in discrimination accuracy, $t(107) < -.80$, $p > .42$ or response bias, $t(107) < -1.62$, $p > .11$, in the whole sample or each age group separately (all *p*s' > .11).

Main analyses

Scores of discrimination accuracy were entered into a mixed design ANOVA with emotion (angry, happy, and sad), intensity (mild – 50%, moderate – 75%, and high – 100%), and modality (face and voice) as within-subject factors and age group as the between-subject factor. As neutral expressions do not vary by intensity level and could not be included in the above model, we ran a separate ANOVA with emotion (angry, happy, sad, and neutral) and modality (face and voice) as within-subjects factor. Scores of response bias were entered into a mixed design ANOVA with emotion (angry, happy, and sad) and modality (face and voice) as within-subject factors and age group as the between-subject factor. We used partial eta-squared (Cohen, 1973, Kennedy, 1970) estimates of effect sized for the ANOVAs. Partial eta-squared can take values between 0 and 1. Values of 0.02, 0.13, and 0.26 are indicative of a small, medium, and large effect size, respectively (Murphy & Myors, 2004).

Results

Discrimination accuracy

Tables 2 and 3 display means and standard deviations for accuracy for facial and vocal expressions by emotion, intensity, and age. There was a significant main effect of age on accuracy, $F(3, 105) = 34.65, p < .001, \eta_p^2 = .50$. *Post-hoc* pairwise comparisons showed that in general, adults were significantly more accurate compared to each child group ($p < .001$) and preschoolers were significantly less accurate compared to all other groups ($p < .001$). The young (6–9-year-old) and older (10–11-year-old) children did not differ significantly from each other ($p > .05$). There was also a main effect of modality on accuracy, $F(1, 105) = 260.80$, $p < .001$, $\eta_p^2 = .70$. Participants were more accurate to recognize faces ($M = 0.68$, $SE = .01$) compared to voices ($M = 0.41$, $SE = .02$). Emotion had a significant main effect on accuracy, $F(2, 105) = 70.17$, $p < .001$, $\eta_p^2 = .40$. Participants were more accurate for angry and happy compared to sad ($p < .001$) and angry compared to happy ($p < .05$). Participants were also more accurate for angry, happy, and sad compared to neutral expressions ($p < .001$). There was a significant emotion × modality interaction effect on accuracy, $F(1, 104) = 8.80, p < .01, \eta_p^2 = .08$. Participants were significantly more accurate to recognize happy compared to neutral expressions for faces compared to voices.

Intensity had a significant main effect on accuracy, $F(2, 105) = 295.18$, $p < .001$, $\eta_p^2 = .73$. Participants were more accurate for high – 100% compared to moderate – 75% and mild – 50% intensity expressions ($p < .001$). The above results are consistent with the hypothesis that children's accuracy would improve with age and that children would be less accurate to recognize sad expressions, voices, and low-intensity expressions. There was a significant emotion × intensity interaction effect on accuracy, $F(1, 105) = 69.58$, $p < .001, \eta_p^2 = .40$. Participants were significantly more accurate ($p < .001$) to recognize high – 100% compared to mild – 50% intensity expressions for angry compared to sad expressions. There was no significant age × modality × emotion interaction effect on accuracy, $F(6, 105) = 1.60, p > .05, \eta_p^2 =. 04$.

The age effects varied by emotion type, $F(6, 105)^{\text{emotion} \times \text{age}} = 4.00$, $p < .001$, $\eta_p^2 = .10$; (see Figure 1). To explore this, we ran additional analyses in which accuracy scores of the modality × intensity conditions per emotion were averaged and then entered in one-way ANOVA examining the effect of emotion on accuracy for the age groups separately. There was a significant difference in accuracy between the age groups

Table 2. Mean (*SD*) of discrimination accuracy for facial expressions per age group, emotion, and intensity

	Angry			Happy			Sad		
Age group	50%	75%	100%	50%	75%	100%	50%	75%	100%
Preschoolers	0.39 (0.29)	0.50 (0.32)	0.60 (0.33)	0.52 (.24)	0.63 (0.27)	0.65 (0.24)	0.31 (0.28)	0.36 (0.28)	0.36 (0.28)
Young children	0.55 (0.26)	0.80 (.20)	0.84 (.19)	0.62 (0.30)	0.78 (0.23)	0.80 (0.23)	0.45 (0.24)	0.55 (0.25)	0.60 (0.24)
Older children	0.67 (0.23)	0.88 (.09)	0.90 (.03)	0.69 (0.26)	0.87 (0.13)	0.90 (0.08)	0.45 (0.22)	0.58 (0.22)	0.70 (0.18)
Adults	0.74 (0.21)	0.91 (.04)	0.93 (.02)	0.87 (0.09)	0.91 (0.06)	0.91 (0.04)	0.57 (0.26)	0.79 (0.17)	0.89 (0.05)

Note. Accuracy: −1 = worse than chance, 0 = chance, 1 = better than chance, preschoolers (4–5 years), young children (6–9 years), older children (10–11 years).

Table 3. Mean (*SD*) of discrimination accuracy for vocal expressions per age group, emotion, and intensity

	Angry			Happy			Sad		
Age group	50%	75%	100%	50%	75%	100%	50%	75%	100%
Preschoolers	0.06 (0.12)	0.20 (0.28)	0.21 (0.30)	0.08 (0.13)	0.09 (0.21)	0.14 (0.24)	0.08 (0.21)	0.11 (0.20)	0.11 (0.16)
Young children	0.20 (0.26)	0.68 (0.31)	0.67 (0.34)	0.18 (0.16)	0.47 (0.36)	0.56 (0.38)	0.28 (0.25)	0.29 (0.30)	0.26 (0.28)
Older children	0.33 (0.34)	0.83 (0.16)	0.81 (0.23)	0.13 (0.19)	0.65 (0.31)	0.69 (0.31)	0.28 (0.27)	0.32 (0.33)	0.26 (0.29)
Adults	0.52 (0.32)	0.90 (0.12)	0.90 (0.11)	0.18 (0.22)	0.80 (0.16)	0.90 (0.08)	0.58 (0.22)	0.63 (0.23)	0.64 (0.25)

Note. Accuracy: -1 = worse than chance, 0 = chance, 1 = better than chance, preschoolers (4–5 years), young children (6–9 years), older children (10–11 years).

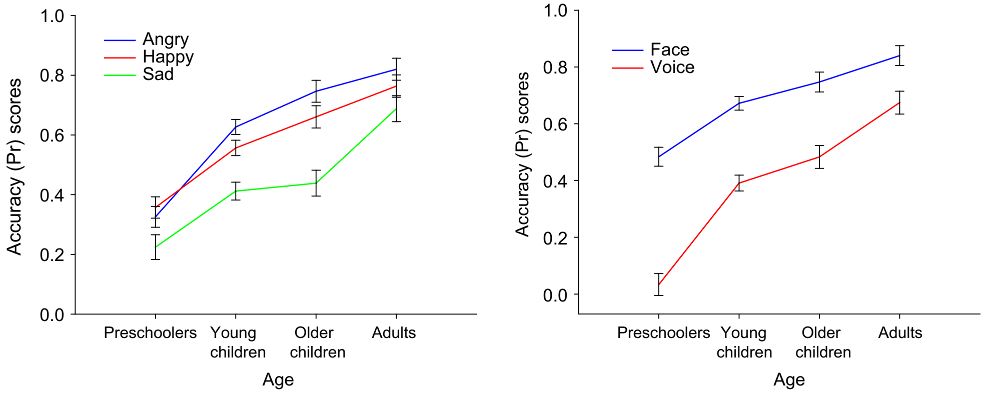

Figure 1. Line graph with error bars showing the mean accuracy (Pr) scores for each emotion type, modality type, and age group.

for angry, happy, sad, and neutral expressions, $F(3, 108) > 20.16$, *ps*' $< .001$. For angry and happy expressions, older children were not significantly different from adults ($p > .05$), and for sad and neutral expressions, however, older children were significantly less accurate compared to adults ($p < .001$). The above results are consistent with the hypothesis that accuracy for sadness would follow a slower developmental trajectory.

The age effects also varied by modality type, $F(3, 105)^{\text{modality} \times \text{age}} = 5.27$, $p < .01$, $\eta_p^2 = .13$; (see Figure 1). To explore this, we ran additional analyses in which accuracy scores of the three emotions × intensity conditions per modality were averaged and then entered in one-way ANOVA examining the effect of modality on accuracy for the age groups separately. There was a significant difference in accuracy between the age groups for facial and vocal expressions, $F(3, 108) > 19.70$, *ps*' $< .001$. For facial expressions, older children were not significantly different from adults ($p > .05$), and for vocal expressions, however, older children were significantly less accurate compared to adults ($p < .01$). The above results are consistent with the hypothesis that accuracy for voices would follow a slower developmental trajectory.

The age effects also varied by intensity type, $F(6, 105)^{\text{intensity} \times \text{age}} = 10.17$, $p < .001$, $\eta_p^2 = .22$. To explore this, we ran additional analyses in which accuracy scores of the modality × emotion conditions per intensity were averaged and then entered in one-way ANOVA examining the effect of intensity on accuracy for the age groups separately. There was a significant difference in accuracy between age groups for mild – 50%, moderate – 75%, and high – 100% intensity expressions, $F(3, 108) > 22.90$, *ps*' $< .001$. For moderate – 75% and high – 100% intensity expressions, older children were not significantly different from adults ($p > .05$), and for mild – 50% intensity expressions, however, older children were significantly less accurate compared to adults ($p < .01$). No other interactions were significant ($p > .05$). The above results are consistent with the hypothesis that accuracy for low-intensity expressions would follow a slower developmental trajectory.

Response bias

Tables 4 and 5 display the means and standard deviations for response bias to facial and vocal expressions by emotion and age. Response bias varied by emotion, $F(2, 210) = 13.90$, $p < .001$, $\eta_p^2 = .12$. Participants presented higher response bias to sad

Table 4. Mean (*SD*) of response bias to facial expressions per age group and emotion

	Facial emotional expression		
Age group	Angry	Happy	Sad
Preschoolers	0.19 (0.16)	0.28 (0.17)	0.27 (0.19)
Young children	0.15 (0.10)	0.18 (0.17)	0.23 (0.18)
Older children	0.14 (0.11)	0.12 (0.10)	0.21 (0.18)
Adults	0.15 (0.11)	0.14 (0.10)	0.17 (0.16)

Note. Absence of bias = 0, presence of bias = 1, preschoolers (4–5 years), young children (6–9 years), older children (10–11 years).

Table 5. Mean (*SD*) of response bias to vocal expressions per age group and emotion

	Vocal emotional expression		
Age group	Angry	Happy	Sad
Preschoolers	0.23 (0.17)	0.29 (0.16)	0.28 (0.13)
Young children	0.18 (0.14)	0.13 (0.10)	0.32 (0.17)
Older children	0.13 (0.09)	0.11 (0.12)	0.22 (0.06)
Adults	0.16 (0.18)	0.05 (0.06)	0.26 (0.18)

Note. Absence of bias = 0, presence of bias = 1, preschoolers (4–5 years), young children (6–9 years), older children (10–11 years).

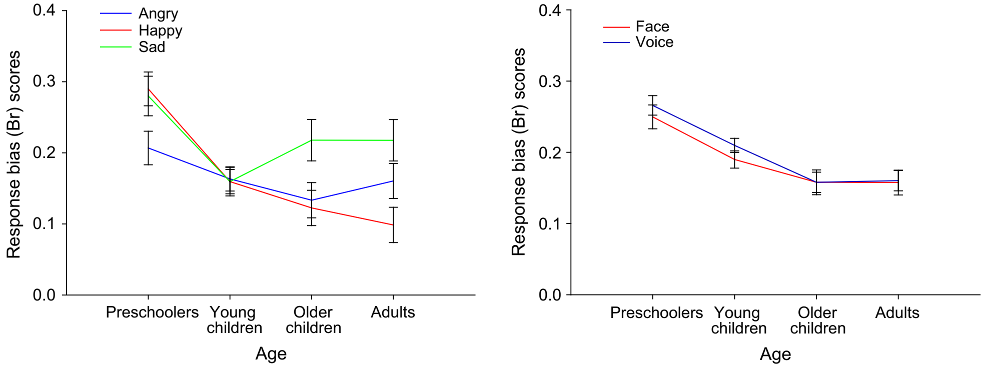

Figure 2. Line graph with error bars showing the mean response bias (Br) scores for each emotion type, modality type, and age group.

(M = 0.25, SE = .01) compared to angry (M = 0.16, SE = .01) and happy (M = 0.16, SE = .01) stimuli, suggesting that they were more likely to mistakenly identify non-sad expressions as sad. Bias varied by age group, $F(3, 105) = 12.90$, $p < .01$, $\eta_p^2 = .27$ with preschoolers displaying significantly higher bias (tendency to confuse emotions) (M = 0.26, SE = .01) compared to other groups ($ps < .001$). These age effects varied by emotion type, $F(3, 105)^{\text{emotion} \times \text{age}} = 3.00$, $p < .05$, $\eta_p^2 = .08$; (see Figure 2). To explore this, we ran additional analyses as in the case of accuracy. There was a significant difference in bias between the age groups for happy expressions, $F(3, 108) = 11.96$, $p < .001$. Preschoolers presented significantly higher bias to happy expressions compared to all other age groups. The age effects did not vary by modality type, $F(3, 105)^{\text{modality} \times \text{age}} = .43, p > .05, \eta_p^2 = .01$; (see Figure 2). There was no significant age × modality × emotion interaction effect on bias, $F(6, 210) = 1.54, p > .05, \eta_p^2 = .04$.

Discussion

This is the first study to examine the development of emotional recognition, in terms of both accuracy and response bias across facial and non-linguistic vocal modalities at multiple intensities in numerous age groups, and compare childhood developmental patterns to adult-level performance. Children more accurately recognized angry and happy, compared to sad faces and voices. Age-related effects on accuracy were different for faces and voices. Accuracy improved with age for sadness in faces and voices, but not happiness or anger. Similarly, accuracy improved with age for mild-intensity expressions but not for moderate- and high-intensity expressions, highlighting that the use of less intense (more subtle) emotional expressions is more sensitive to demonstrating development across facial and vocal modalities. A developmental pattern in bias was also evident. Age-related effects on response bias were similar for faces and voices with preschoolers displaying significantly higher bias than other age groups. Preschoolers presented a higher tendency to attribute happiness to faces and voices compared to other groups.

Our findings are consistent with developmental research in facial emotion processing showing that sadness is one of the least accurately recognized emotions among happiness, fear, anger, and sadness (Chronaki *et al.*, 2013; Gao & Maurer, 2009; Montirosso *et al.*, 2010). While previous research has mainly focused on accuracy, the present study also measured response bias to provide a novel opportunity to examine the nature of the confusion patterns underlying recognition. Response bias was higher for sad, compared to angry and happy for both faces and voices, indicating an increased tendency in children to mistakenly identify non-sad expressions as sad.

Considering vocal emotion recognition, emotion effects on accuracy were similar to those reported in adults with non-linguistic stimuli (Maurage *et al.*, 2007). Preschoolers were significantly less accurate compared to all other groups when identifying emotion from prosody. The current findings extend previous studies on the development of emotion recognition from speech. Our results show that non-verbal vocalizations can be effective for communicating emotion in young children (Chronaki *et al.*, 2012). The findings converge with developmental theory and research highlighting the preschool years as an important period for the development of emotion processing (Denham *et al.*, 2003; Nowicki & Mitchell, 1998). In the current study, 11-year-olds were significantly less accurate to recognize vocal emotional expressions compared to adults. Although previous studies using linguistic stimuli have shown that vocal emotion recognition reaches adult-like levels at 10 years of age (Baum & Nowicki, 1998), in the present study using non-linguistic stimuli, we show that vocal emotion recognition continues to develop beyond 11 years. This is consistent with previous research showing that when linguistic and paralinguistic cues in speech conflict, children rely more on language content, whereas adults rely on prosody, suggesting that children's understanding of the communicative functions of paralinguistic information are more limited in comparison with their linguistic comprehension (Morton & Trehub, 2001).

The present study did not find gender differences in emotion recognition from faces and voices (but see Hall, 1978; McClure, 2000; which showed a slight female advantage in visual and auditory emotion processing). Our findings are consistent with recent research (Sauter *et al.*, 2013) showing no gender differences in vocal emotion recognition in children.

Although recognition of emotion from prosody improved with age, this study showed that it developed at a slower rate when compared to recognition of emotion from faces. For facial expressions, older children were not significantly different from adults; however, they were less accurate compared to adults for vocal expressions. Findings extend previous research using linguistic stimuli in preschoolers (Nelson & Russell, 2011) and primary school children (Nowicki & Duke, 1994) showing higher recognition accuracy of faces compared to emotional speech. In the current study, results showed that emotion recognition from pure emotion prosody lagged behind recognition from facial expressions, suggesting that recognition from prosody develops more gradually. Future research could usefully incorporate both vocal and facial stimuli to develop a more comprehensive picture of emotion processing.

This research demonstrated for the first time a developmental pattern of response bias to emotion processing across modalities, showing that younger children presented higher bias to facial and vocal expressions compared to older children. The above findings suggest that with development, children become less biased towards a particular expression during emotion recognition. Preschoolers presented significantly higher bias to happy expressions compared to all other age groups; this is consistent with recent research showing that 3- to 6-year-old children exhibited a positivity bias when asked to judge the personality of another person (Boseovski, 2010). While the data support a positivity bias in preschool children, this finding is different to recent evidence which suggests a negativity bias that emerges the first year of life and reflects children's propensity to attend and respond more strongly to negative information, which is argued to serve evolutionarily adaptive functions (Vaish, Grossmann, & Woodward, 2008).

Current findings extend previous developmental research focusing merely on recognition accuracy (Herba *et al.*, 2006). Future research should address response bias because it provides the opportunity for identifying where the emotion misinterpretations lie which can inform remediation efforts which target the development of social-cognitive processing. The current study further demonstrated emotion-specific developmental trajectories and provided valuable information on the development of sadness perception in children. This is the first study to use emotional morphed auditory stimuli in children to demonstrate a slower developmental trajectory for sadness perception. Sadness was the least accurately recognized emotion, and it also exhibited a delayed developmental time course compared to anger and happiness. Our findings are consistent with developmental models of facial emotion processing, suggesting that recognition of happiness and anger is acquired earlier compared to sadness (Widen & Russell, 2008). Sadness has been argued to be a more ambiguous emotion compared to anger and happiness (Stifter & Fox, 1986) which might explain why children first recognize anger and happiness and later come to recognize sadness. This insensitivity to sadness and its delayed developmental course may limit children's ability to empathize with others and to appropriately modify their behaviour in response to social interactions. Improvements in sensitivity to sadness are likely to affect children's responses in social interactions, leading to enhanced social competence (Denham, Way, Kalb, Warren-Khot, & Bassett, 2013).

Limitations of the present study include the absence of IQ or other non-emotional recognition measures. However, research has consistently identified that emotion recognition is unrelated to IQ in children (Baum & Nowicki, 1998; Rothman & Nowicki, 2004). In addition, children in the present study did not present marked cognitive disability or behaviour problem. Furthermore, a verbal ability measure was not included in this study. Recent research has shown that verbal ability is linked to the development of emotional understanding (De Stasio, Fiorilli, & Chiacchio, 2014). It is possible that children with poor verbal abilities may be at a disadvantage when performing tasks that rely on verbal responses and future research should include verbal ability measures in emotion recognition tasks that rely on verbal responses. Finally, although the word 'okay' as a synonym of neutral is not ideal, it was chosen because children in our pilot study found it difficult to understand the concept of neutrality. The term 'okay' instead of neutral has been used in a similar way in previous forced-choice emotion recognition tasks with preschoolers (Chronaki *et al.*, 2013; Denham *et al.*, 2013).

Age effects cannot be attributed to task difficulty or stimuli properties as all stimuli were well validated prior to inclusion in the study. In addition, we ensured that all children fully understood the task and successfully completed the practice block before taking part in the task. The performance differences between modalities and emotions in the current study are consistent with previous research. Vocal stimuli are typically harder to recognize than facial stimuli (Pell, 2002), and sadness is typically harder to identify than other emotions (Batty & Taylor, 2003). Sadness has been argued to be easily confused with neutrality as it is closer to neutral than angry and happy expressions at a perceptual level (Juslin & Laukka, 2003; Young *et al.*, 1997). Future studies should include a number of male and female models. An additional limitation includes the relatively small number of participants within each group. Future research would benefit from the use of longitudinal designs that measure emotion processing throughout childhood and adolescence to early adulthood to further clarify age-related changes in visual and auditory modalities and their interaction. The interpretation of response bias effects is limited by the fact that a forced-choice paradigm with only three emotions (plus neutral) was used. Future research should aim to examine response bias with a greater number of emotional expressions.

The present study has demonstrated that sensitivity to non-linguistic vocal emotion is established early in life and continues to improve with age. It supports a developmental model in which emotion recognition from prosody follows that of facial emotion processing. This modality-specific pattern of developmental change is not evident for response bias which develops congruently across modalities. Sadness perception follows a slower developmental trajectory compared to anger and happiness perception from the preschool years until early adolescence. Knowledge from the current study can inform emotion-centred intervention and prevention programmes that aim to foster the development of socio-emotional processes linked to emotional understanding (Izard *et al.*, 2008). Intervening early can help children 'read' sadness, subtle (low intensity) expressions and vocal expressions in others successfully, and develop effective social skills.

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Supporting Information

The following supporting information may be found in the online edition of the article:

Data S1. Vocal stimuli morphing procedure.
Table S1. Item by item % agreement on vocal expressions in validation study in adults, children and overall.
Figure S1. Vocal emotion rating task for children used in the stimuli validation study.