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Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions

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Most previous studies investigating children's ability to recognize facial expressions used only intense exemplars. Here we compared the sensitivity of 5-, 7-, and 10-year-olds with that of adults ($n = 24$ per age group) for less intense expressions of happiness, sadness, and fear. The developmental patterns differed across expressions. For happiness, by 5 years of age, children were as sensitive as adults even to low intensities. For sadness, by 5 years of age, children were as accurate as adults in judging that the face was expressive (i.e., not neutral), but even at 10 years of age, children were more likely to misjudge it as fearful. For fear, children's thresholds were not adult-like until 10 years of age, and children often confused it with sadness at 5 years of age. For all expressions, including even happy expressions, 5- and 7-year-olds were less accurate than adults in judging which of two expressions was more intense. Together, the results indicate that there is slow development of accurate decoding of subtle facial expressions.

Introduction

Facial expressions are an important source of social information. Accurate recognition of facial expressions allows us to make inferences about other people's feelings, thereby guiding our social behavior. Normal human adults are fast and accurate at recognizing facial expressions, even from still photographs (Ekman, 1993). This ability is seen universally; there is high agreement among adults from different cultures on what emotion is shown in still photographs of facial expressions of basic emotions (happiness, sadness, anger, surprise, fear, and disgust) (Ekman & Friesen, 1971; Ekman et al., 1987; Elfenbein & Ambady, 2002; Izard, 1971). However, the development of this ability remains largely unclear.

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Most previous studies investigating children's ability to recognize facial expressions used photographs of intense facial expressions of basic emotions. Children's performance in identifying emotion from such photographs improves with age (reviewed in Herba & Phillips, 2004), with positive expressions recognized earlier and more accurately than negative expressions (Boyatzis, Chazan, & Ting, 1993; Camras & Allison, 1985; Widen & Russell, 2003). Overall, the improvement can be characterized by a large increment in accuracy between 3 and 7 years of age (Camras & Allison, 1985; Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Markham & Wang, 1996; Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000) and an increment in speed between 7 and 10 years of age (De Sonneville et al., 2002). The developmental patterns for intense emotional expressions are similar across studies that used photographs of children's faces (Boyatzis et al., 1993; Camras & Allison, 1985; Widen & Russell, 2003), photographs of adults' faces (Durand et al., 2007; Markham & Wang, 1996; Vicari et al., 2000), or both (De Sonneville et al., 2002). At least with some stimulus sets, there is continued improvement in accuracy into early adolescence (Kolb, Wilson, & Taylor, 1992). Moreover, children's pattern of brain activation when processing different intense facial expressions differs from that of adults until at least 11 years of age for functional magnetic resonance imaging (fMRI) activation to neutral versus fear (Thomas et al., 2001; see also Monk et al., 2003) and until late adolescence for event-related potential (ERP) patterns (Batty & Taylor, 2006).

The previous studies with intense emotional expressions documented that children are accurate in judging intense exemplars by approximately 7 years of age, with subsequent changes in reaction time and neural specificity. However, in everyday life, we see less intense facial expressions more frequently than intense facial expressions. The ability to recognize less intense facial expressions and subtle changes in the intensity of facial expressions (e.g., to see that someone is mildly amused by a joke) facilitates smooth social interactions. Therefore, it is important to investigate children's ability to recognize facial expressions of lower intensity.

The intensity of a facial expression is determined by the amount of muscle displacement away from a neutral state (Hess, Blairy, & Kleck, 1997). For example, the intensity of a happy expression can be characterized by the degree of displacement of zygomaticus major and orbicularis oculi muscles relative to their relaxed states (Duchenne de Boulogne, 1990). Three recent studies of children used a morphing process to move the positions of features in a neutral face toward their positions in an intense emotional face, a change simulating the consequences of facial muscle movements. One study compared children with and without psychopathic tendencies in a program for troubled children (Blair, Colledge, Murray, & Mitchell, 2001). Children with psychopathic tendencies needed significantly more intensity to recognize the sad expression, and they were more likely to mistake the fearful expression for another expression even at full intensity. However, the children spanned the age range of 9 to 17 years, and the authors did not investigate the effect of age on thresholds or errors. In a second study, Herba and colleagues (2008; see also Herba, Landau, Russell, Ecker, & Phillips, 2006, for related results on matching expression across intensity) used 10 levels of intensity to investigate the effect of familiarity on 4- to 15-year-olds' perception of five facial expressions (happiness, sadness, anger, fear, and disgust) in familiar and unfamiliar adult faces. Sensitivity improved with increasing ages for happy and fearful expressions but not for disgust, sad, and angry expressions, with no facilitation by familiarity for any facial expression and in fact some evidence that familiarity degraded sensitivity. However, because there was no adult comparison group, it is not possible to determine when sensitivity reaches adult levels. A different pattern emerged in a recent study that used morphing to create six intermediate intensities between neutral and expressions of fear and anger; children (7–13 years of age) and adolescents (14–18 years of age) were less sensitive than adults for both anger and fear (Thomas, De Bellis, Graham, & LaBar, 2007). These data suggest that the development of sensitivity to at least some facial expressions continues into adolescence. However, the authors used wide age groupings and did not analyze misidentifications. Adults tend to make systematic confusions among facial expressions. For example, they often confuse fear with surprise and also confuse anger with disgust (Ekman & Friesen, 1971; Etcoff & Magee, 1992; Young et al., 1997). Little information is known about whether children show the same pattern of confusion among facial expressions as do adults.

The purpose of our study was to build on these previous findings by including more intensity levels and a method that allowed us to measure both thresholds for each expression and confusions among expressions. We systematically manipulated the intensity of three facial expressions (happiness, sadness, and fear) by morphing photographs of intense exemplars of these expressions with photographs of neutral faces of the same models to create 20 levels of intensity. With intensity of expression as a factor in the experiment, accuracy is not an adequate measure of children's performance because participants can make two types of errors. The first type of error is specific to low-intensity expressions. Children, as well as adults, may fail to detect any expression in a face when the intensity of that expression is very low. To measure this type of error, we calculated thresholds to detect expressions in faces, that is, to see that the expression is not neutral. The second type of error, as in studies using only intense facial expressions, is to misidentify one expression as another. To measure this type of error, we calculated the percentage of misidentifications in faces that were recognized as emotional. One concern is whether the values are affected by the particular choices of expression presented to the participants, in this case happiness, sadness, and fear. We suspect that the threshold measure will not be affected by the particular choices because it measures the intensity at which the expression is seen as no longer neutral even if the expression cannot be identified correctly at that low intensity level. However, the specific choices will affect the pattern of misidentifications because the forced-choice procedure limits the types of errors that can occur. In the discussion, we consider the effect of this limitation on the interpretation of our findings.

We chose to study happy and sad expressions because, with intense expressions, children show adult-like accuracy for them earlier than they do for other expressions (Boyatzis et al., 1993; Camras & Allison, 1985; Widen & Russell, 2003), perhaps because of relatively greater exposure to happy and sad faces in everyday life. We chose fear as the third expression because it is likely to show a different developmental trajectory. With intense exemplars, adult-like sensitivity to fear develops relatively late (Camras & Allison, 1985; Durand et al., 2007; Markham & Wang, 1996; Vicari et al., 2000), possibly because of low exposure in everyday life. From an evolutionary perspective, the late development of adult-like accuracy for fear is surprising because fear signals potential environmental threat and the need to take action to avoid the threat. Consistent with this evolutionary perspective, by 7 months of age infants generalize habituation across different individual faces showing fearful expression (Nelson & Dolgin, 1985) and they look longer at fearful faces than at happy faces. This early onset of processing of fearful faces may be related to the functioning of a specific brain circuit involving the amygdala (Adolphs, Tranel, Damasio, & Damasio, 1995). In human adults, the amygdala can be activated by exposure to fearful faces through a fast and seemingly automatic response to low spatial frequency information carried through subcortical connections as well as by slower cortical input that is likely to develop later (Vuilleumier, Armony, Driver, & Dolan, 2003). Here we investigated whether the developmental trajectories for happiness, sadness, and fear for less intense exemplars are similar to those reported previously for intense expressions. The same method could be used in future studies to explore the development of sensitivity to the other basic emotions (anger, surprise, and disgust). We did not do so here because we were worried that including additional expressions would make the task too complex for the youngest children.

In Experiment 1, we investigated age differences in sensitivity to happy, sad, and fearful expressions in 5-, 7-, and 10-year-olds and a comparison group of adults. We also investigated confusions among these expressions at intensity levels above threshold. In Experiment 2, we investigated children's ability to distinguish between different intensities of the same expression. We expected that, unlike the results of previous studies using only intense expressions, young children would differ from adults in the detection and discrimination of all three facial expressions and would more often misidentify expressions of moderate intensity. For each experiment, we developed a child-friendly procedure suitable for children as young as 5 years of age.

Experiment 1

In Experiment 1, we presented photographs of neutral faces and of happy, sad, and fearful faces with 20 levels of intensity to adults and children (7–10 years of age) who were instructed to sort the photographs into four categories: happiness, sadness, fear, and neutrality. In addition, because pilot work indicated that 5-year-olds were not able to respond consistently during such a long procedure, we tested a group of 5-year-olds with 10 of the intensity levels.

Method

Participants

Participants were 24 5.5-year-olds (±3 months), 24 7.5-year-olds (±3 months), 24 10.5-year-olds (±3 months), and 24 adults (18–22 years of age). Child participants were recruited from names on file of parents who had volunteered their children at birth for participation in later studies. Adult participants were undergraduate students enrolled in an introductory psychology course and received course credit for participation. All of the participants had normal or corrected to normal vision. Half of the participants in each age group were female and half were male. An additional three children (two 5-year-olds and one 7-year-old) were excluded from data analysis because of inattention to the tasks.

Stimuli

A total of 16 photographs of four models (two females [Models 3 and 10] and two males [Models 24 and 25]) posing happy, sad, fearful, and neutral expressions were selected from the NimStim Face Stimulus Set (Tottenham et al., in press). Each photograph has a resolution of 506 × 650 pixels with RGB color. The selected models and photographs are ones for which adults agree about the posed expression (mean = 84.6%, range = 67.7–100%) and rate the expression as high in intensity (mean = 5.30, range = 5.15–5.43, on a 7-point scale) (Palermo & Coltheart, 2004).

For the happy faces, 20 levels of intensity were created by morphing a neutral face with the happy face of the same model with proportions adjusted in 5% increments so as to create 5% happy, 10% happy, ... 100% happy (Fig. 1A). A similar procedure was used for the sad (Fig. 1B) and fearful (Fig. 1C) faces. Morphs were created using MorphX software (http://www.norrkross.com/software/morphx/MorphX.php) following the procedure described by Calder, Young, Perrett, and Etcoff (1996) and based on 160 points manually positioned on the anatomical landmarks in each face photograph. Distortions caused by the morphing process in the eye and mouth regions[1] were fixed using Photoshop (Version 8.0). There were 260 stimuli in total ([20 intensity levels × 3 expressions × 4 models] + [5 neutral expressions × 4 models]). The neutral expressions were included to prevent participants from being biased to see all of the faces as expressive. For each model, the 5 neutral faces were identical. Photographs were printed out in full color using a Cannon CP-200 photo printer on 4 × 6-inch photo paper with lamination. The size of the faces was approximately 7 cm (width) by 11 cm (height).

Procedures

The procedures were approved by the institutional research ethics board. After the procedures were explained, we obtained written consent from the adult participants or from parents of the child participants, and we obtained verbal assent from the 10-year-olds.

Participants were tested individually in a quiet room illuminated by overhead fluorescent lights. Each participant sat in front of a desk, on which sat four miniature houses, each with a schematic face[2] (Fig. 2) on its roof showing a happy, sad, fearful, or neutral expression. The experimenter explained the task as follows: "In one of these houses, people are telling a happy [sad, fearful] story. Could you tell me which one it is?" After the participant pointed to the appropriate houses for these three expressions, the experimenter said, "In one house, people are not telling a story and they are not feeling anything. Could you point it out?" After the participant correctly identified the neutral house, the experimenter showed a box with the test photographs inside and said, "Now we have more people here. Your job is to help them to find the right house. They can only go to one house if they have the same feeling as people inside of that house." The experimenter emphasized that there could be different intensities by saying, "One thing

[1] Morphing between two stimuli containing lighting reflections in different locations in an eye resulted in two light reflections in the morphed eye. We fixed this distortion by replacing the two reflections with one reflection midway between them. Morphing between a closed-mouth neutral face and an open-mouth toothy face distorted the teeth in the morphed pictures. This distortion was corrected by replacing the distorted tooth region with the tooth region from the original picture (100% intensity). Brightness and contrast of the replaced area were adjusted to match the morphed picture.

[2] The facial expressions on the schematic faces were accurately identified by eight adults in pilot work.

Fig. 1. Examples of happy (A), sad (B), and fearful (C) expressions at varying intensity levels.

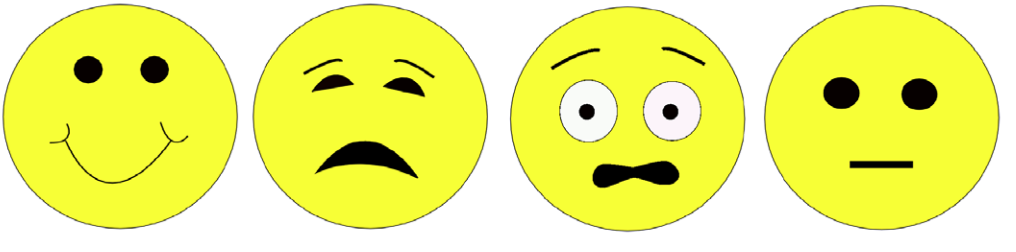

Fig. 2. Schematic faces. From left to right: happy, sad, fearful, and neutral.

you may notice is that sometimes a whole group feels sad, but some feel just a little sad while others feel very sad. In this game, they all go together. Do the same thing with happy and fearful people. Don't care about how happy or fearful they are." We also used synonyms of fearful (i.e., scary and frightening) throughout the experiment.

The experimenter handed the photographs to the participant one by one. The participant put the photographs into the house that he or she judged to be appropriate through a slot in the roof. Because the slots in the roofs of the toy houses were very narrow (approximately 1 cm wide), the participant could not see the cards he or she had already placed in each house. Half of the participants of each sex within each age group were assigned to one set of photographs containing all of the stimuli of one male model (Model 25) and one female model (Model 3), and the other half of the participants were assigned to the other male (Model 24) and the other female model (Model 10). Therefore, except for the 5-year-olds, each participant saw 130 photos ([3 emotions × 20 intensity levels × 2 models] + [5 neutral expressions × 2 models]). For 5-year-olds, pilot work indicated that the procedure was too long, and so the number of photographs was reduced by using only half of the intensities: 10 levels of intensity with 10% intervals from 10% to 100% for a total of 64 photos ([3 emotions × 10 intensity levels × 2 models] + [2 neutral expressions × 2 models]). Although we collected less information from 5-year-olds, this decision appeared to better equate the attentional demands across age. All participants appeared to understand the task and enjoy the game. The task took approximately 30 min for children and 25 min for adults to complete.

Data analysis

The intense exemplars of each expression (100%) were chosen based on high agreement among adults about the expression being displayed and high ratings of intensity. However, we cannot be sure that all of the endpoint expressions convey the maximum possible expressions or fall equally short of maximum expressions and, hence, that the steps between the endpoint and neutral expressions are equivalent. For that reason, we examined age differences for each expression in separate analyses.

We combined the data from the two sexes for all analyses because preliminary analyses revealed no effect of sex or interaction of sex with any other variable.

Accuracy

Fig. 3 shows mean accuracy at each intensity level for each expression when the data were first averaged across the two models seen by each participant and then averaged across participants in each age group. There were mainly two types of error: (a) at low intensities, identifying an expressive face as neutral; and (b) at higher intensities, misidentifying one expression as another (e.g., classifying a sad expression as fearful). We quantified these two types of error by (a) calculating the threshold to discriminate each expression as different from neutral and (b) calculating the misidentification rates above threshold.

Thresholds

To measure children's and adults' sensitivity to facial expressions, we calculated their thresholds to differentiate each facial expression from neutral. Responses were categorized as neutral or nonneutral, with nonneutral responses including both correct identifications (e.g., 40% sadness classified as sad) and misidentifications (e.g., 40% sadness classified as fearful). We fitted a cumulative Gaussian function to the responses of each participant for each expression by using the following formula:

$$P(\text{identification}) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} \exp\left(-\frac{(u-\mu)^2}{2\sigma^2}\right) du,$$

where x is intensity and P is the probability of identification. We estimated two parameters: μ, the mean, and σ, the standard deviation of the normal distribution $X \sim N(\mu, \sigma^2)$. The estimated value of μ was used as the threshold and corresponds to $P = 0.5$. In other words, the threshold value represents the intensity level at which 50% of the time the expressive face will be recognized as neutral and 50% of the time it will be recognized as having one of the three expressions. The individual's threshold for each expression was calculated by averaging across the independently derived estimates for the two models (Fig. 4).[3]

[3] Thresholds based on an arbitrary rule (e.g., the lowest intensity at which began the first string of two correct responses) yielded similar results.

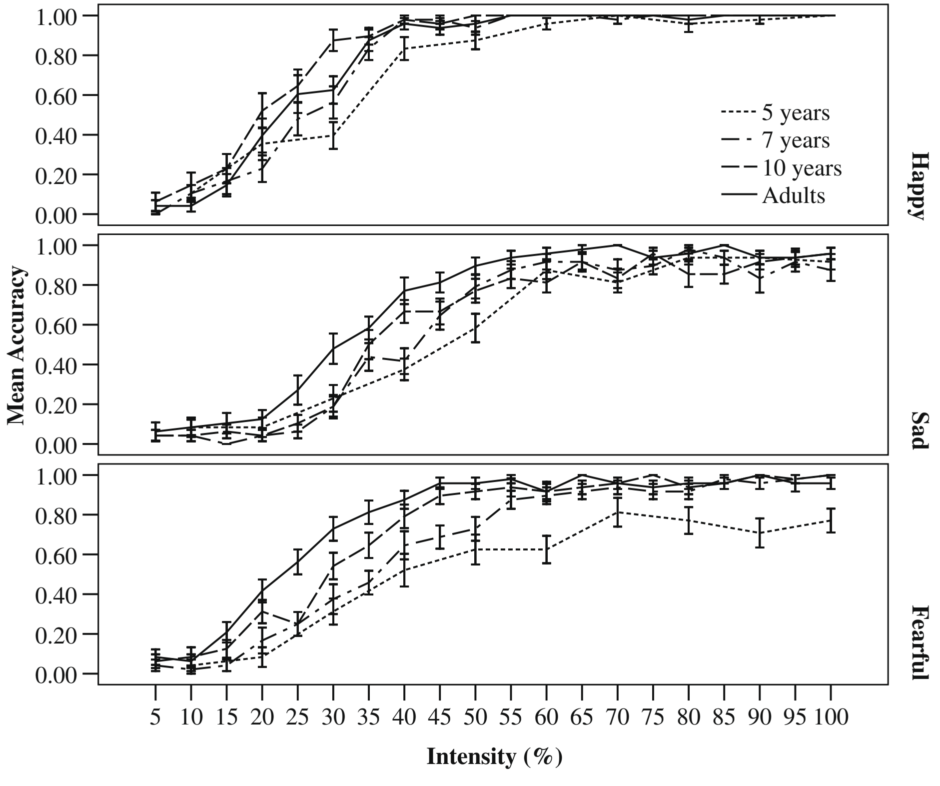

Fig. 3. Mean accuracy (±1 SE) for each expression at each age in Experiment 1.

Misidentification rates

The thresholds measured children's ability to distinguish expressive faces from neutral faces but did not indicate whether they identified the correct expressions. To assess age differences in misidentifications, we calculated the misidentification rates combining all intensity levels that were above threshold for each participant by dividing the frequency of misidentification (e.g., sadness being misidentified as happiness or fear) by the total number of faces above threshold (Fig. 5).[4] The rates for each participant were averaged across the two models. Table 1B indicates the mean number of faces included in the denominator at each age.

Analyses

For both the thresholds and misidentification rates, we conducted one-way analyses of variance (ANOVAs) testing the effect of age separately for each expression.[5] We also tested the effect of age on accuracy for the 100% intense expressions to allow our results to be compared directly with previous

[4] When misidentification rates were restricted to the 10 levels of intensity tested for all four age groups, the results were similar except that the misidentification rates for sadness of the 10-year-olds were no longer significantly different from those of adults (p = .092).

[5] The conclusions are similar if the analyses are based on mixed-model ANOVAs with age as a between-participant factor and expression as a repeated measure. For threshold, there are significant main effects of age, $F(3, 92) = 4.36$, $p < .01$, and expression $F(2, 184) = 47.13$, $p < .01$, and a significant interaction between age and expression, $F(26, 184) = 3.56$, $p < .01$. For misidentification rate, there are significant main effects of age $F(3, 92) = 9.00$, $p < .01$, and expression, Greenhouse–Geisser corrected $F(1.7, 153.6) = 24.96$, $p < .01$, and a significant interaction between age and expression, Greenhouse–Geisser corrected $F(5.0, 153.6) = 4.23$, $p < .01$. To investigate the interactions, we examined the simple effects of age for each expression. The results are the same as when the data for each expression are analyzed separately.

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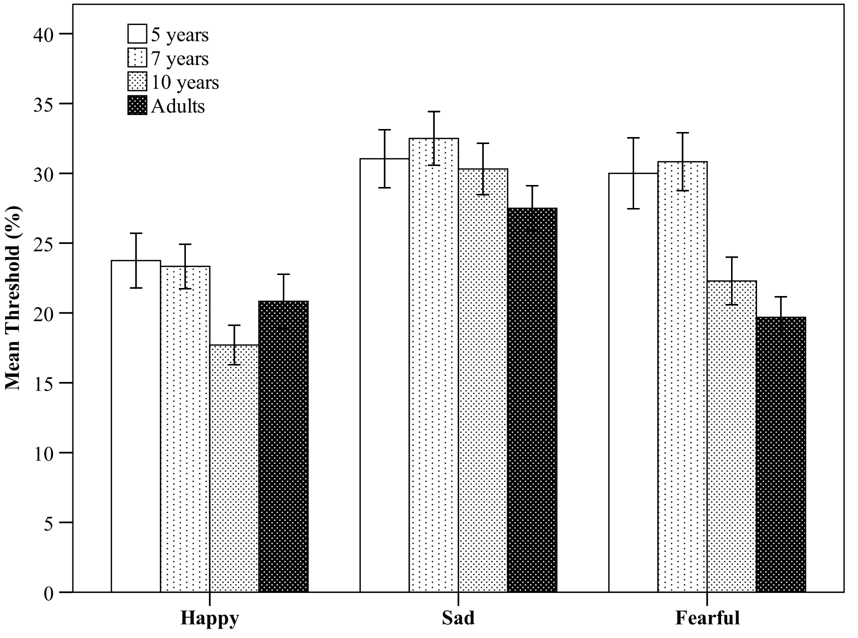

Fig. 4. Mean threshold (±1 SE) for each expression at each age.

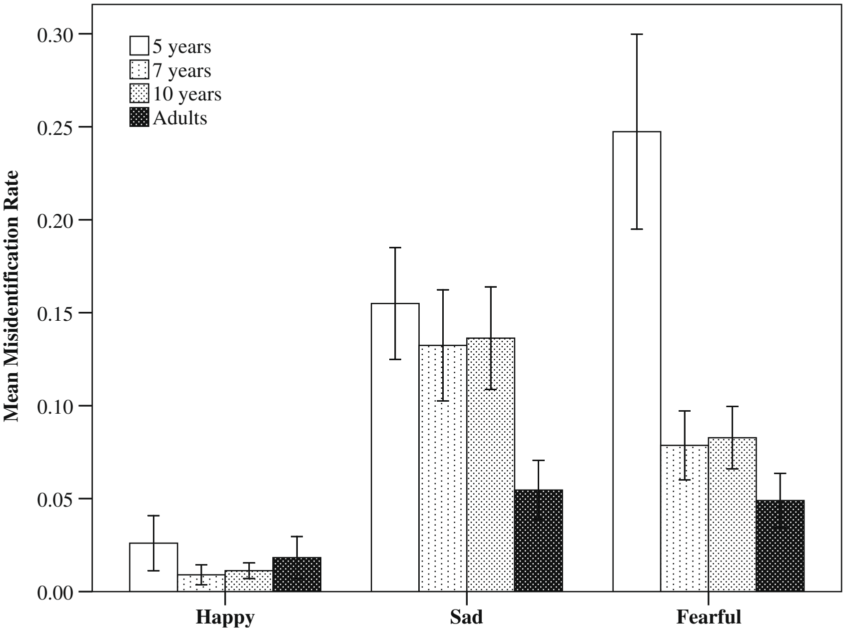

Fig. 5. Misidentification rate (±1 SE) for each expression at each age.

studies. Dunnett's tests with adults as the control group were performed when there was a significant main effect of age (one-tailed, testing the hypothesis that children have higher thresholds or higher misidentification rates than adults).

Results

Happy expression

All age groups had perfect accuracy (100%) at recognizing the highest intensity happy faces. Inspection of Fig. 3 indicates possible age differences in the range of intensities from 30% to 40%. However, this difference did not lead to a significant difference in threshold. The threshold was reached at a low intensity around 20% (Fig. 4), and misidentifications were rare (Fig. 5). The ANOVAs confirmed that there was no main effect of age on accuracy at 100% intensity, $F(3, 95) < 1$, on thresholds, $F(3, 95) = 2.55$, $p > .05$, or on misidentification rates, $F(3, 95) < 1$.

Sad expression

At the highest intensity, there was no difference in accuracy among age groups, $F(3, 95) = 1.04$, $p > .10$. Inspection of Fig. 3 suggests age differences in accuracy across a broad range of intensities from approximately 20–70%. The analyses revealed that the age differences were in misidentification rates. There was no main effect of age on thresholds, $F(3, 95) = 1.26$, $p > .10$ (see Fig. 4). However, children misidentified sad as another expression more often than adults (Table 1A). This was supported by a main effect of age, $F(3, 95) = 2.81$, $p < .05, \eta^2 = .08$, on misidentification rates, with both 5- and 10-year-olds having significantly higher misidentification rates than adults and a trend in the same direction for 7-year-olds (Dunnett's tests: $p < .05$, Cohen's $d = .77$ for 5-year-olds; $p = .051$, Cohen's $d = .60$ for 7-year-olds; $p < .05$, Cohen's $d = .63$ for 10-year-olds). At every age, most errors were to misidentify sad faces as fearful (Table 1A).

Fearful expression

Inspection of Fig. 3 reveals a different developmental pattern for fear than for happy or sad expressions, such that 5-year-olds made more errors than other age groups even at high intensities ($\geqslant$60%). There was a significant main effect of age on accuracy at the highest intensity, $F(3, 95) = 10.80$, $p < .01$, $\eta^2 = .26$. The 5-year-olds were significantly less accurate than the adults at the highest intensity ($p < .01$, Cohen's $d = 1.14$), but the 7-year-olds and 10-year-olds did not differ significantly from adults ($ps > .10$). There was also a significant main effect of age on thresholds, $F(3, 92) = 7.82$, $p < .01$, $\eta^2 = .20$. Dunnett's tests revealed that 5-year-olds and 7-year-olds had significantly higher thresholds than adults ($p < .01$, Cohen's $d = 1.06$ for 5-year-olds; $p < .01$, Cohen's $d = 1.15$ for 7-year-olds) and that 10-year-olds did not differ significantly from adults ($p > .10$). The mean thresholds to distinguish fear-

Table 1(A)
Mean misidentification rates.

	Happy			Sad			Fearful		
Misidentified as	Sad	Fearful	Total	Happy	Fearful	Total	Happy	Sad	Total
5-year-olds	0.3	2.4	2.7	3.0	12.4	15.4	2.6	22.9	25.5
7-year-olds	0.5	0.4	0.9	3.4	10.0	13.4	1.2	7.0	8.2
10-year-olds	0.6	0.5	1.1	4.0	10.6	14.6	2.8	5.9	8.7
Adults	1.3	0.8	2.1	0.3	5.0	5.3	0.9	4.1	5.0

Table 1(B)
Mean numbers of faces identified as expressive for each expression averaged across models

	Happy	Sad	Fearful
5-year-olds	7.7 (1.0)	6.9 (0.9)	7.1 (1.1)
7-year-olds	15.4 (1.5)	13.5 (1.8)	13.9 (1.9)
10-year-olds	16.5 (1.5)	14.0 (1.8)	15.6 (1.8)
Adults	15.9 (1.9)	14.6 (1.6)	16.1 (1.5)

Note. Standard deviations are in parentheses. For each expression except neutral, 5-year-olds saw 10 faces of each model, whereas other age groups saw 20 faces of each model.

ful expressions from neutral expressions ranged from 30–31% for 5- and 7-year-olds to 20–22% for 10-year-olds and adults (Fig. 4).

The mean misidentification rates for fearful faces were 25.5% for 5-year-olds and 8.7% or less for the other age groups. There was a significant main effect of age, $F(3, 188) = 6.22$, $p < .01$, $\eta^2 = .23$. Dunnett's tests revealed that 5-year-olds had a significantly higher misidentification rate than adults for fearful faces ($p < .01$, Cohen's $d = 1.34$) but that 7- and 10-year-olds were not different from adults ($ps > .10$). At every age, the most common error was to misidentify fearful faces as sad faces (Table 1A).

Discussion

It has been well documented that children can recognize happy expressions of high intensity with the high accuracy rates seen in adults as early as 5 or 6 years of age (Boyatzis et al., 1993; Camras & Allison, 1985; Kolb et al., 1992;Widen & Russell, 2003). Our findings for intense expressions are consistent with these previous findings: the 5-year-olds' accuracy was nearly perfect with exemplars of 60% and higher (see Fig. 3), and misidentification rates were low at all ages (see Fig. 5). We also found that children's thresholds to detect emotion in less intense happy faces were adult-like at 5 years of age.[6] Our findings differ from those of a previous study by Herba and colleagues (2008) showing that children's threshold to accurately recognize happy expression decreases with age in 4- to 15-year-olds. One possible explanation is that in our study choices were self-paced, whereas in Herba and colleagues' study each picture disappeared after 1 s. It is possible that Herba and colleagues' pattern of decreasing thresholds between 4 and 15 years of age reflects increasing speed of processing facial expressions, consistent with decreasing reaction time (De Sonneville et al., 2002), whereas our results reflect the early development of adult-like sensitivity.

The implication of our findings is that by 5 years of age, when children are not under time pressure, they are as sensitive as adults to subtle expressions of happiness such as a teacher's subtle smile when the child gets a hard problem correct. Being able to recognize such subtle signals increases children's potential to react appropriately in social situations and to be shaped by subtle feedback from adults and peers.

Children also performed well with the sad expressions. Children in the youngest age group (5 years) were as accurate as adults for intense expressions and had adult-like thresholds. These findings are consistent with previous reports that children can recognize intense sad expression as accurately as adults by 5 years of age (Durand et al., 2007; Vicari et al., 2000) and that children's thresholds to accurately recognize sad expression do not change between 4 and 15 years of age (Herba et al., 2008). However, children made more classification errors than adults when viewing sad expressions that were above threshold but below 100% intensity even at 10 years of age: they more often misidentified such sad faces as fearful. The higher confusion rates with fear at lower intensity levels imply that children are not as sensitive as adults to typical expressions of sadness. This insensitivity may limit their ability to empathize with others and to monitor the impact of their shortcomings on parents and teachers, although it is possible that low empathizing ability limits the information they find salient in the sad facial expressions they see every day and thereby slows the development of adult-like sensitivity. Misidentifying a sad face as fearful may also cause them to take inappropriate action.

[6] The 5-year-olds were tested with only 10 levels of intensity, whereas the other age groups were tested with 20 levels of intensity. The threshold values estimated with more levels of intensity from the older age groups may be more accurate than those for the 5-year-olds estimated with fewer levels of intensity. To investigate how the difference affected the developmental patterns, we recalculated the thresholds of the 7- and 10-year-olds and adults based only on their responses for the 10 intensity levels used with 5-year-olds. The ANOVA results for threshold were overall similar to those reported in the text; there was no main effect of age for sadness, and the main effect of age for fear resulted from higher thresholds for 5- and 7- year-olds than for adults. In addition, there was a main effect of age for happiness, but as in the original analyses, there was no significant difference in threshold between adults and any of the younger ages. The main effect of age resulted from slightly higher thresholds at 5 years of age than at 10 years of age. Thus, the overall conclusions of Experiment 1 were not affected by using fewer intensities for the youngest group.

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Children performed less well with the fearful expressions. Even at the peak intensity (100%), 5-year-olds were significantly less accurate than adults in recognizing fearful faces and they more often misidentified fearful faces as sad. The results for the intense expressions are similar to the report by Durand and colleagues (2007) that 5-year-olds are less accurate than older children and adults in recognizing fearful expressions and, as in the current study, are as accurate as older children in recognizing intense sad and happy expressions. Our results extend those findings by showing that their thresholds are also significantly higher. The 7-year-olds performed like adults for higher intensities, but they had significantly higher thresholds. By 10 years of age, children performed as well as adults on all measures. Like the results from previous studies (Herba et al., 2008; Thomas et al., 2007) with 4- to 15-year-olds, our results indicate that there are changes after 7 years of age in sensitivity to subtle fearful expressions, although our data suggest that the change occurs in the earlier part of the wide age range in the previous two studies. The slow development of sensitivity to fearful expressions implies that 5- and 7-year-olds often miss or misread fearful expressions that signal potential danger in the environment.

It is possible that the developmental patterns we observed reflect the particular forced-choice procedure we used and that results might be different had we given different choices or asked participants to label the emotional expressions. As reviewed by Russell (1994), when a free labeling procedure is used, adults usually are poorer at recognizing facial expressions than when they have a fixed number of choices that limit the errors that can be made. The difference is likely to be even greater in children (Markham & Adams, 1992; Widen & Russell, 2003) and perhaps differ between facial expressions. Moreover, in our experiment, children had only four expressions to choose from: one neutral, one positive, and two negative. The limited set of choices may have made misidentifications more likely for the negative expressions. Children may have recognized that a sad face was expressive and negative but been unsure of which negative expression; there was no comparable confusion possible for the happy expression. To control for this possible confound, we ignored misidentifications in calculating the thresholds: each response was scored as neutral or expressive, with both correct identifications and misidentifications being counted as expressive. However, we cannot rule out the possibility that when viewing a low intense sad or fearful face, the uncertainty of whether it is sad or fearful might bias young children to put it in the neutral pile.

Although we acknowledge that the four-alternative forced procedure may have affected the pattern of results, we note that the same limitation applies to the interpretation of previous studies of sensitivity to facial expressions in children and adults. Other aspects of the data confirm different developmental patterns for fear and sadness. The patterns of misidentification were not symmetrical; sadness was misidentified as fear on approximately 10% of trials in all three child groups, whereas fear was misidentified as sadness at higher rates (22.9%) but only by 5-year-olds. Although it is possible that for the 5-year-olds sadness was treated as the default negative emotion, leading to an asymmetrical pattern of confusion with fear, this asymmetrical pattern was not seen in the other age groups. Moreover, at 5 years of age, the plot of overall accuracy against intensity for fear was quite different from that for sadness (see Fig. 3). Thus, our conclusions about different developmental patterns for different emotions are not likely to be merely an artifact of the three emotions we chose to study and the use of a forced-choice procedure. Future studies using other sets of emotional expressions (e.g., happiness and pleasant surprise along with two negative expressions) with the same methodology can address this issue directly.

Experiment 2

Although children's ability to recognize intense facial expressions has been investigated by many studies, little attention has been paid to their ability to discriminate between different intensities of the same facial expression that can convey information about subtle differences in a person's feelings. In Experiment 2, we assessed this ability by asking the participants from Experiment 1 to indicate the more intense expression in pairs of faces showing the same expression. To our knowledge, this is the first study to assess sensitivity to subtle differences in emotional intensity using a direct method (see Thomas et al. (2007) for an indirect measure for fearful and angry expressions based on slopes).

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Method

Participants

The participants were the same as in Experiment 1. One 7-year-old was excluded from the data analysis because of chance performance in all conditions of Experiment 2.

Stimuli

The stimuli were the same as in Experiment 1 except that they were displayed on a 19-inch HP p1179 CRT monitor with a 75-Hz refresh rate at 1024 × 768 controlled by a Macintosh G4 computer via PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). Each picture was 11.4 cm (width) × 14.8 cm (height) (approximately 10.7 × 14.1° in visual angle when viewed from a distance of 60 cm) with a separation of 8 cm (7.6° in visual angle) between the two pictures presented during each trial.

Procedures

Participants had a 5-min break before beginning Experiment 2. In Experiment 2, they were asked to indicate the more intense expression in a simultaneously displayed pair of images of the same model showing two different intensities of one of the expressions. Different expressions were separated by blocks (happy, sad, and fearful) with the order of expression blocks counterbalanced among participants in each age group. Participants were told the target expression before each block.

All four models were used, but the two pictures shown on any given trial were always from the same model. The pairs were drawn from the relatively high intensities (70–95%) so as to be clearly above threshold.[7] In pilot work with 7-year-olds (the middle age group) and adults, we determined that 7-year-olds with a 10% difference were as accurate as adults with a 5% difference. Therefore, we tested adults with differences of 5%, 10%, 15%, and 20% (70% vs. 75%, 80%, 85%, and 90%) and children with differences of 10%, 15%, 20%, and 25% (70% vs. 80%, 85%, 90%, and 95%). We used all levels tested for analyses for linear trends within each age group. For the ANOVA with all four age groups, we included only the overlapping levels of differences. Each pairing appeared once with the correct answer on the left and once with it on the right. Each participant saw 32 pairs of pictures in random order for each expression (4 levels of difference × 4 models × 2 positions of correct answer). For 5-year-olds, the position of the correct response for each test pair was randomized and not repeated in the opposite position so as to halve the number of trials.

The experimenter explained the task as follows: "Here we have a competition. In this competition, people send us their pictures of happy faces, sad faces, and fearful faces. The happiest, saddest, and most fearful ones will win the competition. Now you are the referee of this competition." At the beginning of each expression block, the experimenter told the participant, "This round is the happy [sad, fearful] round. We will show you pairs of happy [sad, fearful] faces and let you decide which one looks happier [sadder, more fearful] than the other." Photographs were displayed on the screen until the experimenter entered the participant's response. The task took approximately 30 min for children and 25 min for adults to complete.

Data analysis

For the same reasons as mentioned in Experiment 1 (e.g., the endpoint expressions might not be equally intense), we analyzed the data for Experiment 2 separately for each expression.[8] Preliminary analysis revealed no effect of sex of participant or interaction of sex with any other variable. Therefore, in the following analyses, we combined data from the two sexes.

[7] We also tested low-intensity pairs (40–65%). The results of Experiment 1 showed that individual thresholds to detect emotion ranged from 5 to 65%, indicating that for some participants one or both faces in the low-intensity pairs may look neutral. Therefore, we did not analyze the data from the low-intensity pairs.

[8] The conclusions are similar if the analyses are based on a mixed-model ANOVA with age as a between-participant factor and expression and difference level as repeated measures. There are significant main effects of age, $F(3, 91) = 11.22$, $p < .01$, expression $F(2, 182) = 3.29$, $p < .05$, and difference level, $F(2, 182) = 38.18$, $p < .01$, and a significant three-way interaction among these factors $F(12, 364) = 2.47$, $p < .01$. To investigate the interaction, we examined the effects of age and difference level for each expression. The results are the same as when the data for each expression are analyzed separately.

For each participant, mean accuracy was calculated across the four models for each expression at each difference level (Fig. 6). For each expression, a mixed-model ANOVA was conducted on mean accuracy with age as a between-participant factor and difference level (10%, 15%, or 20%, the levels tested at all four ages) as a repeated measure. Interactions between age and difference level were investigated by looking at the simple main effect of age at each difference level. Dunnett's tests comparing each group of children with adults (one-tailed, testing the hypothesis that children have lower accuracy than adults) were used to investigate significant age differences at any difference level.

To examine whether accuracy increases with increasing differences between two intensities, we tested linear contrasts between accuracy and the four levels of difference for each age group.

Results

Happy expression

The ANOVA revealed significant main effects of age, $F(3, 91) = 8.31$, $p < .01$, $\eta_p^2 = .22$, and difference level, $F(2, 182) = 15.39$, $p < .01$, $\eta_p^2 = .15$, and a significant interaction between age and difference level, $F(2, 91) = 5.55$, $p < .01$, $\eta_p^2 = .11$. There were main effects of age at all three difference levels ($ps < .01$, $\eta_s^2 = .25$, .16, and .09 for 10%, 15%, and 20%, respectively). Dunnett's tests revealed that 5-year-olds were less accurate than adults at the 10% ($p < .01$, Cohen's $d = 1.55$) and 15% ($p < .01$, Cohen's $d = 1.17$) difference levels but not at the 20% difference level ($p > .10$) and that 7-year-olds were less accurate than adults at the 10% ($p < .01$, Cohen's $d = .69$) and 20% ($p < .01$, Cohen's $d = .88$) difference levels. The 10-year-olds did not differ from adults at any difference level ($ps > .10$).

Sad expression

There were significant main effects of age, $F(3, 91) = 6.47$, $p < .01$, $\eta_p^2 = .18$, and difference level, $F(2, 182) = 22.47$, $p < .01$. $\eta_p^2 = .20$. There was no significant interaction between age and difference level,

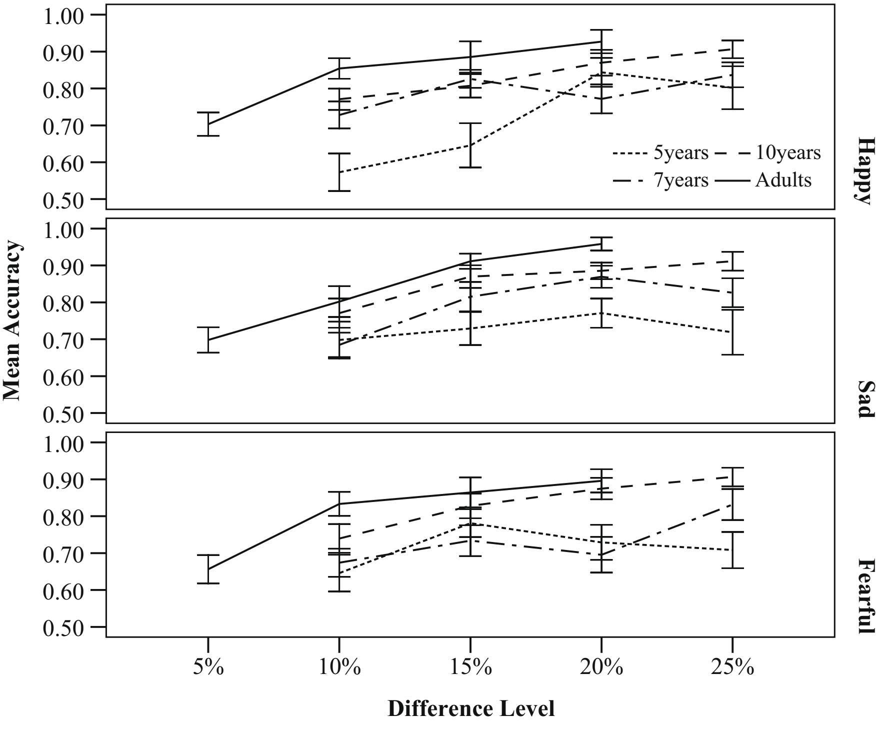

Fig. 6. Mean accuracy (±1 SE) for each expression at each age in Experiment 2.

$F(6, 182) < 1$. Therefore, we investigated the effect of age by collapsing the data across difference levels. Dunnett's test revealed that 5- and 7-year-olds were less accurate than adults ($ps < .01$, Cohen's $ds = 1.21$ and 0.77 for 5- and 7-year-olds, respectively), whereas 10-year-olds were not different from adults ($p > .10$).

Fearful expression

The results for the fearful expressions were similar to the results for the sad expressions. There were significant main effects of age, $F(3, 91) = 7.15$, $p < .01$, $\eta_p^2 = .19$, and difference level, $F(2, 182) = 7.36$, $p < .01$, $\eta_p^2 = .08$. There was no significant interaction between age and difference level, $F(6, 182) = 1.02$, $p > .10$. When we collapsed the data across difference levels, Dunnett's test revealed that 5- and 7-year-olds were less accurate than adults ($ps < .01$, Cohen's $ds = 1.03$ and 1.16 for 5- and 7-year-olds, respectively), whereas 10-year-olds were not different from adults ($p > .10$).

Linear contrasts

Adults and 10-year-olds showed linear increments in accuracy with increasing difference levels for all three expressions ($ps < .01$, $\eta_s^2 = .57$ [happy], .75 [sad], and .60 [fearful] for adults, $\eta_s^2 = .53$ [happy], .35 [sad], and .60 [fearful] for 10-year-olds). The 5-year-olds showed linear increments in accuracy with increasing difference levels only for happy expressions ($p < .01$, $\eta^2 = .35$). The 7-year-olds showed significant linear increments in accuracy with increasing difference levels for sad and fearful expressions ($ps < .01$, $\eta_s^2 = .67$ for sad and .42 for fearful) and a trend for happy expressions ($p = .077$, $\eta^2 = .21$).

Discussion

Infants as young as 7 months of age are able to discriminate between two happy or two fearful faces differing in intensity (Nelson, 1987). Here we report the first study to investigate developmental changes in children's ability to discriminate between different intensities of happy, sad, and fearful expressions, all of which were above threshold. Younger children were less sensitive than adults to subtle differences in the intensity of a facial expression; the accuracy of 5- and 7-year-olds was significantly lower than that of adults for all three expressions, and for sad and fearful expressions 5-year-olds' accuracy did not increase as the task was made easier by increasing the difference in intensity between the two faces. By 10 years of age, children were adult-like on all of the measures.

The insensitivity in young children to differences in the intensity of facial expressions may hinder their ability to perceive subtle changes in facial expressions in social situations. Those subtle changes could otherwise function as cues and feedback during social interactions. Note, however, that in real-world situations children's sensitivity to such changes in the intensity of facial expressions is likely to be aided by dynamic information as it is in adults (Ambadar, Schooler, & Cohn, 2005). We discuss the limitation of using static images further in the next section.

General discussion

The current study used facial expressions of varying intensities to investigate children's sensitivity to happy, sad, and fearful expressions. Children's threshold to indicate that a happy face is expressive (i.e., not neutral) is adult-like by 5 years of age, but their accuracy in discriminating different intensities of happy expressions improves after that age, with continued improvement between 7 and 10 years of age. These same patterns emerged for sad faces. However, unlike happy faces, even at 10 years of age children are more likely than adults to misidentify a sad face (as fearful). The pattern is different for fearful faces; children have higher thresholds than adults for recognizing that a fearful face is expressive through 7 years of age, and at 5 (but not 7) years of age, children are significantly more likely to misidentify it (as sad) even at high intensities. As with happy and sad faces, until 10 years of age, children also are less accurate at determining which of two fearful expressions is more intense.

Before we attribute the statistical effects of age to developmental changes in sensitivity to facial expressions, we must consider the alternative possibility that they arise from more general changes such as improvements in memory, attention, and/or motivation. Developmental improvements in these factors may lead to developmental improvements in children's performance on our tasks, for

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example, by making it more likely that they will attend to the face long enough to detect a subtle facial expression or notice that it differs only slightly from the neutral face seen a moment earlier. Although such alternatives can never be completely eliminated, they are unlikely to account for the patterns reported here for the following reasons. First, the story scenario and visual icons helped to make the task easily understood by all age groups tested, as evidenced by the high accuracy in recognizing intense expressions in Experiment 1 and the above chance performance in Experiment 2. In addition, the game scenario appeared to be successful in motivating children to perform the task, as evidenced by the low drop rate (3 of 75 children). Second, we minimized memory demands by using unlimited viewing time for both experiments and displaying the two faces to be compared simultaneously in Experiment 2. Third, the structure of the tasks was the same for all three expressions, but we found different developmental patterns across expressions. Therefore, the developmental changes found here are likely to arise, at least in part, from developmental changes in sensitivity to facial expressions. Of course, developmental changes in attention and memory may affect the information children extract from faces during everyday social interactions and, in turn, lead to developmental changes in sensitivity to facial expressions.

The developmental patterns identified here may have been influenced by the use of the static faces of adults as the targets rather than the faces of children or dynamic images. It is possible that children are more sensitive to subtle facial expressions in the faces of their peers, from whom subtle feedback may be especially salient to children for regulating ongoing social interactions or in dynamic images of the type typically seen during social interactions. Indeed, adults are more accurate in recognizing facial expressions from dynamic displays than from static images, likely because the dynamic information enhances the perception of change (Ambadar et al., 2005). Had we used dynamic displays, the difference between adults and children might have been diminished, but it could instead have been increased if adults are more adept than children at using the dynamic cues. It is unlikely that we would have found greater sensitivity had we used the faces of children rather than adults because there is no systematic difference in the results from previous studies using the faces of adults (Durand et al., 2007; Markham & Wang, 1996; Vicari et al., 2000) and of children (Boyatzis et al., 1993; Camras & Allison, 1985; Widen & Russell, 2003). We also note that children need to become adept at reading the subtle facial expressions on the faces of their parents, teachers, friends' parents, and club leaders, and our results indicate that this skill develops slowly during middle childhood and at different rates for different facial expressions. A future study could use the technique described here to investigate empirically whether there is any difference in sensitivity for peer faces versus adult faces as well as whether sensitivity is higher for faces of familiar individuals.

The errors by 5-year-olds in detecting low intensity expressions of fear and sadness (Experiment 1) and in discriminating intensity differences in all three expressions (Experiment 2) might be related to limits on their visual acuity and contrast sensitivity, limits that disappear by 7 years of age (Ellemberg, Lewis, Liu, & Maurer, 1999; reviewed in Maurer & Lewis, 2001). Limits on sensitivity to high spatial frequencies (i.e., fine detail) will make it harder for 5-year-olds to see the subtle differences in the shape of the mouth and eyes that distinguish neutral faces from expressive faces both in our experiment and in real-world interactions. Studies of adults indicate that discrimination of neutral faces from faces conveying happiness, sadness, or fear is optimal when high spatial frequencies are available (Goren & Wilson, 2006). High spatial frequencies are likely also important for discriminating between intensities of the same emotion and in recognizing which emotion is conveyed in low-intensity exemplars. Indirect evidence for their role in correct identification is the dropoff in adults' accuracy when faces are moved to the periphery, where acuity and contrast sensitivity are known to be degraded (Goren & Wilson, 2006). Thus, limitations in acuity and contrast sensitivity may limit 5-year-olds' performance on our tasks and in real-world processing of facial expressions. However, they cannot explain the limitations at 7 years of age because by that age both acuity and spatial contrast sensitivity are adult-like (Ellemberg et al., 1999).

Developmental changes in two other basic visual abilities may contribute to improved sensitivity to subtle facial expressions: vernier acuity and contour integration, both of which continue to improve into early adolescence (Kovács, Kozma, Fehér, & Benedek, 1999; Skoczenski & Norcia, 2002). Both require fine sensitivity to the alignment between two local elements: to judge which one is offset in a particular direction (vernier acuity) and to judge which elements among many form a shape-defining contour (contour integration). Improvements in these visual abilities will enhance the ability to detect small changes in the relationship between two nearby facial features. Some critical information for expressions is conveyed in this way, for example, by the distance of the eyebrows from the eyes and each other. Although children begin to process faces holistically by 4 to 6 years of age (de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Pellicano & Rhodes, 2003; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998), it takes many years for children's face processing abilities to reach adult levels. Children younger than 10 years of age are not adult-like in processing facial identity based on small differences in the spacing of features (second-order relations) (Mondloch, Dobson, Parson, & Maurer, 2004; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch, Le Grand, & Maurer, 2002; but see McKone & Boyer, 2006, and Pellicano, Rhodes, & Peters, 2006, for adult-like sensitivity on some tasks at a younger age). The late improvements in sensitivity to small differences in the relationship between neighboring facial features may contribute to the observed improvement in distinguishing low-intensity emotions from neutral emotions (Experiment 1) and in discriminating between two intensities of the same emotion (Experiment 2).

The limitations on acuity, contrast sensitivity, vernier acuity, contour integration, and sensitivity to facial feature spacing will affect not only the information children pick up in our laboratory task but also the information they pick up from the world, where context can serve as a tutor to aid children in deciphering the meaning of subtle visual cues to emotion. Context will often disambiguate whether an individual is feeling neutral or mildly emotional and which emotion is being felt. In addition to visual improvements, cognitive changes may affect children's ability to learn from such contextual cues. Deciphering the context often requires taking the perspective of the person conveying the emotion, and perspective-taking ability continues to develop through adolescence (Choudhury, Blakemore, & Charman, 2006). In fact, one explanation of the difficulties individuals with autism have with decoding facial expressions is their deficiency in taking other people's perspective (Baron-Cohen, 2002).

The contribution of experience to developmental changes in sensitivity to facial expressions has been supported empirically by comparing typically developing children with children who are likely to have had abnormally high or low exposure to facial expressions. Neglected children, whose rearing environment is likely characterized by fewer social interactions than normal, are less accurate at discriminating facial expressions than children reared in a normal social environment (Pollak, Cicchetti, Hornung, & Reed, 2000). Physically abused children, who can be assumed to have more than the usual amount of exposure to anger, have a lower threshold to detect anger in a face but perform like typical children in detecting happy and fearful expressions (Pollak & Sinha, 2002). Although both visuo-cognitive development and experience likely contribute to the development of facial expression processing, they might not be separate factors but rather factors that interact with each other. When children with immature sensitivity to facial expression and immature visuo-cognitive skills interact with other people, they may fail to notice subtle facial expressions (e.g., subtle sadness after a loss) or to modify their behavior appropriately even when they see intense facial expressions (a mother's surprise that the house is clean vs. that the child lost a shoe again at school). Improvements in understanding contextual cues and the perspective of others will allow children to more appropriately modify behavior in response to a facial expression and may cause children to attend more carefully to informative facial expressions, leading to improved sensitivity. Improvements in sensitivity to facial expressions, in turn, may make expressive information more salient and hence more likely to affect children's responses in social interactions, leading to improved social cognitive skills.

Our results suggest that sensitivity to happy, sad, and fearful expressions develop at different rates. However, it may be problematic to make direct comparisons of the pattern of age differences for the three expressions because the endpoints (100% intensity) of each expression might not have the same amount of physical difference from neutral in our experiment and, perhaps, in the real world. It is possible that children were adult-like with happy expressions but not fearful expressions simply because the physical difference between the endpoint of our happy expressions and neutral might have been larger than the physical difference between the endpoint of our fearful expressions and neutral. If so, the physical difference between two adjacent intensities in happy faces (e.g., 0% vs. 5%) would be larger than the physical difference between those two values in fearful faces. As a result, happy faces would be easier to detect than fearful faces. This scaling issue is inherent in studies of facial expression, even those limited to intense expressions.

Two analyses of our stimuli suggest that we succeeded in creating a stimulus set in which the endpoints were equally distinct from neutral and, hence, that it is reasonable to compare the developmental patterns across expressions. First, the endpoint faces were selected because adults in a previous study (Palermo & Coltheart, 2004) had rated them as comparably intense examples of the emotional expression; on a 7-point scale, adults gave the endpoint expressions mean intensity ratings, averaged across the four models, of 5.43 for the happy faces, 5.35 for the sad faces, and 5.20 for the fearful faces. Second, correlations between the luminance values in the endpoint faces and in the neutral face were similar for each of the three expressions. For each model, we converted the four pictures (100% happy, 100% sad, 100% fear, and neutral) to grayscale images with 256 levels of intensity. We correlated the luminance values of corresponding pixels in the neutral face and each of the three expressive faces using normalized cross-correlations (Gold, Sekuler, & Bennett, 2004). The means of the correlation coefficients across the four models were .87 for happy compared with neutral, .84 for sad compared with neutral, and .85 for fearful compared with neutral. These values suggest that our endpoint pictures have similar physical differences to their corresponding neutral faces. However, it is possible that, in the real world, the peaks of different expressions may involve different amounts of feature displacement away from a neutral expression (e.g., more displacement for surprise than for happiness or sadness). Future studies could investigate this possibility by measuring the maximum displacement possible of the muscles activated for each expression, asking adults to rate the naturalness of simulations of those maximum displacements and/or creating a database of expressions generated in natural situations that evoke intense feelings. Another methodological concern is that we assumed that linear morphing between a neutral face and an emotional face accurately represents the change in intensity of the corresponding facial expression. Although the same technique was used in previous studies (Blair et al., 2001; Herba et al., 2006; Herba et al., 2008; Hess et al., 1997; Thomas et al., 2007), it is possible that in naturally occurring facial expressions intensity of feeling is not related linearly to facial muscle displacement. To our knowledge, there is no study directly investigating the quantified relationship between intensity of facial expression and displacement of facial features.

In summary, by using varying intensities of facial expression, we made new discoveries about the development of sensitivity to happy, sad, and fearful facial expressions. Future studies could use the techniques described here to study age differences in sensitivity to other facial expressions and how that sensitivity varies with the familiarity of the face (e.g., same race vs. other race, familiar vs. unfamiliar, child vs. adult) and with the possible misidentifications (e.g., fear with surprise). In addition, the threshold technique used in the current study could be used to measure sensitivity to facial expressions in special populations such as children with autism, children with abnormal visual experience, and shy children.

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References

Adolphs, R., Tranel, D., Damasio, A., & Damasio, A. (1995). Fear and the human amygdala. *Journal of Neuroscience, 15*, 5879–5891.

Ambadar, Z., Schooler, J. W., & Cohn, J. F. (2005). Deciphering the enigmatic face: The importance of facial dynamics in interpreting subtle facial expressions. *Psychological Science, 16*, 403–410.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences, 6*, 248–254.

Batty, M., & Taylor, M. J. (2006). The development of emotional face processing during childhood. *Developmental Science, 9*, 207–220.

Blair, R., Colledge, E., Murray, L., & Mitchell, D. (2001). A selective impairment in the processing of sad and fearful expressions in children with psychopathic tendencies. *Journal of Abnormal Child Psychology, 29*, 491–498.

Boyatzis, C. J., Chazan, E., & Ting, C. Z. (1993). Preschool children's decoding of facial emotions. *Journal of Genetic Psychology, 154*, 375–382.

Calder, A. J., Young, A. W., Perrett, D. I., & Etcoff, N. L. (1996). Categorical perception of morphed facial expressions. *Visual Cognition, 3*, 81–117.

Camras, L. A., & Allison, K. (1985). Children's understanding of emotional facial expressions and verbal labels. *Journal of Nonverbal Behavior, 9*, 84–94.

Choudhury, S., Blakemore, S. J., & Charman, T. (2006). Social cognitive development during adolescence. *Social Cognitive and Affective Neuroscience, 1*, 165–174.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers, 25*, 257–271.

de Heering, A., Houthuys, S., & Rossion, B. (2007). Holistic face processing is mature at 4 years of age: Evidence from the composite face effect. *Journal of Experimental Child Psychology, 96*, 57–70.

De Sonneville, L. M., Verschoor, C. A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., & Vranken, M. (2002). Facial identity and facial emotions: Speed, accuracy, and processing strategies in children and adults. *Journal of Clinical and Experimental Neuropsychology, 24*, 200–213.

Duchenne de Boulogne, G. B. (1990). *The mechanism of human facial expression* (Cuthbertson A, Trans.). New York: Cambridge University Press.

Durand, K., Gallay, M., Seigneuric, A., Robichon, F., & Baudouin, J. Y. (2007). The development of facial emotion recognition: The role of configural information. *Journal of Experimental Child Psychology, 97*, 14–27.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48*, 384–392.

Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology, 17*, 124–129.

Ekman, P., Friesen, W. V., O'Sullivan, M., Chan, A., Diacoyanni-Tarlatzis, I., Heider, K., Krause, R., LeCompte, W. A., Pitcairn, T., Ricci-Bitti, P. E., Scherer, K., Tomita, M., & Tzavaras, A. (1987). Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of Personality and Social Psychology, 53*, 712–717.

Elfenbein, H. A., & Ambady, N. (2002). On the universality and cultural specificity of emotion recognition: A meta-analysis. *Psychological Bulletin, 128*, 203–235.

Ellemberg, D., Lewis, T., Liu, C., & Maurer, D. (1999). Development of spatial and temporal vision during childhood. *Vision Research, 39*, 2325–2333.

Etcoff, N. L., & Magee, J. J. (1992). Categorical perception of facial expression. *Cognition, 44*, 227–240.

Gold, J. M., Sekuler, A. B., & Bennett, P. J. (2004). Characterizing perceptual learning with external noise. *Cognitive Science, 28*, 167–207.

Goren, D., & Wilson, H. R. (2006). Quantifying facial expression recognition across viewing conditions. *Vision Research, 46*, 1253–1262.

Herba, C. M., Benson, P., Landau, S., Russell, T., Goodwin, C., Lemche, E., Santosh, P., & Phillips, M. (2008). Impact of familiarity upon children's developing facial expression recognition. *Journal of Child Psychology and Psychiatry, 49*, 201–210.

Herba, C. M., Landau, S., Russell, T., Ecker, C., & Phillips, M. L. (2006). The development of emotion-processing in children: Effects of age, emotion, and intensity. *Journal of Child Psychology and Psychiatry, 47*, 1098–1106.

Herba, C. M., & Phillips, M. (2004). Annotation: Development of facial expression recognition from childhood to adolescence: Behavioural and neurological perspectives. *Journal of Child Psychology and Psychiatry, 45*, 1185–1198.

Hess, U., Blairy, S., & Kleck, R. E. (1997). The intensity of emotional facial expressions and decoding accuracy. *Journal of Nonverbal Behavior, 21*, 241–257.

Izard, C. E. (1971). The face of emotion. New York: Appleton-Century-Crofts.

Kolb, B., Wilson, B., & Taylor, L. (1992). Developmental changes in the recognition and comprehension of facial expression: Implications for frontal lobe function. *Brain and Cognition, 20*, 74–84.

Kovács, I., Kozma, P., Fehér, A., & Benedek, G. (1999). Late maturation of visual spatial integration in humans. *Proceedings of the National Academy of Sciences, 96*, 12204–12209.

Markham, R., & Adams, K. (1992). The effect of type of task on children's identification of facial expressions. *Journal of Nonverbal Behavior, 16*, 21–39.

Markham, R., & Wang, L. (1996). Recognition of emotion by Chinese and Australian children. *Journal of Cross-Cultural Psychology, 27*, 616–643.

Maurer, D., & Lewis, T. (2001). Visual acuity and spatial contrast sensitivity: Normal development and underlying mechanisms. In C. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (pp. 237–250). Cambridge, MA: MIT Press.

McKone, E., & Boyer, B. L. (2006). Sensitivity of 4-year-olds to featural and second-order relational changes in face distinctiveness. *Journal of Experimental Child Psychology, 94*, 134–162.

Mondloch, C. J., Dobson, K. S., Parson, J., & Maurer, D. (2004). Why 8-year-olds can't tell the difference between Steve Martin and Paul Newman: Factors contributing to the slow development of sensitivity to the spacing of facial features. *Journal of Experimental Child Psychology, 89*, 159–181.

Mondloch, C. J., Geldart, S., Maurer, D., & Le Grand, R. (2003). Developmental changes in face processing skills. *Journal of Experimental Child Psychology, 86*, 67–84.

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31*, 553–566.

Mondloch, C., Pathman, T., Maurer, D., Le Grand, R., & de Schonen, S. (2007). The composite face effect in six-year-old children: Evidence of adultlike holistic face processing. *Visual Cognition, 15*, 564–577.

Monk, C. S., McClure, E. B., Nelson, E. E., Zarahn, E., Bilder, R. M., Leibenluft, E., Charney, D. S., Ernst, M., & Pine, D. S. (2003). Adolescent immaturity in attention-related brain engagement to emotional facial expressions. *NeuroImage, 20*, 420–428.

Nelson, C. A. (1987). The recognition of facial expressions in the first two years of life: Mechanisms of development. *Child Development, 58*, 889–909.

Nelson, C. A., & Dolgin, K. G. (1985). The generalized discrimination of facial expressions by seven-month-old infants. *Child Development, 56*, 58–61.

Palermo, R., & Coltheart, M. (2004). Photographs of facial expression: Accuracy, response times, and ratings of intensity. *Behavior Research Methods, Instruments, & Computers, 36*, 634–638.

Pellicano, E., & Rhodes, G. (2003). Holistic processing of faces in preschool children and adults. *Psychological Science, 14*, 618–622.

Pellicano, E., Rhodes, G., & Peters, M. (2006). Are preschoolers sensitive to configural information in faces? *Developmental Science, 9*, 270–277.

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Pollak, S. D., Cicchetti, D., Hornung, K., & Reed, A. (2000). Recognizing emotion in faces: Developmental effects of child abuse and neglect. *Developmental Psychology, 36*, 679–688.

Pollak, S. D., & Sinha, P. (2002). Effects of early experience on children's recognition of facial displays of emotion. *Developmental Psychology, 38*, 784–791.

Russell, J. A. (1994). Is there universal recognition of emotion from facial expression? A review of the cross-cultural studies. *Psychological Bulletin, 115*, 102–141.

Skoczenski, A. M., & Norcia, A. M. (2002). Late maturation of visual hyperacuity. *Psychological Science, 13*, 537–541.

Tanaka, J. W., Kay, J. B., Grinnell, E., Stansfield, B., & Szechter, L. (1998). Face recognition in young children: When the whole is greater than the sum of its parts. *Visual Cognition, 5*, 479–496.

Thomas, L. A., De Bellis, M. D., Graham, R., & LaBar, K. S. (2007). Development of emotional facial recognition in late childhood and adolescence. *Developmental Science, 10*, 547–558.

Thomas, K. M., Drevets, W. C., Whalen, P. J., Eccard, C. H., Dahl, R. E., Ryan, N. D., & Casey, B. J. (2001). Amygdala response to facial expressions in children and adults. *Biological Psychiatry, 49*, 309–316.

Tottenham, N., Tanaka, J., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B. J., Nelson, C. A. (in press). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*.

Vicari, S., Reilly, J. S., Pasqualetti, P., Vizzotto, A., & Caltagirone, C. (2000). Recognition of facial expressions of emotions in school-age children: The intersection of perceptual and semantic categories. *Acta Paediatrica, 89*, 836–845.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. *Nature Neuroscience, 6*, 624–631.

Widen, S. C., & Russell, J. A. (2003). A closer look at preschoolers' freely produced labels for facial expressions. *Developmental Psychology, 39*, 114–128.

Young, A. W., Rowland, D., Calder, A. J., Etcoff, N. L., Seth, A., & Perrett, D. I. (1997). Facial expression megamix: Tests of dimensional and category accounts of emotion recognition. *Cognition, 63*, 271–313.

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