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Children's representations of facial expression and identity: Identity-contingent expression aftereffects

Mark D. Vida, Catherine J. Mondloch *

Department of Psychology, Brock University, 500 Glenridge Avenue, St. Catharines, Ont., Canada L2S 3A1

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A B S T R A C T

This investigation used adaptation aftereffects to examine developmental changes in the perception of facial expressions. Previous studies have shown that adults' perceptions of ambiguous facial expressions are biased following adaptation to intense expressions. These expression aftereffects are strong when the adapting and probe expressions share the same facial identity but are mitigated when they are posed by different identities. We extended these findings by comparing expression aftereffects and categorical boundaries in adults versus 5- to 9-year-olds ($n = 20$/group). Children displayed adult-like aftereffects and categorical boundaries for happy/sad by 7 years of age and for fear/anger by 9 years of age. These findings suggest that both children and adults perceive expressions according to malleable dimensions in which representations of facial expression are partially integrated with facial identity.

Introduction

Face-to-face social interactions require rapid and accurate interpretation of both facial expressions and individual identity. Bruce and Young's (1986) classic model of face perception suggests independent and parallel processing of these two cues, a proposal supported by studies in cognitive psychology (Calder, Young, Keane, & Dean, 2000; Campbell, Brooks, de Haan, & Roberts, 1996; Young, McWeeny, Hay, & Ellis, 1986). Campbell and colleagues (1996) showed that judgments of lip-read speech, expression, and identity were not subject to interference by judgment-irrelevant factors (e.g., judgments of expression were not affected by changes in identity). Calder and colleagues

* Corresponding author. Fax: +1 905 688 6922.
E-mail address: cmondloch@brocku.ca (C.J. Mondloch).

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(2000) presented three types of composite face stimuli produced by aligning the top half of one face with the bottom half of another face: same identity/different expression, different identity/same expression, and different identity/different expression. Adults were slower to identify the expression in the bottom half when the bottom half was aligned with a top half displaying a different emotional expression, but not when the bottom half was aligned with a top half of a different model displaying the same emotional expression. Similarly, adults' reaction time when naming the identity of the bottom half of a face was impaired when the top half had a different identity, but not when the top half had the same identity but was displaying a different facial expression. Calder and colleagues concluded that holistic processing underlies recognition of both identity and facial expressions but that different information may be relevant for the two types of processing.

Further evidence for Bruce and Young's (1986) model comes from cognitive neuropsychology. Prosopagnosics display impaired recognition of facial identity but intact recognition of facial expression, gender, and age (Tranel, Damasio, & Damasio, 1988), and following brain injury some individuals display impaired expression recognition but intact identity recognition, whereas others show the reverse pattern (Young, Newcombe, de Haan, Small, & Hay, 1993). Functional imaging studies have localized processing of facial identity to the lateral fusiform gyrus and processing of facial expression (and other changeable facial characteristics) to the superior temporal sulcus (see Haxby, Hoffman, & Gobbini, 2000, for a review). Based on this evidence, Haxby and colleagues (2000) proposed a distributed neural system for face perception where recognition of changeable and nonchangeable facial characteristics involves separable but overlapping neural structures.

Although processing of facial identity and expression appears to be dissociable, some integration must occur. Recognition of expression and identity may involve partially integrated representations, but the degree of functional integration may depend on information processing demands (Calder & Young, 2005). Indeed, the ability to integrate identity and expression cues allows individuals to recognize the same person in different affective states.

The purpose of our study was to investigate the integration of identity and expression cues in children. Although numerous studies have investigated the development of expert face recognition (Freire & Lee, 2001; Gilchrist & McKone, 2003; Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch, Le Grand, & Maurer, 2002; Pellicano, Rhodes, & Peters, 2006) or expression recognition (Camras & Allison, 1985; Kolb, Wilson, & Taylor, 1992; Markham & Adams, 1992; Markham & Wang, 1996; Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000), no research to date has assessed the integration of expression and identity in children. To do so, we used a relatively new technique that is useful for probing representations underlying various perceptual abilities: face adaptation.

Face adaptation

Adaptation aftereffects are used as a means of investigating visual perception. For example, following adaptation to a visual pattern tilted in one direction (e.g., clockwise), a vertically oriented pattern appears to be tilted in the opposite direction, and following adaptation to a waterfall, a stationary pattern appears to move upward (reviewed in Leopold & Bondar, 2005). Adaptation aftereffects have been observed for other visual characteristics, including luminance, contrast, and direction of motion, and are attributed to reduced neural activation following repeated stimulation (Ibbotson, 2005). Research in social and cognitive psychology has applied similar principles to explain a variety of sociocognitive phenomena such as lower than expected happiness levels in lottery winners (see Brickman, Coates, & Janoff-Bulman, 1978; Helson, 1964).

Adaptation studies indicate that face perception is a dynamic process; exposure to face stimuli biases subsequent perceptions of faces, producing face aftereffects (Fox & Barton, 2007; Leopold, O'Toole, Vetter, & Blanz, 2001; Webster, Kaping, Mizokami, & Duhamel, 2004). Following adaptation to consistently distorted faces (e.g., with very compressed features), unaltered faces appear to be distorted in the opposite direction (Webster & MacLin, 1999), consistent with Valentine's (1991) norm-based coding model. According to this model, faces vary continuously on multiple dimensions (e.g., eye size, distance between nose and mouth), each of which is represented as a vector in "face space." Faces near the prototype are rated as more normal and more attractive than faces that are farther away. Attractiveness aftereffects occur because the adapting stimulus changes the prototype (or norm). Viewing a series of faces with compressed features moves the norm toward the compressed side of the previous average face. Consequently, unaltered faces no longer lie near the prototype; rather, they lie on the opposite (i.e., expanded) side. Adaptation aftereffects have been observed for a variety of facial dimensions (reviewed by Rhodes et al., 2005); for example, after adaptation to a male face, an androgynous face appears to be female, whereas after adaptation to a female face, that same androgynous face appears to be male (Webster et al., 2004).

Aftereffects also have been reported for emotional facial expressions. Webster and colleagues (2004) created morphed continua of facial expressions by using computer software to gradually interpolate between pairs of facial expressions (e.g., happy/sad) in the same facial identity. Following adaptation to an intense expression (e.g., happiness) for 5 s, adults' judgments of the morphed probe expressions were biased in the opposite direction (e.g., adults were more likely to classify faces as sad after adaptation to happy than after adaptation to sad).

To investigate the relationship between facial identity and emotional expressions, Fox and Barton (2007) extended Webster and colleagues' (2004) method by varying the identity and sensory modality of the adapting expressions. In some conditions, the adapting expression was a face that either shared or did not share the same identity as the morphed probe. In other conditions, the adapting expression was not a face (e.g., it presented an auditory expression of emotion). Expression aftereffects were absent when the adapting stimulus was not a face, indicating that the mechanisms mediating expression aftereffects are face specific. Aftereffects were mitigated (for fear/anger) or absent (for happy/sad) when the identity of the adapting face was different from the identity of the morphed probe. Fox and Barton (2007) concluded that adults' perception of facial expression is partially integrated with facial identity, thereby reducing aftereffects in their different-identity condition. In contrast, Fox, Oruç, and Barton (2008) found no reduction in identity aftereffects when the adapting face had the same identity as, but a different expression from, the morphed probe face, indicating an asymmetry in the representations of identity and expression; although the representation of expression depends on facial identity, the representation of facial identity seems to be independent of facial expression.

Expression aftereffects are consistent with dimensional accounts of expression perception. The classic circumplex model of affect (Bimler & Kirkland, 1997, 2001; Russell, 1980; Russell & Bullock, 1986; Russell, Lewicka, & Niit, 1989) suggests that two dimensions, valence (unpleasant/pleasant) and arousal (low/high), account for similarity ratings between pairs of facial expressions. Some studies have also suggested a third dimension corresponding to approach/avoidance (e.g., Russell, 1978; Russell & Bullock, 1985). If expressions are coded in relation to a set of underlying dimensions, it is possible that adaptation to a given expression could shift the perception of subsequently viewed faces along a given dimension (e.g., biased toward the unpleasant end of the valence dimension after adaptation to a pleasant expression such as happiness).

Development of sensitivity to facial expressions

In most previous studies investigating the development of sensitivity to facial expressions, children have been asked to match or label intense (i.e., prototypical) facial expressions (Camras & Allison, 1985; Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Kolb et al., 1992; Markham & Adams, 1992; Markham & Wang, 1996; Vicari et al., 2000). These studies reported few age-related differences in the perception of happy expressions and a gradual improvement in recognition and labeling performance for other expressions between 4 and 10 years of age. Even young children may process emotional expressions based on underlying dimensions; for example, 2-year-olds sort faces on a pleasure/displeasure dimension (Russell & Bullock, 1986), and by 8 years of age children sort prototypical expressions much like adults do (Kolb et al., 1992), although the clustering of emotions and the dimensions underlying similarity judgments might not be adult-like until after 7 years of age (Gao & Maurer, 2009b). In the one developmental study measuring threshold sensitivity to facial expressions, Gao and Maurer (2009a) blended intense exemplars of three emotional facial expressions (happiness, sadness, and fear) with neutral expressions to determine the minimal proportion of each target expression required for children and adults to recognize that the expression was not neutral and to accurately label the blends. They reported adult-like sensitivity to happiness by 5 years of age. In contrast, although 5-year-olds were no more likely than adults to label a sad face as neutral, they were more likely than adults to mislabel sad faces as fearful, and children's thresholds for fear were not adult-like until 10 years of age. To our knowledge, no previous study has tested the independence of representations of facial identity and facial expressions in children.

We replicated Fox and Barton's (2007) study with 5- to 9-year-olds. In Experiment 1, we asked adults and 5- and 7-year-olds to classify blends of happy/sad in three conditions: no-adaptation, same-identity adaptation, and different-identity adaptation. In Experiment 2, we asked adults and 7- and 9-year-olds to classify blends of fear/anger in the same three conditions. In both experiments, aftereffects in the same-identity condition will indicate the extent to which children's perception of facial expression is altered by previously viewed stimuli; differential aftereffects in the same-identity versus different-identity conditions will indicate the extent to which children's perception of facial expression is integrated with their perception of identity. We hypothesized that, like the adults in Fox and Barton's (2007) study, adults in the current investigation would show stronger expression aftereffects in the same-identity condition than in the different-identity condition. Our primary goal was to determine the age at which children show an adult-like pattern for each expression pair.

Like Fox and Barton (2007), we administered two blocks of no-adaptation trials at the beginning of the test session to determine whether young children and adults perceive blended facial expressions according to similar categories. To our knowledge, only three previous studies have assessed children's sensitivity to blended expressions. de Gelder, Teunisse, and Benson (1997) presented adults and 9- and 10-year-olds with three continua of facial expressions: happy/sad, angry/sad, and angry/afraid. Although the slopes of children's identification functions were shallower than those of adults, children's functions for all three continua were nearly adult-like and their discrimination performance on an ABX task was more accurate for expression pairs that crossed a category boundary than for face pairs that fell within a category for two of the three expression pairs (happy/sad and angry/afraid but not angry/sad). Thomas, De Bellis, Graham, and LaBar (2007) presented children (7–13 years of age), adolescents (14–18 years of age), and adults (25–57 years of age) with faces from three morphed continua: anger/neutral, fear/neutral, and fear/anger. Adults' sensitivity exceeded that of children for all three morphed continua and that of adolescents for the neutral/anger and fear/anger morphs. Pollak and Kistler (2002) compared categorization of morphed expressions in normal 9-year-olds versus 9-year-olds identified as victims of abuse and neglect. Relative to typically developing children, abused children were significantly biased toward angry expressions, indicating that high exposure to threat and hostility biases perception of emotional expressions. To our knowledge, no study to date has tested children younger than 7 years of age with blended expressions, and no study has investigated developmental change in the perception of blended expressions between 5 and 10 years of age.

We elected to test children with a happy/sad continuum and a fear/anger continuum for two reasons. First, these continua were used in the Fox and Barton (2007) study on which our developmental study was based. Second, these pairings are of interest developmentally because sensitivity to happiness and sadness in the human face develops relatively early (e.g., threshold sensitivity to happiness is adult-like by 5 years of age [Gao & Maurer, 2009a]), whereas sensitivity to fear and anger develops later (e.g., threshold sensitivity to fear is not adult-like until 10 years of age [Gao & Maurer, 2009a; see also Durand et al., 2007; Vicari et al., 2000]). Because of the different developmental timelines observed previously for different facial expressions, in both experiments we began by testing 7-year-olds and adults and then, based on the performance of 7-year-olds, we tested 5-year-olds on happy/sad (Experiment 1) and 9-year-olds on fear/anger (Experiment 2).

Experiment 1

Method

Participants

Participants in Experiment 1 were 20 adult undergraduate students between 18 and 25 years of age (M = 19.60 years, 18 women and 2 men), 20 7-year-olds (M = 7.58 years, 10 girls and 10 boys), and 20 5-year-olds (M = 5.50 years, 9 girls and 11 boys). Adults received partial course credit or a small monetary reward. Children were recruited from local elementary schools and from a community database.

All participants were Caucasian and right-handed. Adults' handedness was measured with a questionnaire adapted from Peters (1988) that asks participants to indicate the hand used most frequently for 10 different activities (e.g., "Which hand do you use to write?"). A modified version of the hand preference questionnaire was administered to 5- and 7-year-olds (see Mondloch et al., 2002, for details). Adults and 7-year-olds had normal or corrected-to-normal vision; we did not test 5-year-olds' vision. An additional 6 participants were tested but were excluded from all analyses because they did not pass either inclusion trials (2 5-year-olds) or catch trials (2 adults and 2 5-year-olds) (see procedure section for description of catch trials).

Materials

Experiment 1 used 12 photographs of six different adult women posing happy and sad facial expressions. All face stimuli were gathered from the NimStim Face Stimulus Set (Tottenham et al., in press). One identity (Model 10) was used to create a morphed continuum of expressions ranging from happy to sad. These stimuli were produced using Norrkross MorphX software (http://www.norrkross.com), resulting in a continuum of 13 faces displaying emotions ranging from 20% happy/80% sad to 80% happy/20% sad in 5% increments (see Fig. 1). The unaltered versions of the identity used to generate the happy/sad continuum were also used as the adapting stimuli for the same-identity adaptation condition. The happy and sad versions of another identity (Model 3) were used as the adapting stimuli for the different-identity adaptation condition. One of the remaining identities (Model 1) was used to create training stimuli, and the remaining three identities (Models 5, 6, and 9) were used in inclusion trials. All facial images were presented at the center of a 23-in. Apple Cinema Display computer monitor. All images were presented in gray scale. Each image spanned a distance of 9.04 cm (8.60° at a viewing distance of 60 cm) horizontally and 12.40 cm (11.80°) vertically. All experimental trials were presented via Superlab 4.0 computer software (http://www.cedrus.com).

Procedure

Written consent was obtained from adult participants and parents of child participants. Child participants were tested in empty rooms of their respective schools or in a laboratory testing room within Brock University. The Brock University research ethics board approved all procedures used in all experiments in the current investigation.

Participants were seated 60 cm from the computer monitor. The experimenter sat behind participants so as to not enter their field of view at any time during testing. Participants used a McCally

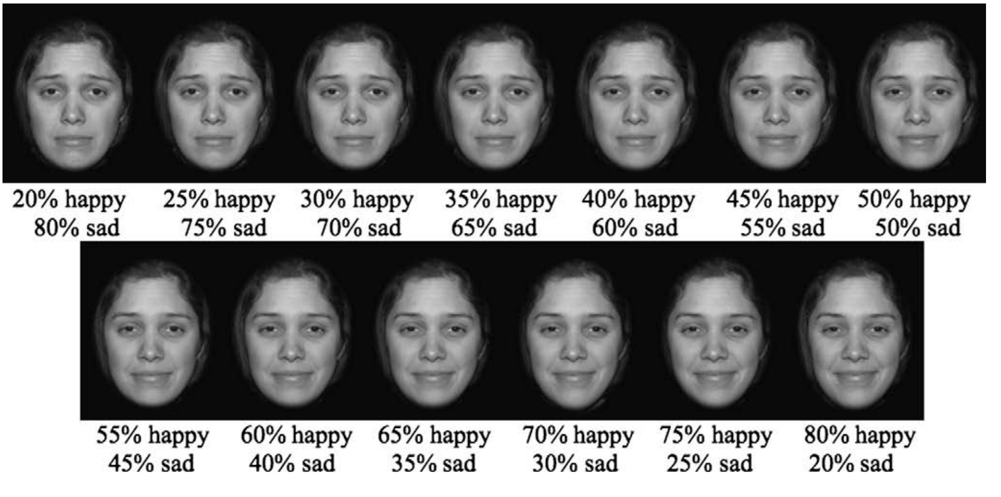

Fig. 1. Example of a morphed happy/sad continuum. The identity depicted here differs from the identity used to create the morphed continua presented in Experiment 1. In accordance with publication guidelines set forth by the Research Network on Early Experience and Brain Development, we were unable to publish images of the identity used in Experiment 1.

iShock II controller to indicate all responses. Participants held the controller in both hands and used the right hand to press the appropriate buttons, located on the right side of the controller. Within this set of buttons, the "H" button (for indicating recognition of a happy expression) was always located on the left side and the "S" button (for indicating recognition of a sad expression) was always located on the right side. Each experimental session was composed of three stages: six inclusion trials, two no-adaptation blocks, and two adaptation blocks. The two adaptation blocks always occurred after the no-adaptation blocks, but their order was counterbalanced across participants. Within each adaptation block, we embedded four catch trials designed to ensure that participants were attentive.

The experimenter introduced the experiment in the following way:

> I am going to show you some pictures of faces. They are all going to look either happy or sad. I need you to take a really good look at the face you see and watch to see how each person is feeling. After you see the picture of the face, a question mark will appear on the screen. The "H" button on the joystick in front of you means happy, and the "S" button means sad. When you see the question mark, use the "H" and "S" buttons on the joystick to choose whether the face you just saw looked happy or sad.

Participants then completed two familiarization trials in which they saw an intense happy expression and an intense sad expression displayed in a single NimStim face identity that did not appear elsewhere in the procedure. The experimenter controlled the timing of familiarization trials to ensure that participants understood the response protocol. Each facial expression was replaced by a question mark that remained on the screen until participants responded. Familiarization trials were followed by six inclusion trials. Prior to commencement of these trials, the experimenter presented the following verbal message:

> Now I am going to show you some more faces. This time, the faces are going to appear rather quickly, and so you will only have a moment to look at them. After each face, you'll see a question mark. When you see the question mark, press "H" if the face you just saw looked happy and "S" if the face looked sad.

On each inclusion trial, a face depicting an intense happy expression ($n = 3$ trials) or an intense sad expression ($n = 3$ trials) was presented for 500 ms, followed by a question mark that remained on the screen until a response was made. Inclusion trials were presented in random order. Participants were required to correctly identify five of the six facial expressions presented to be included in the experiment.

In each of two blocks of no-adaptation trials, we presented each face in the continuum once for a total of 26 trials across both no-adaptation blocks. As in the inclusion trials, stimuli were presented for 500 ms and were followed by a question mark that remained on the screen until a response was made. Prior to the first no-adaptation trial, the experimenter presented an example of a morphed image from the happy/sad expression continuum (50% happy/50% sad). During presentation of this example image, the experimenter verbally relayed the following message:

> This is Jen. I'm going to show you some pictures of Jen at a birthday party. Sometimes when Jen is at a birthday party, she might look happy if she is having a good time or sad if she is having a bad time. I need you to look at some pictures of Jen and help me sort out which pictures look happy and which ones look sad. Press the "H" button if Jen looks happy and the "S" button if she looks sad. Most of the photos will look somewhere between happy and sad, so it might be kind of hard to tell how Jen is feeling, but do your very best! Try to go as fast as you can without making any mistakes.

Each participant received each of the morphed probe stimuli in a different random order.

On each trial of the adaptation blocks, a central fixation cross was presented until the experimenter judged participants to be attentive, followed by an adaptation stimulus for 5000 ms. The adapting expression was happy on half of the trials and sad on the other half. Following presentation of the adapting stimulus, a 50-ms mask stimulus (random arrangement of black and white pixels) appeared, followed by 1 of the 13 morphed probe faces for 500 ms. Finally, a question mark appeared on the screen and remained until participants responded via key press (see Fig. 2). Each block was composed of 26 test trials, with each face in the continuum being presented on 2 trials: once after adaptation to happy and once after adaptation to sad. At the beginning of the same-identity adaptation block, the experimenter relayed the following verbal message:

> I'm going to show you some more pictures of Jen at the party. This time, you'll see one picture of Jen for a while, and then a second picture of Jen will come up very fast. Next, you will see a question mark appear on the screen. When you see the question mark, I need you to use the buttons on the joystick to show how Jen was feeling in the second picture. You have to watch the first picture very carefully so that you don't miss the second picture. Again, try to go as fast as you can without making mistakes.

At the beginning of the different-identity adaptation block, the experimenter verbally relayed the following message:

> I am going to show you some more pictures of people at a party. This time, you'll see a new girl for a few seconds, and then a picture of Jen will briefly flash up on the screen. Next, you will see a question mark appear on the screen. When you see the question mark, I need you to use the buttons on the joystick to show how Jen was feeling in the second picture. You have to watch the first picture very carefully so that you don't miss the second picture. Again, try to go as fast as you can without making mistakes.

Four catch trials were embedded into each adaptation block. In each catch trial, a gray-scale cartoon image of a wrapped present was presented in place of a morphed probe. Presents followed happy faces on two trials and sad faces on two trials. Before the first adaptation block, the experimenter provided the following verbal instructions for the catch trials:

> Another thing that happens at parties is that people get presents! Whenever you see a picture of a present, say "Present!"

Child participants also received the following verbal message:

> If you catch all of the presents, you get to pick two stickers from my sticker collection.

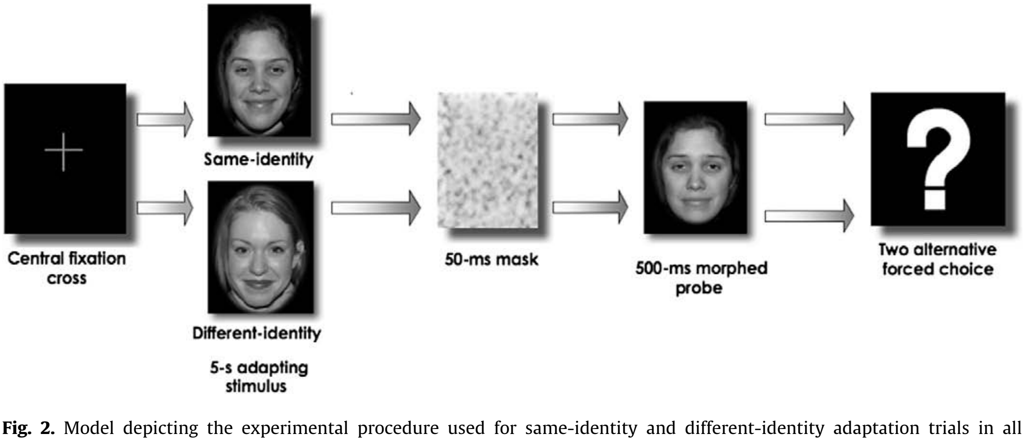

Fig. 2. Model depicting the experimental procedure used for same-identity and different-identity adaptation trials in all experiments in this investigation. As in Fig. 1, the identities depicted here differ from those presented in Experiment 1.

Catch trials allowed the experimenter to determine whether participants were attentive. Participants were required to detect three of four catch trials to be included. On completion of the same-identity and different-identity blocks, the experimenter thanked and debriefed participants and their parents.

Analysis

To determine whether children performed as well as adults on inclusion trials (i.e., when 100% expressions were presented), we conducted a one-way analysis of variance (ANOVA) comparing the numbers of correct responses made by 5-year-olds, 7-year-olds, and adults. A lack of age differences would indicate that any age effects for morphed expressions could not be attributed to children failing to understand the task or failing to accurately judge the most intense expressions. To determine the sharpness and location of the category boundary on no-adaptation trials, we calculated the proportion of participants from each age group who classified each face on the continuum as happy during the second no-adaptation block. (We treated the first block of no-adaptation trials as practice.) Because we wanted to use the method implemented by Fox and Barton (2007), each participant categorized each face in the continuum only once. We were able to conduct only two formal analyses of the no-adaptation trials. First, we defined an ambiguous region as any morphed expression for which 33% to 66% of participants categorized the face as happy (see Beale & Keil, 1995). Positions on the continuum where the proportion of participants who classified the target face as happy fell within the 33% to 66% ambiguous region were considered to be part of the happy/sad perceptual boundary (see Fig. 3A). More points in this ambiguous region indicate a weaker perceptual boundary. For each age group, we counted the number of points that fell within that ambiguous region and the location of those points. To compare children's and adults' ability to accurately categorize faces at the end points of the continuum, we conducted chi-square tests of independence (one at 20% happy/80% sad and another at 80% happy/20% sad) comparing the proportions of happy responses in adults with those in each age group of children (i.e., one test comparing adults with 5-year-olds and another test comparing adults with 7-year-olds).

To determine whether the strength of expression aftereffects varied as a function of age group and identity condition, we calculated the size of the aftereffect for each age group in each condition. For each participant, we subtracted the proportion of faces in the continuum classified as happy following adaptation to sad from the proportion classified as happy following adaptation to happy. To examine the effect of age group and identity condition on aftereffect magnitude, we conducted a two-way mixed factorial ANOVA with age as a between-participants factor and identity condition as a within-participants factor. To determine whether the aftereffects observed in each age group and identity condition were significantly different from a hypothetical null result, we conducted a series of a priori two-tailed single-sample t tests comparing the aftereffect observed in each age group and identity condition with a hypothetical null value of zero.

Results

The one-way ANOVA comparing scores on inclusion trials revealed no significant differences between age groups, $p > .05$. As shown in Fig. 3A, both adults and children displayed evidence of clear perceptual boundaries for the happy/sad continuum. The proportions of adults, 7-year-olds, and 5-year-olds who classified the expression morphs as happy fell within the ambiguous response region at a single position on the happy/sad continuum (60% happy for all groups). Nearly all adults and 7-year-olds classified the 70%, 75%, and 80% happy faces as happy, whereas no more than 80% of 5-year-olds classified these morphs as happy. At 80% happy/20% sad, a chi-square test of independence revealed a significant difference between adults and 5-year-olds only, $\chi^2(1, N = 40) = 4.44$, $p < .05$, $\phi = .33$. Only 10% or fewer adults, 5-year-olds, and 7-year-olds classified the 20%, 25%, and 30% happy faces as happy. At 20% happy/80% sad, the chi-square test of independence revealed no significant differences in the proportions of happy and sad responses between 5-year-olds and adults or between 7-year-olds and adults, $ps > .05$. Collectively, these results suggest that all age groups classified the expressions in the happy/sad continuum according to a relatively clear perceptual boundary, but the pattern of classification was not fully adult-like until 7 years of age.

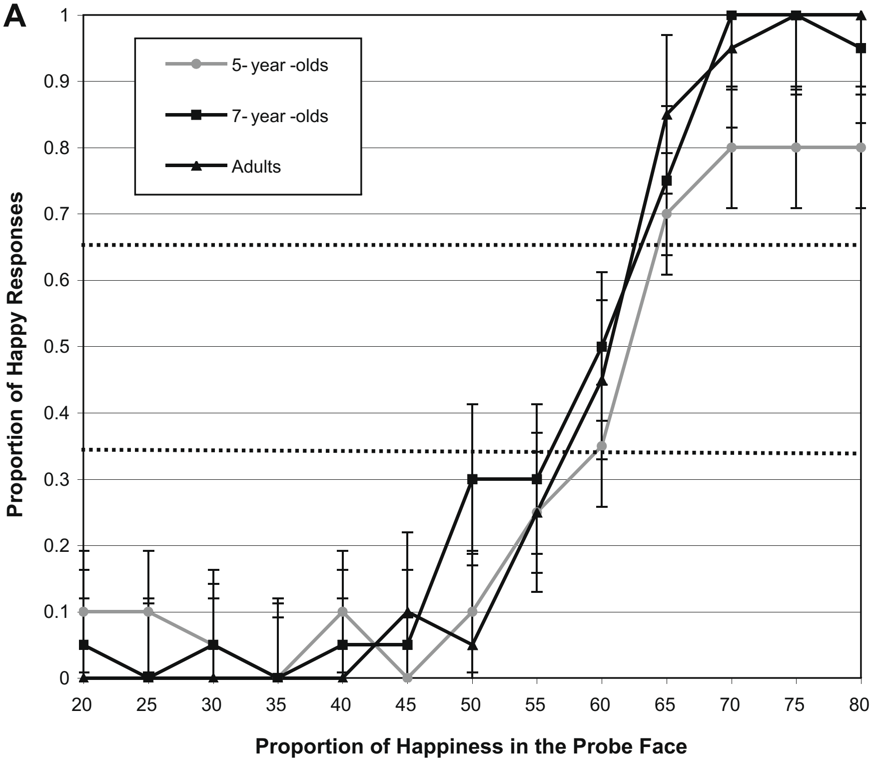

Fig. 3. (A) Proportions (±1 *SE*) of 5-year-olds, 7-year-olds, and adults (Experiment 1) who classified each morphed probe in the happy/sad continuum as happy. The horizontal dashed lines mark the upper and lower boundaries of the 33% to 66% ambiguous response region. (B) Proportions (±1*SE*) of 7-year-olds, 9-year-olds, and adults (Experiment 2) who classified each morphed probe in the fear/anger continuum as fear.

As shown in Fig. 4A, all age groups showed larger aftereffects in the same-identity condition than in the different-identity condition. A two-way mixed factorial ANOVA revealed a significant effect of identity, $F(1, 57) = 47.49$, $p < .001$, $\eta^2 = .45$, on aftereffect magnitude, such that same-identity aftereffects ($M = .28$, $SD = .09$) were significantly greater than different-identity aftereffects ($M = .07$, $SD = .07$). There was a significant effect of age group, $F(2, 57) = 5.31$, $p < .01$, $\eta^2 = .15$, but no significant interaction between age group and identity condition, $p > .05$. A Tukey's HSD post hoc test (collapsing across identity conditions) showed that 5-year-olds displayed significantly greater aftereffects than did adults, $p < .01$. All other comparisons between age groups were not significant, all $ps > .05$. Two-tailed single-sample t tests revealed that same-identity aftereffects were significantly different from zero in adults ($M = .18$, $SD = .17$), $t(19) = 4.67$, $p < .001$, Cohen's $d = 1.06$; 7-year-olds ($M = .30$, $SD = .28$), $t(19) = 4.85$, $p < .001$, Cohen's $d = 1.07$; and 5-year-olds ($M = .36$, $SD = .24$), $t(19) = 6.53$, $p < .001$, Cohen's $d = 1.50$. Different-identity aftereffects were significantly different from zero in 5-year-olds ($M = .15$, $SD = .20$), $t(19) = 3.35$, $p < .01$, Cohen's $d = 0.75$, but not in adults ($M = .01$, $SD = .08$) or 7-year-olds ($M = .05$, $SD = .13$), $ps > .20$. Thus, happy/sad aftereffects were fully adult-like by 7 years of age and nearly adult-like by 5 years of age.

Discussion

The results of Experiment 1 replicate the pattern of aftereffects reported by Fox and Barton (2007) for adults; happy/sad aftereffects were strong when the adapting expression and probe shared the same identity and were absent when the adapting expression and probe did not share the same identity.

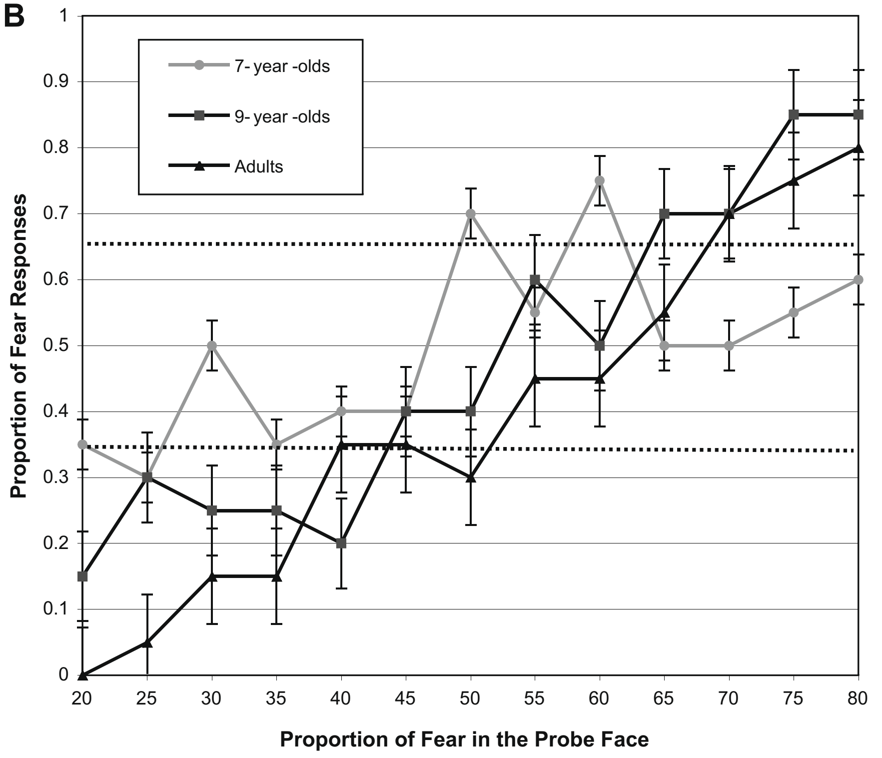

Fig. 3 (*continued*)

Our findings provide the first evidence that children display adult-like expression aftereffects. Like adults, 5-year-olds showed larger aftereffects in the same-identity condition than in the different-identity condition. The 5-year-olds differed from adults in two ways: They showed larger aftereffects overall, and they showed significant aftereffects in the different-identity condition. Both of these differences disappeared by 7 years of age. Children also displayed adult-like category boundaries by 5 years of age. These results are consistent with previous studies reporting early development of sensitivity to happy and sad expressions (Gao & Maurer, 2009a). Thus, the findings of Experiment 1 provide the first evidence indicating that children's representation of happy and sad facial expressions is dependent on facial identity. In Experiment 2, we tested children and adults on fear and anger, the second expression pair used by Fox and Barton (2007) and a set of expressions for which sensitivity develops slower than for happy and sad (Durand et al., 2007; Gao & Maurer, 2009a; Vicari et al., 2000).

Experiment 2

Method

Participants

Participants in Experiment 2 were 20 adult undergraduate students between 18 and 24 years of age (M = 19.15 years, 16 women and 4 men), 20 7-year-olds (M = 7.58 years, 11 girls and 9 boys), and 20 9-year-olds (M = 9.50 years, 11 girls and 9 boys). All participants were Caucasian and met the hand preference and visual criteria established in Experiment 1. An additional 2 adults were tested but failed to pass catch trials and were excluded from all analyses. An additional 4 9-year-olds were tested but were excluded from all analyses because they failed visual screening (n = 1), were not right-handed (n = 2), or experienced technical difficulties with the joystick controller (n = 1).

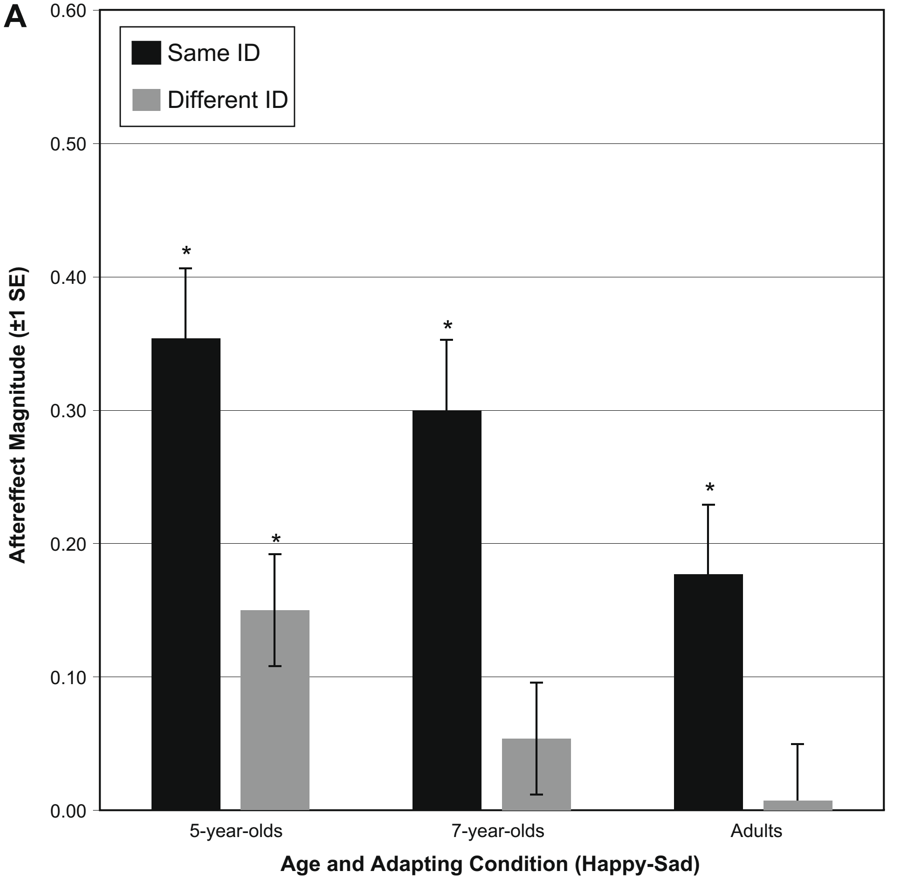

Fig. 4. (A) Happy/Sad aftereffects (±1 *SE*) in 5-year-olds, 7-year-olds, and adults. Each vertical bar represents the total aftereffect in a given identity condition and age group in Experiment 1. Standard error bars represent the standard error for the corresponding adapting condition and age group. $^{*}p < .05$. (B) Fear/Anger aftereffects (±1*SE*) in 7-year-olds, 9-year-olds, and adults in Experiment 2. $^{*}p < .05$. ID, identity.

Materials

Experiment 2 used 12 NimStim photographs of eight different adult women posing fearful and angry facial expressions. The identities used for same-identity and different-identity adapting stimuli were the same as those used in Experiment 1. We used Norrkross MorphX software to interpolate between fearful and angry facial images of the identity used to generate the happy/sad continuum in Experiment 1 (Model 10), resulting in a morphed continuum of 13 faces displaying emotions ranging from 20% fear/80% anger to 80% fear/20% anger in 5% increments (see Fig. 1). The unaltered versions of this model were used as the adapting stimuli for the same-identity adaptation condition. The anger and fear versions of another identity (Model 3) were used as the adapting stimuli for the different-identity adaptation condition. Two identities (Models 1 [fear] and 6 [anger]) were used to create training stimuli. One of these (Model 6 [fear]) and four additional identities (Models 5 [fear], 7 [anger], 8 [fear and anger], and 9 [anger]) were used in inclusion trials.

Procedure

The procedure for Experiment 2 was identical to that for Experiment 1 with one exception: Experiment 2 used facial images of NimStim face identities depicting fear and anger instead of happiness and sadness. Accordingly, verbal instructions accompanying procedures in Experiment 2 were

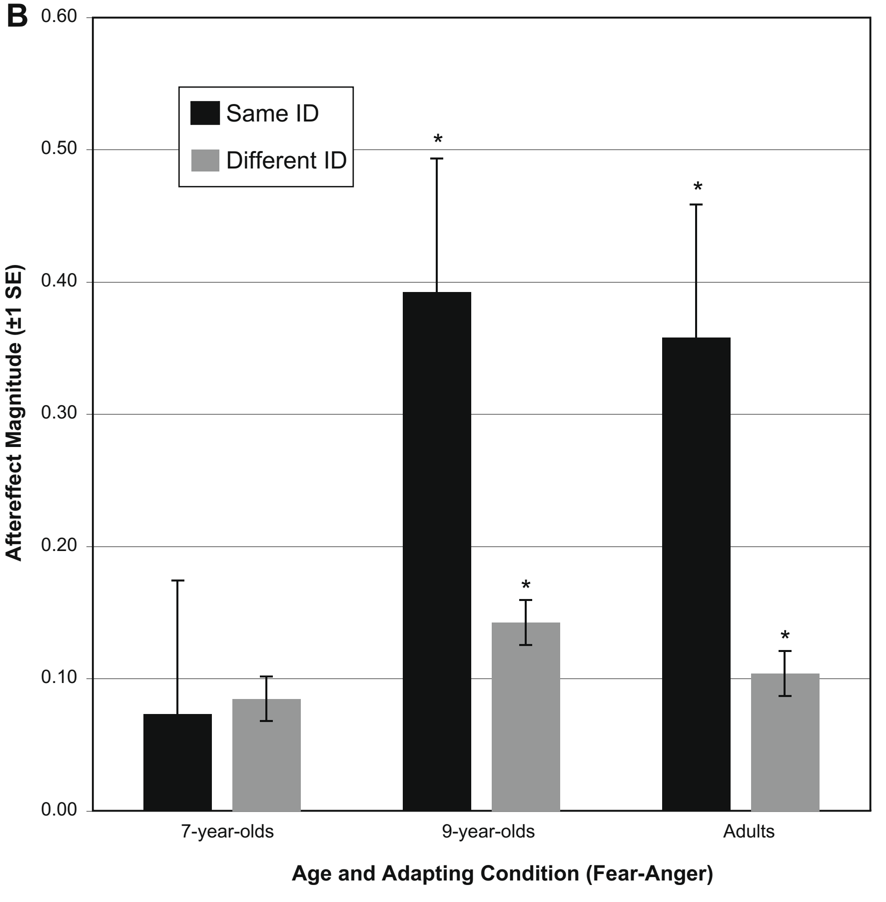

Fig. 4 (*continued*)

adjusted to reflect the use of fearful and angry expressions. For example, participants were told to press the button labeled "F" or "A" to indicate fear or anger, respectively, instead of pressing "H" or "S" to indicate happiness or sadness.

Results

The analytic procedures used in Experiment 2 were identical to those established in Experiment 1 with the sole exception that analyses for Experiment 2 evaluated perceptual boundaries and aftereffects for fear/anger instead of happy/sad. The one-way ANOVA comparing scores on inclusion trials showed no significant effect of age, $ps > .05$. Thus, children and adults displayed a similar ability to recognize intense expressions of fear and anger. As shown in Fig. 3B, none of the three age groups showed a clear boundary. Adults and 9-year-olds displayed a linear pattern of classification in the no-adaptation condition, with several points on the fear/anger continuum falling within the ambiguous region. The proportion of participants who classified the target expression as fear fell within the ambiguous region at five points for adults and four points for 9-year-olds. The proportion of 7-year-olds who classified target expressions as fearful fell within the ambiguous region at all but three points on the fear/anger continuum, two of which were not near the end points of the fear/anger continuum. Relative to Experiment 1, fewer participants in Experiment 2 categorized expressions at the ends of the continuum in a manner consistent with the more dominant expression. Whereas at least 80% of adults and children categorized faces showing 70%, 75%, or 80% happiness as happy, between 50% and 85% of adults and children categorized faces showing 70%, 75%, or 80% fear as fearful. At 80% fear/20% anger, a chi-square test of independence revealed no significant difference between adults and 9-year-olds and no significant difference between adults and 7-year-olds, all *p*s > .05. Whereas no more than 10% of adults and children classified faces showing 20%, 25%, and 30% happiness as happy, between 0% and 50% of adults and children classified faces showing 20%, 25%, and 30% fear as fearful. At 20% fear/80% anger, a chi-square test of independence revealed no significant difference between the proportions of adults and 9-year-olds who classified the target expression as fear, $p > .05$. There was a significant difference between the proportions of adults and 7-year-olds who classified the target expression as fear, $\chi^2(1, N = 40) = 8.48$, $p < .05$, $\phi = .46$, such that more 7-year-olds classified the target expressions as fear despite the face having a stronger weighting of anger (80%). Thus, although 9-year-olds and adults displayed some ability to classify the fear/anger morphs accurately, the morphed expressions of the fear/anger continuum seem to represent a more difficult discrimination than those displayed in the happy/sad continuum. Because the proportion of 7-year-olds who classified the target expression as fear did not reliably exceed the boundaries of the ambiguous response region, 7-year-olds were excluded from all further analyses.

A two-way mixed factorial ANOVA revealed a significant effect of identity condition, $F(1, 38) = 50.02$, $p < .001$, $\eta^2 = .57$, on aftereffect magnitude, such that same-identity aftereffects ($M = .37$, $SD = .23$) were significantly greater than different-identity aftereffects ($M = .12$, $SD = .23$) (see Fig. 4B). There was no significant effect of age, $p > .20$, and no significant interaction between age group and identity condition, $p > .20$. Two-tailed single-sample *t* tests showed that same-identity aftereffects were significantly different from zero in adults ($M = .36$, $SD = .16$), $t(19) = 10.12$, $p < .001$, Cohen's $d = 2.25$, and 9-year-olds ($M = .39$, $SD = .29$), $t(19) = 6.06$, $p < .001$, Cohen's $d = 1.34$. Corresponding tests in the different-identity condition showed significant aftereffects in adults ($M = .10$, $SD = .14$), $t(19) = 3.21$, $p < .01$, Cohen's $d = 0.71$, and 9-year-olds ($M = .14$, $SD = .30$), $t(19) = 2.14$, $p < .05$, Cohen's $d = 0.47$. These results indicate that fear/anger aftereffects are adult-like by 9 years of age.

Discussion

Adults in Experiment 2 replicated the pattern reported by Fox and Barton (2007); fear/anger aftereffects were strong when the adapting expression and probe shared the same identity and were mitigated when the adapting expression and probe did not share the same identity. As in Fox and Barton's study, adults in Experiment 2 showed significant different-identity aftereffects.

Like adults, 9-year-olds showed large aftereffects in the same-identity condition but much smaller aftereffects in the different-identity condition. We were unable to measure aftereffects for this continuum in younger children because they were unable to accurately categorize these blended expressions despite being very accurate when labeling the prototypical (i.e., 100%) expressions. The results of Experiment 2 indicate that, like adults, children's representation of fearful and angry facial expressions is dependent on facial identity.

Unlike Fox and Barton (2007), who employed more than one adapting identity for each identity condition, the current investigation used a single identity for each identity condition. Thus, the pattern of aftereffects observed in Experiments 1 and 2 must be interpreted with caution. In particular, it seemed possible that the observed pattern of aftereffects could be attributed to properties of the particular identities chosen (i.e., to differences in expression intensity). Specifically, we thought that the expressions displayed by the identity used for the same-identity adapting stimuli were more intense than those displayed by the identity used for the different-identity adapting stimuli, particularly for happy and sad. Prior to drawing conclusions about the development of expression aftereffects, we conducted a third experiment with adult participants in which we reversed the roles of the two facial identities used as adapting stimuli in Experiments 1 and 2.

Experiment 3

In Experiment 3, the facial identity that was used as the same-identity adapting expression and morphed probe expression in Experiments 1 and 2 ("Jen") was used as the different-identity adapting expression. The facial identity that was used as the different-identity adapting expression in Experiments 1 and 2 ("Sue") was used as the same-identity adapting expression and morphed probe in Experiment 3. If the pattern of aftereffects observed in Experiments 1 and 2 was a result of Jen showing more intense expressions than Sue, the difference between the size of the aftereffects in the same-identity versus different-identity conditions should be reduced or reversed in Experiment 3. Alternatively, if stronger aftereffects in the same-identity condition reflect the integration of expression and identity, as hypothesized by Fox and Barton (2007), the effect of identity observed in Experiments 1 and 2 should also emerge when the identities are reversed.

Method

Participants

Participants in Experiment 3 were 20 adult undergraduate students between 18 and 27 years of age ($M = 21.00$ years, 18 women and 2 men). All participants were Caucasian and met the hand preference and visual criteria established in Experiment 1. An additional participant classified nearly all expressions as happy and was excluded from all analyses. An additional 3 participants failed visual screening and were also excluded.

Materials and procedure

This experiment used the same materials and procedure as Experiment 1 with one exception: The identity that served as the same-identity adaptor and morphed probe in Experiment 1 became the different-identity adaptor in Experiment 3. Likewise, the identity serving as the different-identity adaptor in Experiment 1 became the same-identity adaptor and probe in Experiment 3.

Results

As shown in Fig. 5A, adults displayed evidence of a clear perceptual boundary for the expressions in the happy/sad continuum. The proportion of adults who classified the target expression as happy fell within the ambiguous region at a single position on the happy/sad continuum (55% happy). Fully 95% or more of the participants classified the 70%, 75%, and 80% happy expressions as happy, whereas 5% or fewer of the participants classified the 20%, 25%, and 30% happy expressions as happy.

A paired-samples two-tailed t test revealed that same-identity aftereffects ($M = .25$, $SD = .15$) were significantly greater than different-identity aftereffects ($M = .14$, $SD = .18$), $t(19) = 2.11$, $p < .05$, Cohen's $d = 1.49$ (see Fig. 5B). Single-sample two-tailed t tests revealed significant aftereffects in the same-identity condition, $t(19) = 7.38$, $p < .001$, Cohen's $d = 1.67$, and different-identity condition, $t(19) = 3.46$, $p < .01$, Cohen's $d = 0.78$.

Discussion

Adults replicated the pattern of aftereffects observed in Experiments 1 and 2. Most notably, same-identity aftereffects were significantly greater than different-identity aftereffects, although unlike in Experiment 1, different-identity aftereffects reached significance in Experiment 3, perhaps because the adapting expressions were more intense in the different-identity condition of Experiment 3. Nonetheless, in both studies adults displayed clear perceptual boundaries, with only one point in the ambiguous region, and in both studies same-identity aftereffects were greater than different-identity aftereffects. The consistency of key findings across all three experiments allows us to address our central question: Is children's representation of facial expression dependent on facial identity?

General discussion

Adaptation aftereffects

In this investigation, we used adaptation aftereffects to examine the development of dynamic perception of emotional facial expressions. We first asked whether young children would display evi-

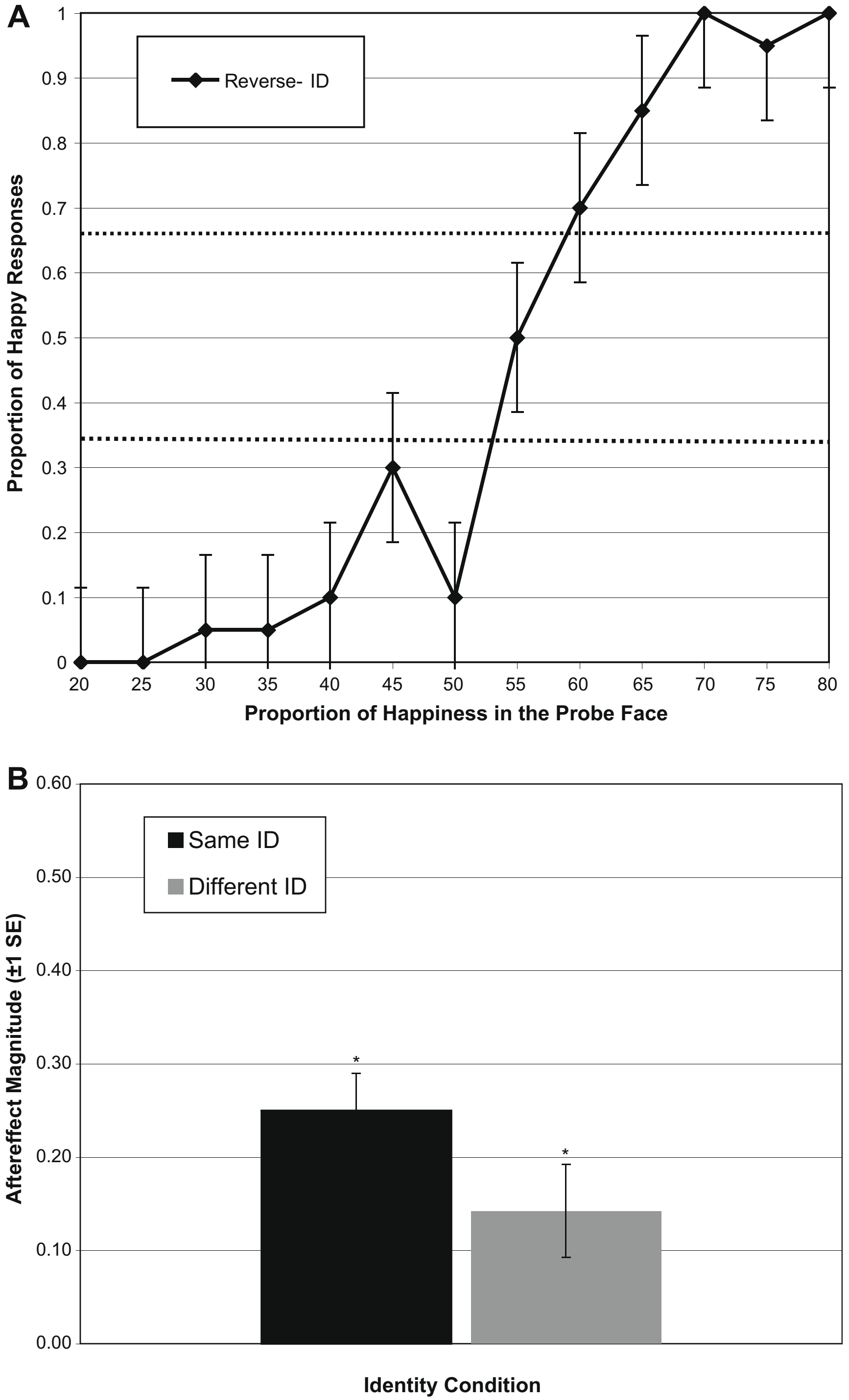

Fig. 5. (A) Proportions (±1 *SE*) of adults in Experiment 3 who classified each morphed probe in the reverse-identity happy/sad continuum as happy. (B) Same-identity and different-identity aftereffects in adults in Experiment 3. $^{*}p < .05$. ID, identity.

dence of facial expression aftereffects when the adapting face and the morphed probe face shared the same identity. In Experiment 1, happy/sad aftereffects were evident at 5 years of age, the youngest age tested. The effects were significantly larger in 5-year-olds (*M* = 25%) than in 7-year-olds (*M* = 17%) and adults (*M* = 9%), indicating that 5-year-olds' perception of blends of happy and sad expressions may be more malleable than that of older children and adults. Presumably, this could occur if the neural mechanisms underlying expression aftereffects were more sensitive to adaptation in young children or if the neural mechanisms were equally sensitive but children's decision-making processes were more easily influenced by the perceptual changes induced by adaptation (see also Durand et al., 2007). In Experiment 2, fear/anger aftereffects were adult-like by 9 years of age but were absent at 7 years of age. The lack of aftereffects in 7-year-olds is not surprising given that 7-year-olds were unable to reliably classify the expressions displayed in the baseline no-adaptation condition (despite being able to classify pure expressions of both anger and fear as well as adults). These findings provide the first evidence of facial expression aftereffects in children.

Our primary goal was to investigate whether children's representation of emotional expressions is dependent on facial identity, as was reported for adults by Fox and Barton (2007). According to these authors, smaller aftereffects in the different-identity condition than in the same-identity condition indicate that the representation of expression is dependent on (or integrated with) the representation of facial identity. Like adults, both 5- and 7-year-olds had larger aftereffects in the same-identity condition than in the different-identity condition for the happy/sad continuum. The lack of an age by identity condition interaction indicates that at all ages the representation of facial expression is integrated with the representation of facial identity. The 5-year-olds did show significant aftereffects in the different-identity condition (*M* = 15%), and this may indicate that their representation of facial expression is less well integrated with facial identity than that of 7-year-olds and adults. However, two findings argue against this possibility: First, the difference in the magnitude of same-identity versus different-identity aftereffects for the happy/sad continuum was similar for all age groups (range = 17% for adults to 25% for 7-year-olds); thus, the significant effect in the different-identity condition observed in 5-year-olds is consistent with their showing the largest aftereffects in the same-identity condition and may indicate that their category boundaries are more flexible than those of 7-year-olds and adults. Second, even adults showed small but significant aftereffects in the same-identity condition in Experiment 3, where the identities of the adapting face and the morphed probe face were reversed. This finding serves as a reminder that the presence/absence of different-identity aftereffects is less informative than their size relative to same-identity aftereffects. Likewise, 9-year-olds (the youngest age group to show same-identity aftereffects for the fear/anger continuum) showed an adult-like pattern for the fear/anger continuum. Their aftereffects in the different-identity condition were much smaller (*M* = 14%) than those in the same-identity condition (*M* = 39%), indicating that, like adults, their representation of blended expressions composed of fear and anger was dependent on facial identity. Thus, despite sensitivity to these four facial expressions developing at different rates, children's representation of facial expression appears to be integrated with facial identity in every case.

Face adaptation aftereffects typically are described in terms of Valentine's (1991) model of face perception. According to this model, adults' multidimensional face space is centered on a prototypical face that is the average of the faces viewed previously. Adaptation shifts the prototype in the direction of the adapting stimuli (e.g., toward compressed features, toward Chinese) and away from the average face. Thus, after adaptation to compressed faces, unaltered faces appear to be slightly expanded (Webster & MacLin, 1999), and after adaptation to Chinese faces, a racially ambiguous face appears to be Caucasian (Webster et al., 2004). Face aftereffects are consistent with adults' perception of various facial characteristics (e.g., identity, race, attractiveness) being based on underlying dimensions that are dynamically updated as new faces are encountered. Expression aftereffects appear to be most consistent with dimensional views of expression perception (Bimler & Kirkland, 1997, 2001; Russell, 1980; Russell & Bullock, 1985, 1986; Russell et al., 1989). Adaptation to a given expression presumably shifts the perception of subsequently viewed faces along a given dimension (e.g., biased toward the unpleasant end of the valence dimension after adaptation to a pleasant expression such as happiness).

Only two previous studies have reported face adaptation aftereffects in children. Anzures, Mondloch, and Lackner (2009) reported attractiveness aftereffects in 8-year-olds. After adaptation to faces with compressed facial features, 8-year-olds rated faces with slightly compressed features as more attractive than unaltered faces, whereas after adaptation to faces with expanded facial features, 8-year-olds rated faces with slightly expanded features as most attractive. Nishimura, Maurer, Jeffery, Pellicano, and Rhodes (2008) reported identity aftereffects in 8-year-olds. After adaptation to a face that was the computational opposite of a known identity (e.g., after adaptation to "anti-Dan"), both 8-year-olds and adults labeled a previously ambiguous face as "Dan." These two previous studies suggested that by 8 years of age, the youngest age tested, children's perception of both identity and attractiveness is based on underlying dimensions and their face prototype is dynamically updated as new faces are encountered.

The results of our study are consistent with the hypothesis that children process facial expressions based on underlying dimensions. Even 2-year-olds sort faces on a pleasure/displeasure dimension (Russell & Bullock, 1986), a finding that is consistent with adult-like aftereffects for the happy/sad continuum. More recently, Gao and Maurer (2009b) used the multidimensional scaling technique to determine how 7-year-olds and adults organize facial expressions. They presented each of six expressions (happiness, fear, surprise, sadness, disgust, and anger) at three different intensities. They reported evidence that adults' perception of expression can be accounted for by three dimensions (pleasure, potency, and arousal), whereas 7-year-olds' perception of expression can be accounted for by two dimensions (pleasure and arousal). Our findings clearly indicate that categorization is dynamically updated as new faces are encountered and is consistent with previous accounts of face adaptation.

Category boundaries

As a secondary question, we sought to determine whether children categorize blended expressions according to a clear perceptual boundary. Blended expressions (e.g., a mixture of hate and sorrow) can be both depicted and perceived in still photographs (Ekman & Friesen, 1976; Nummenmaa, 1988). Adults perceive blended expressions categorically (Calder, Young, Perrett, Etcoff, & Rowland, 1996; de Gelder et al., 1997; Etcoff & Magee, 1992); they perceive a sharp categorical boundary between two expressions and are more accurate when discriminating expressions that straddle a categorical boundary than when discriminating two expressions that differ by the same amount (e.g., 10%) but fall into the same category.

Our results are consistent with and extend previous studies demonstrating that children's categorization of blended expressions shows prolonged development. In Experiment 1, both 5- and 7-year-olds showed a clear happy/sad boundary, with the pattern of categorization falling within the ambiguous region at only one point for both age groups. However, children's classification of the happy/sad morphs was not fully adult-like until 7 years of age. Significantly fewer 5-year-olds than adults classified the target expression displaying 80% happy/20% sad as happy, a difference that disappeared by 7 years of age. This pattern of results is consistent with that reported by de Gelder and colleagues (1997). In their study, 9- and 10-year-olds showed nearly adult-like categorization of a happy/sad continuum, with the only difference between children and adults being that children had a slightly shallower slope.

Across all age groups, the fear/anger boundary observed in Experiment 2 was not as clear as the happy/sad boundary observed in Experiment 1. The 9-year-olds displayed an adult-like linear pattern of classification for fear/anger, whereas the 7-year-olds performed at chance levels. These findings are consistent with the aforementioned recognition/sensitivity literature showing that recognition of fearful and angry expressions is not fully adult-like until late childhood (Markham & Adams, 1992; Thomas et al., 2007; Vicari et al., 2000). It is likely that typically developing children receive more experience with happy and sad expressions than with fearful and angry expressions. Thomas and colleagues (2007) suggested that sensitivity to anger may be especially slow to develop because anger is a social emotion that is initiated by internal thoughts or memories, whereas fear is an instinctual reaction to an external threat.

Future studies

The current results raise several interesting questions worthy of future research. First, in most previous studies, children have been asked to match or label intense (i.e., prototypical) facial expressions

(Camras & Allison, 1985; Kolb et al., 1992; Markham & Adams, 1992; Markham & Wang, 1996; Vicari et al., 2000). Our results, and those of other recent studies (e.g., Gao & Maurer, 2009a; Thomas et al., 2007), emphasize the importance of testing children with subtle facial expressions and with blended facial expressions. Additional studies investigating the relationship between children's representation of facial expressions and facial identity are needed. As noted above, Fox and colleagues (2008) reported an asymmetry in the relationship between representations of identity and facial expressions in adults. Whereas the magnitude of expression aftereffects is modulated by facial identity (Fox & Barton, 2007), the magnitude of identity aftereffects is not modulated by facial expression. We are currently investigating whether this same asymmetry is present in young children, (i.e., whether, like adults, children's representation of facial identity is independent of facial expression).

Second, the relationship between identity and expression should be investigated using a child-friendly version of the composite face task (Calder et al., 2000). The composite face task is a measure of holistic face processing; participants are asked to make judgments about the top half of faces while ignoring the bottom half. Interference from the bottom half of faces provides evidence of holistic processing (Hole, 1994; Young, Hellawell, & Hay, 1987). Although holistic processing of emotional expressions is modulated by the same variables that affect the holistic processing of facial identity (i.e., inversion but not stimulus negation) (Calder & Jansen, 2005), the two effects appear to be independent (Calder et al., 2000). Adults' reaction time for naming the expression displayed in the bottom half of faces is not increased when the bottom half is aligned with the top half of a different model displaying the same emotional expression, and their reaction time for naming the identity of the bottom half of a composite face is not increased when the bottom half is aligned with the top half of the same model displaying a different facial expression. Calder and colleagues (2000) concluded that holistic processing underlies recognition of both identity and facial expressions but that different information may be relevant for the two types of processing. This is consistent with their principal component analysis of facial expressions in which the components for coding sex and facial identity were largely independent of those for coding facial expression (Calder, Burton, Miller, Young, & Akamatsu, 2001). Studies have shown that 4- to 6-year-olds process facial identity (de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Pellicano et al., 2006) and facial expressions (Durand et al., 2007) holistically, but no study has investigated whether the information they use to process facial identity is different from that used to process facial expressions. Hence, testing children with Calder and colleagues' (2000) method would be worthwhile.

Third, factors that influence the magnitude of aftereffects and the conditions under which aftereffects occur in the different-identity condition should be investigated. The magnitude of aftereffects we observed may depend on specific emotion pairings. The two emotion pairings we used differed in at least two key ways. One is that happy and sad lie on opposite sides of the pleasant/unpleasant dimension, whereas both anger and fear are "unpleasant" emotions. Another way they differed is that clear perceptual boundaries were observed at all ages for the happy/sad continuum, whereas only a linear pattern was observed even in adults for the fear/anger continuum. The larger aftereffects observed for fear/anger may indicate that the perceptions of one negative expression (e.g., anger) are more influenced by another negative expression (e.g., sadness, fear) than by a positive impression (e.g., happy). Alternatively, the greater number of ambiguous exemplars in the fear/anger continuum may enhance the malleability of adults' and children's categorization. Future studies should blend each expression with neutral and then measure the extent to which threshold sensitivities can be altered by adaptation to intense expressions and whether that depends on the adapting stimulus having the same identity as, or a different identity from, the probe face. Furthermore, each expression should be paired with multiple expressions (e.g., fear/anger, anger/sad, anger/happy) to determine the extent to which these effects vary as a function of specific pairings.

Summary

This investigation has provided the first evidence of expression aftereffects in young children, showing that happy/sad aftereffects are adult-like by 7 years of age, whereas fear/anger aftereffects are adult-like by 9 years of age. This investigation also showed that children, like adults, perceive facial expression and identity in a partially integrated manner. We found larger adaptation aftereffects in the same-identity condition than in the different-identity condition both for happy/sad, expressions that young children identify accurately and for which there was a sharp category boundary, and for fear/anger, expressions that are more difficult for young children to identify and for which there was a more gradual change in categorization. The consistency of the results across these two expression pairs suggests the robustness of this pattern.

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References

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face adaptation and attractiveness aftereffects in 8-year-olds. *Child Development, 80*, 178–191.

Beale, J. M., & Keil, F. C. (1995). Categorical effects in the perception of faces. *Cognition, 57*, 217–239.

Bimler, D., & Kirkland, J. (1997). Multidimensional scaling of hierarchical sorting data applied to facial expressions. *Scandinavian Journal of Psychology, 38*, 349–357.

Bimler, D., & Kirkland, J. (2001). Categorical perception of facial expressions of emotion: Evidence from multidimensional scaling. *Cognition and Emotion, 15*, 633–658.

Brickman, P., Coates, D., & Janoff-Bulman, R. (1978). Lottery winners and accident victims: Is happiness relative? *Journal of Personality and Social Psychology, 36*, 917–927.

Bruce, V., & Young, A. W. (1986). Understanding face recognition. *British Journal of Psychology, 77*, 305–327.

Calder, A. J., Burton, A. M., Miller, P., Young, A. W., & Akamatsu, S. (2001). A principal component analysis of facial expressions. *Vision Research, 41*, 1179–1208.

Calder, A. J., & Jansen, J. (2005). Configural coding of facial expressions: The impact of inversion and photographic negative. *Visual Cognition, 12*, 495–518.

Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and expression. *Nature Reviews: Neuroscience, 6*, 641–651.

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 527–551.

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

Campbell, R., Brooks, B., de Haan, E., & Roberts, T. (1996). Dissociating face processing skills: Decisions about lip read speech, expression, and identity. *Quarterly Journal of Experimental Psychology A, 49*, 295–314.

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

de Gelder, B., Teunisse, J., & Benson, P. (1997). Categorical perception of facial expressions: Categories and their internal structure. *Cognition and Emotion, 11*, 1–23.

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.

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

Ekman, P., & Friesen, W. V. (1976). Measuring facial movement. *Journal of Environmental Psychology and Nonverbal Behavior, 1*, 56–75.

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

Fox, C. J., & Barton, J. S. (2007). What is adapted in face adaptation? The neural representations of expression in the human visual system. *Brain Research, 1127*, 80–89.

Fox, C. J., Oruç, I., & Barton, J. S. (2008). It doesn't matter how you feel: The facial identity aftereffect is invariant to changes in facial expression. *Journal of Vision, 8*, 11.1–11.13.

Freire, A., & Lee, K. (2001). Face recognition in 4- to 7-year-olds: Processing of configural, featural, and paraphernalia information. *Journal of Experimental Child Psychology, 80*, 347–371.

Gao, X., & Maurer, D. (2009a). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. *Journal of Experimental Child Psychology, 102*, 503–521.

Gao, X., & Maurer, D. (2009b). Surprised but not scared: Similarities and differences in the perceptual structure of facial expressions of 7-year-olds and adults. *Journal of Experimental Child Psychology*, submitted for publication.

Gilchrist, A., & McKone, E. (2003). Early maturity of face processing in children: Local and relational distinctiveness effects in 7-year-olds. *Visual Cognition, 10*, 769–793.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4*, 223–233.

Helson, H. (1964). *Adaptation-level theory*. New York: Harper & Row.

Hole, G. J. (1994). Configurational factors in the perception of unfamiliar faces. *Perception, 23*, 65–74.

Ibbotson, M. R. (2005). Physiological mechanisms of adaptation in the visual system. In C. W. G. Clifford & G. Rhodes (Eds.), *Fitting the mind to the world: Adaptation and aftereffects in high-level vision* (pp. 17–45). Oxford, UK: Oxford University Press.

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.
Leopold, D. A., & Bondar, I. (2005). Adaptation to complex visual patterns in humans and monkeys. In C. W. G. Clifford & G. Rhodes (Eds.), *Fitting the mind to the world: Adaptation and after-effects in high-level vision* (pp. 189–211). Oxford, UK: Oxford University Press.
Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature, 4*, 89–94.
Markham, R., & Adams, K. (1992). The effect of task type 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.
Mondloch, C. J., Dobson, K. S., Parsons, J., & Maurer, D. (2004). Why 8-year-olds cannot 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. J., Pathman, T., Maurer, D., Le Grand, R., & de Schonen, S. (2007). The composite face effect in 6-year-old children: Evidence of adult-like holistic face processing. *Visual Cognition, 15*, 564–577.
Nishimura, M., Maurer, D., Jeffery, L., Pellicano, E., & Rhodes, G. (2008). Fitting the child's mind to the world: Adaptive norm-based coding of facial identity in 8-year-olds. *Developmental Science, 11*, 620–627.
Nummenmaa, T. (1988). The recognition of pure and blended facial expressions of emotion from still photographs. *Scandinavian Journal of Psychology, 29*, 33–47.
Pellicano, E., Rhodes, G., & Peters, M. (2006). Are preschoolers sensitive to configural information in faces? *Developmental Science, 9*, 270–277.
Peters, M. (1988). Description and validation of a flexible and broadly usable handedness questionnaire. *Laterality, 3*, 77–96.
Pollak, S. D., & Kistler, D. J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. *Proceedings of the National Academy of Sciences of the United States of America, 99*, 9072–9076.
Rhodes, G., Robbins, R., Jaquet, E., McKone, E., Jeffery, L., & Clifford, C. (2005). Adaptation and face perception: How after-effects implicate norm-based coding of faces. In C. Clifford & G. Rhodes (Eds.), *Fitting the mind to the world: Adaptation and after-effects in high-level vision* (pp. 213–240). Oxford, UK: Oxford University Press.
Russell, J. A. (1978). Evidence of convergent validity on the dimensions of affect. *Journal of Personality and Social Psychology, 36*, 1152–1168.
Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161–1178.
Russell, J. A., & Bullock, M. (1985). Multidimensional scaling of facial expressions: Similarity from preschoolers to adults. *Journal of Personality and Social Psychology, 48*, 1290–1298.
Russell, J. A., & Bullock, M. (1986). On the dimensions preschoolers use to interpret facial expressions of emotion. *Developmental Psychology, 22*, 97–102.
Russell, J. A., Lewicka, M., & Niit, T. (1989). A cross-cultural study of a circumplex model of affect. *Journal of Personality and Social Psychology, 57*, 848–856.
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*, 547–557.
Tottenham, N., Tanaka, J., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., et al. (in press). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*.
Tranel, D., Damasio, A. R., & Damasio, H. (1988). Intact recognition of facial expression, gender, and age in patients with impaired recognition of facial identity. *Neurology, 38*, 690–696.
Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race on face recognition. *Quarterly Journal of Experimental Psychology, 43*, 161–204.
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.
Webster, M. A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature, 428*, 557–561.
Webster, M. A., & MacLin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review, 6*, 647–653.
Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception, 16*, 747–759.
Young, A. W., McWeeny, K. H., Hay, D. C., & Ellis, A. W. (1986). Matching familiar and unfamiliar faces on identity and expression. *Psychological Research, 48*, 63–68.
Young, A. W., Newcombe, F., de Haan, E. H. F., Small, M., & Hay, D. C. (1993). Face perception after brain injury: Selective impairments affecting identity and expression. *Brain, 116*, 941–959.