Recognizing identity in the face of change: The development of an expression-independent representation of facial identity

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Perceptual aftereffects have indicated that there is an asymmetry in the extent to which adults' representations of identity and expression are independent of one another. Their representation of expression is identity-dependent; the magnitude of expression aftereffects is reduced when the adaptation and test stimuli have different identities. In contrast, their representation of identity is expression-independent; the magnitude of identity aftereffects is independent of whether the adaptation and test stimuli pose the same expressions. Like adults, children's representation of expression is identity-dependent (Vida & Mondloch, 2009). Here we investigated whether they have an expression-dependent representation of facial identity. Adults and 8-year-olds \( (n = 20 \text{ per group}) \) categorized faces in an identity continuum (Sue/Jen) after viewing an adapting stimulus that displayed the same or a different emotional expression. Both groups showed identity aftereffects that were not influenced by facial expression. We conclude that, like adults, 8-year-old children’s representation of identity is expression-independent.

Keywords: identity aftereffects, face perception, perceptual development, facial expression


Introduction

Adults’ expertise in recognizing the identity of individual faces has been attributed to their exquisite sensitivity to differences among faces in the shape of individual features and the spacing among them (reviewed in Maurer, Le Grand, & Mondloch, 2002), their representing each individual face relative to a norm (Valentine, 1991; reviewed in Webster & MacLeod, 2011), and their ability to ignore transient changes in appearance caused by variations in facial expression or point of view (Duchaine & Nakayama, 2006; Mondloch, Geldart, Maurer, & Le Grand, 2003; Schweinberger, Burton, & Kelly, 1999). The development of adult-like expertise is prolonged; although even young children perform above chance levels on some measures of face recognition (Brace et al., 2001; McKone & Boyer, 2006; Mondloch, Leis, & Maurer, 2006), performance on a variety of tasks continues to improve until early adolescence (Bruce et al., 2000; Carey & Diamond, 1994; Carey, Diamond, & Woods, 1980; Johnston et al., 2011; Mondloch, Le Grand, & Maurer, 2003).

Numerous studies have been conducted with the goal of determining why children make more errors than adults. Holistic processing appears to be adult-like by 4 to 6 years of age (de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Pellicano & Rhodes, 2003) and children as young as 5 years of age appear to process faces in a multi-dimensional face space (Anzures, Mondloch, & Lackner, 2009; Jeffery et al., 2010; Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008; Short, Hatry, & Mondloch, 2011). They show identity aftereffects by age 7 to 9 years (the youngest age tested; Jeffery et al., 2011; Nishimura et al., 2008) and attractiveness (figural) aftereffects by age 4 to 6 years (Jeffery et al., 2010; Short et al., 2011). Like adults, the magnitude of children’s aftereffects is larger following exposure to extreme adaptors (e.g., eyes moved up 50 vs. 10 pixels), a marker that many interpret as strong evidence of norm-based coding (see Jeffery et al., 2010, 2011 for a thorough explanation).

Nonetheless, several factors appear to contribute to the slow development of adult-like expertise: enhanced susceptibility to distraction by paraphernalia (Carey & Diamond, 1977; Freire & Lee, 2001), reduced sensitivity to feature shape and feature spacing (Baudouin, Gallay, Durand, & Robichon, 2010; Freire & Lee, 2001; Gilchrist & McKone, 2003; Mondloch, Le Grand, & Maurer, 2002), general cognitive factors
(Crookes & McKone, 2009), and reduced sensitivity to variation within dimensions (Anzures et al., 2009; Jeffery et al., 2010). Furthermore, despite being sensitive to multiple dimensions, they rely almost exclusively on a single dimension (eye color) when judging face similarity (Nishimura, Maurer, & Gao, 2009). In the current study we tested one other potential explanation for the slow development of expert face recognition: failure to ignore changes in facial expression when processing face identity. Children aged 6 to 8 years make more errors than adults in a delayed match-to-sample task when asked to match faces based on identity across changes in facial expression (Mondloch, Geldart et al., 2003; see also Bruce et al., 2000), suggesting that when an unfamiliar face is transformed by changes in facial expression, children may be more likely than adults to perceive a different identity.

**Adults’ representation of facial identity and expression**

Bruce and Young’s (1986) classic model of face perception suggests that stable (e.g., identity, age, sex) and transient (e.g., eye gaze, facial speech, emotional expressions) cues are processed in parallel and independently of one another. Support for independent processing of stable versus transient cues is mixed. Neuropsychological studies using fMRI technology have provided conflicting information about the extent to which identity and facial expression are processed by separate neural substrates (see Haxby, Hoffman, & Gobbini, 2000 and Calder & Young, 2005 for contrasting views).

Whereas fMRI allows researchers to measure changes in neural activity when expression versus identity varies, adaptation aftereffects allow researchers to investigate the extent to which representations of identity include a representation of expression and the extent to which representations of expression include a representation of identity. Adaptation aftereffects have been observed for a variety of facial dimensions, including attractiveness, sex, race, and emotional expression (e.g., Webster, Kaping, Mizokami, & Duhamel, 2004; reviewed by Rhodes et al., 2005). For example, after adaptation to a female face, an androgynous face appears to be male, whereas after adaptation to a male face, that same androgynous face appears to be female (Webster et al., 2004).

Adaptation influences adults’ perception of facial identity. After adaptation to a face that is the computational opposite of a target identity (anti-Dan), adults label target faces with very weak identity strengths (e.g., 20% Dan/80% average) accurately, presumably because their face prototype has shifted towards anti-Dan (Leopold, O’Toole, Vetter, & Blanz, 2001). Likewise, adults’ labeling of faces in a morphed continuum comprising different blends of two facial identities (e.g., 20% Bill/80% Paul) is biased by adaptation; the probability of their assigning the label Paul is higher after being adapted to Bill than after being adapted to Paul (Fox, Oruç, & Barton, 2008). Adaptation also influences adults’ perception of emotion; their perception of ambiguous expressions (e.g., a blend of happy and sad) is biased by the expression viewed during adaptation. For example, a blend of sad/fear is more likely to be labeled ‘fear’ after adaptation to sad than after adaptation to fear (Fox & Barton, 2007; Vida & Mondloch, 2009).

Of central importance to the current study is evidence that there is an asymmetry in the extent to which representations of identity and expression are independent of one another. Adults’ representation of expression is identity-dependent (Fox & Barton, 2007; Vida & Mondloch, 2009); expression aftereffects are reduced or eliminated when the adapting stimulus has a different identity than the test stimulus. In contrast, adults’ representation of identity excludes information about expression. The magnitude of identity aftereffects is independent of changes in emotional expression (Fox et al., 2008); identity aftereffects are not reduced when the adapting stimulus displays a different emotion than the test stimulus (e.g., when the adapting identity displayed happiness and the morphed test stimulus displayed sadness) relative to when both stimuli display the same emotion (e.g., both happy). If adults’ representation of identity included a representation of expression, then aftereffects would be reduced in the different-expression condition relative to the same-expression condition. Because an expression-independent representation of facial identity likely facilitates one’s ability to recognize individual faces across changes in expression (e.g., to recognize an individual displaying anger who was previously encountered while displaying happiness), it is important to investigate the extent to which children’s representation of identity is expression-independent, and aftereffects provide an ideal tool for doing so.

**Children’s representation of facial identity and expression**

Although children make more errors than adults when asked to recognize individual faces across changes in expression (Mondloch et al., 2003; see also Bruce et al., 2000), very few studies have systematically investigated the extent to which their representations of identity and expressions are independent. Two studies have employed a Garner interference task to investigate whether children are able to selectively attend to
identity when facial expression varies (Baudouin, Durand, & Gallay, 2008; Spangler, Schwarzer, Korell, & Maier-Karius, 2010). Children were unable to selectively attend to emotional expression in either study; response times in the expression task were longer on orthogonal trials in which identity varied than on control trials in which identity was constant. However, whereas one study reported that 5- to 6-year-old children were able to selectively attend to identity (response times did not increase on orthogonal trials; Spangler et al., 2010) the other reported that both 5- to 6-year-olds and 9- to 11-year-olds could not (response times increased on orthogonal trials; Baudouin et al., 2008). Given that the findings on selective attention are mixed and that Garner interference tasks do not directly address the nature of children’s representation of identity and expression, the goal of the current experiment was to investigate the extent to which children’s representation of facial identity is expression-dependent using adaptation aftereffects.

One previous study (Vida & Mondloch, 2009) used an adaptation aftereffects paradigm to investigate whether children’s representation of expression was identity-dependent. Like adults, 5-year-old children’s expression aftereffects for happy/sad and 9-year-old children’s expression aftereffects for sad/fear (the youngest children tested) were smaller when the adapting and test stimuli had different identities than when they had the same identities. In contrast, no study has investigated whether children’s identity aftereffects are expression-independent, and thus it is unknown whether, like adults, their representation of identity excludes a representation of expression.

The goal of the current experiment was to investigate the extent to which children’s representation of facial identity is expression-dependent using adaptation aftereffects. Adults and 8-year-old children made two-alternative forced-choice judgments about facial identity for 13 faces in a morphed continuum. The faces ranged from looking mostly like ‘Sue’ (80% Sue/20% Jen) to looking mostly like ‘Jen’ (20% Sue/80% Jen). Within each block of trials participants saw each face in the morphed continuum twice—one after being adapted to Sue and once after being adapted to Jen. Aftereffects would be evident if participants were more likely to label a face ‘Sue’ after being adapted to Jen than after being adapted to Sue. In the same-expression block the adapting stimulus displayed the same emotional expression (happy or sad) as the faces in the morphed continuum; in the different-expression block the adapting stimulus displayed a different emotional expression (e.g., happy) than the faces in the morphed continuum (e.g., sad). If children’s representation of facial identity is expression-independent, then like the adults tested by Fox et al. (2008), the magnitude of their identity aftereffects should be similar on trials in which the adapting stimulus has the same expression as the test stimulus (same-expression trials) and on trials in which the adapting stimulus has a different expression (different-expression trials). In contrast, if children’s representation of facial identity is expression-dependent, then their identity aftereffects should be reduced on different-expression trials. We elected to test 8-year-old children because they are the youngest age known to show identity aftereffects (Nishimura et al., 2008), they make more errors than adults when asked to recognize a face despite a change in expression (Mondloch, Geldart et al., 2003; see also Bruce et al., 2000), and they reliably discriminate happy versus sad facial expressions (Gao & Maurer, 2009; Vida & Mondloch, 2009). Adults were tested in order to ensure that our testing protocol replicated the pattern of results reported by Fox et al. (2008).

### Method participants

Participants were 20 Caucasian adult undergraduate students between the ages of 18 and 25 (M = 20.46 years, 17 female), and 20 Caucasian 8-year-olds (±6 months, M = 8.04 years, 13 female). Adults received partial course credit or a small monetary reward. Children were recruited from local elementary schools and from a community database. They received a small toy for their participation. Four additional children were tested but excluded because they did not meet our inclusion criterion on reduced identity training trials; because these children were tested in their school, time constraints precluded our giving them additional training. One additional child failed to meet our inclusion criterion on full identity trials and another refused to complete the training protocol. Two adults were excluded for failing to meet our criterion on full identity training trials (n = 1) or because of experimenter error (n = 1).

### Materials

Photographs of two females (Models 1 and 7) from the NimStim Face Stimulus Set (Tottenham et al., 2009) comprised the stimulus set. Each model posed a neutral, a sad, and a happy facial expression. Morph software was used to create blends of two identities that varied in identity strength. Test stimuli comprised two continua of identities ranging from ‘Jen’ (Model 1) to ‘Sue’ (Model 7); each continuum included 13 faces ranging from 20% Jen/80% Sue to 80% Jen/20% Sue in 5% increments. One continuum of test stimuli was created from happy facial expressions and the other...
from sad facial expressions. Training stimuli comprised the unaltered versions (100% identity) of each identity plus four morphed versions (90%, 80%, 20%, 10% Jen) displaying both a sad and a happy facial expression. The unaltered versions displaying happy and sad facial expressions were used as adapting stimuli; the unaltered versions displaying neutral facial expressions were used only as familiarization stimuli. All facial images were grayscale and were presented at the center of a 23-inch Apple Cinema Display computer monitor (Apple, Inc., Cupertino, CA). Each image spanned a distance of 9.04 cm (8.6° at a viewing distance of 60 cm) horizontally and 12.4 cm (11.8°) vertically. All experimental trials were presented via Superlab 4.0 computer software (Cedrus Corp., San Pedro, CA, 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 procedure received clearance from the Brock University Research Ethics Board.

Participants were seated 60 cm from the computer monitor. The experimenter sat behind the participant so as to not enter the participant’s field of view at any time during testing. Participants used a Logitech Dual Action controller (Logitech, Newark, CA) to indicate all responses. Participants held the controller in both hands and used their right hand to press the appropriate buttons, located on the right side of the controller. Within this set of buttons, the ‘J’ button (for indicating recognition of Jen) was always located on the left side and the ‘S’ button (for indicating recognition of Sue) was always located on the right side. Each experimental session comprised three stages: training/inclusion, no-adaptation, and adaptation. There were two no-adaptation blocks followed by two adaptation blocks: same-expression and different-expression blocks. The two adaptation blocks always occurred last, 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 began the experiment by introducing the participant to ‘Jen’ and ‘Sue.’ Three pairs of images were shown in which the two facial identities were displaying a neutral, a happy, and a sad facial expression; the experimenter pointed to and identified each face on these three familiarization trials. After viewing each of the three face pairs participants began the training phase.

Training protocol

100%-identity training

The training protocol was modified based on the procedure implemented by Nishimura et al. (2008) in their identity aftereffects study. To facilitate children's recognition of Jen and Sue across facial expressions, participants first completed three blocks of eight trials in which all stimuli had 100% identity strength and remained on the screen until a response was made. All faces posed a neutral expression in Block 1, a happy expression in Block 2, and a sad expression in Block 3. Jen was presented on half of the trials within each block and stimulus presentation time was unlimited. Participants were instructed to press one button ‘J’ if the face was Jen’s face and another button ‘S’ if the face was Sue’s face. Auditory feedback was provided and children repeated any trial on which an error was made.

Participants were introduced to variation in facial expressions in Blocks 4 and 5. Within each block, Jen and Sue were each presented on six trials; each face was shown posing each facial expression (happy/sad) on three trials. Auditory feedback was provided after each response. Stimuli were presented until a response was made in Block 4 and then for 500 ms (full-identity inclusion trials) in Block 5. Participants were required to correctly identify each of the last six faces presented in Block 5 in order to progress to the next phase of training. This criterion was set to ensure that participants could reliably recognize the difference between the facial identities, which is critical to successful adaptation. Each participant was allowed two attempts to meet this criterion; the entire training procedure was repeated after a failed attempt. Sixteen children met this criterion after one attempt, and four children did so after their second attempt. Only one 8-year-old and one adult failed to meet this criterion after two attempts.

Reduced-identity training

Participants completed 12 trials in which training stimuli were presented until a response was made (familiarization trials) followed by 12 trials in which stimuli were presented for 500 ms (reduced-identity inclusion trials). Participants assigned to the happy identity continuum only viewed happy facial expressions during this training phase; likewise, participants assigned to the sad identity continuum only viewed sad facial expressions. Within each block, participants viewed six faces that looked like Jen, two at each of three identity strengths (100%, 90%, and 80%) and six faces that looked like Sue (same identity strengths). Auditory feedback was provided after each response. Prior to commencement of these trials, the experimenter presented the following verbal message: “Jen and Sue both work at the zoo. Jen has some cousins that look a lot
like her and they work on Jen’s team. Sue has some cousins that look a lot like her and they work on Sue’s team. You are going to see pictures of Jen and her cousins and pictures of Sue and her cousins. Your job is to indicate whether the person is from Jen’s team or Sue’s team by pressing the correct button.” Inclusion trials were presented in the same random order to each participant. To be included in the experiment, participants were required to be correct on five of the last six trials on which faces of 80% or 90% identity strength were presented. Both familiarization trials (unlimited presentation) and inclusion trials (500 ms) were repeated after a failed attempt. Meeting this criterion ensures that participants can reliably recognize the identities at the end points of the identity strength continuum. Each participant was allowed unlimited attempts to meet this criterion. Most (n = 19) children met the criterion after two attempts, although one child tested in the lab did so on their fourth attempt. Time constraints in the school environment led to our excluding four additional children who failed to meet the criterion after two or three attempts and were showing no improvement across training blocks.

No-adaptation phase

On each trial of the no-adaptation blocks, a central fixation cross was presented until the experimenter judged the participant to be attentive; the tester then presented one of the morphed test faces for 500 ms. Finally, a question mark appeared on the screen and remained until the participant responded via key press. Half of the participants within each age group were tested with the identity continuum in which all test faces posed a happy facial expression, and half were tested with the identity continuum in which all test faces posed a sad facial expression. To capture and maintain the attention of participants, the experimenter presented the following story prior to no-adaptation blocks: “It is a busy day at the zoo today! Some monkeys escaped from the cage and the teams have to work hard to get those monkeys back into their cages. The faces you are going to see are happy because they are finding the monkeys, and I need you to press the button to tell me which team each person belongs to. [Children tested with the continuum in which faces posed a sad facial expression were told that the faces were sad because they were having a hard time finding the monkeys.] Let’s see who catches more monkeys! Sometimes it will be really hard to tell if the face is from Jen’s team or Sue’s team, but do your very best.” Participants completed two blocks of no-adaptation trials. Within each block, each face in the morphed identity continuum was presented once. No feedback was given.

Adaptation phase

As shown in Figure 1, in each trial of the adaptation blocks, a central fixation cross was presented until the experimenter judged the participant to be attentive, followed by an adaptation stimulus for 5000 ms. The adapting identity was Jen (100% identity) on half of the trials and Sue (100% identity) on the other half. After presentation of the adapting stimulus, a 50 ms mask stimulus (random arrangement of black and white pixels) appeared, followed by one of the 13 morphed test stimuli (ranging from 20% to 80% Sue) faces for 500 ms. Each block comprised 26 test trials; each face in the continuum was presented on two trials, once after adaptation to Jen and once after adaptation to Sue; the two adapting identities were randomly intermixed within each block (see also Fox et al., 2008). In the same-expression block, the adapting face posed the same expression as the faces in the morphed identity continuum; in the different-expression block, the adapting face posed the opposite facial expression. Prior to the different-expression block, participants were told that the expression would vary. Half of the participants were tested on same-expression trials first, and half were tested on different-expression trials first.

To capture and maintain the attention of participants the experimenter presented the following story prior to adaptation blocks: “I’m going to show you more pictures of the two teams at the zoo. This time you will see one face and then another. The first face will stay on the screen for a little while and then a second face will pop up quickly. Watch the first picture carefully so you don’t miss the second picture! Remember—we want to see which team catches more monkeys! When you see a question mark, I need you to use the buttons to tell me if the second picture was someone on Jen’s team or Sue’s team. Jen and Sue’s teams are still having a hard time finding all of the monkeys, so they need your help! Sometimes you will see a picture of one of the monkeys that escaped. When that happens, don’t press any buttons. Just say “monkey!” so someone can come and catch it.” Monkeys followed Jen’s face on two trials.
and Sue’s face on two trials within each adaptation block. Participants were required to respond ‘monkey’ on three of the four catch trials in order to be included; every participant met this requirement. Upon completion of the same-expression and different-expression blocks, the experimenter thanked and debriefed participants and their parents.

**Analyses**

To determine whether the strength of identity aftereffects varied as a function of age and expression condition, we conducted a three-way mixed factorial ANOVA with age as a between-subjects factor and expression condition (same/different) and identity (adapt to Sue/Jen) as within-subjects factors. Because the task required two-alternative forced-choice judgments, the dependent variable was the proportion of trials on which each participant responded ‘Sue.’

**Results**

On no-adaptation trials, the proportion of trials on which participants responded ‘Sue’ increased linearly as a function of the proportion of Sue in the probe face (see Figure 2). The linear regression was significant for both adults, $F(1, 12) = 146.277, p < 0.001, R^2 = 0.93$, and 8-year-olds, $F(1, 12) = 87.794, p < 0.001, R^2 = 0.89$. The quadratic model was significant for adults, $F(1, 12) = 6.345, p < 0.05, R^2 = 0.25, p < 0.05$, but not for 8-year-olds, $p > 0.5$. The quadratic trend for adults indicates that performance reached asymptote at the end points. The mean proportion of ‘Sue’ responses did not differ between groups, $t(38) = 0.67, p > 0.5$ and for each group did not differ from the chance value of 0.50, $ps > 0.15$.

As shown in Figure 3, both adults and 8-year-old children showed identity aftereffects, and these aftereffects were independent of facial expression; the age × expression condition × identity interaction was not significant, $p > 0.15$. The analysis of identity aftereffects revealed a main effect of identity $F(1, 38) = 83.78, p < 0.001, \eta^2 = 0.69$; both adults and 8-year-olds made a higher proportion of Sue (vs. Jen) responses after adaptation to Jen than after adaptation to Sue. There was also a main effect of age, $F(1, 38) = 8.49, p < 0.01, \eta^2 = 0.18$; adults were more likely than 8-year-old children to respond ‘Sue.’ All other main effects and interactions were nonsignificant, $ps > 0.15$. Separate repeated-measures ANOVAs with the adapting identity and adapting expression condition as independent variables confirmed that the size of the adaptation effect did not vary as a function of the adapting facial expression for either child or adult participants, $ps > 0.25$.

**Discussion**

The results provide the first evidence that identity aftereffects are expression-independent in 8-year-old children; like adults in the current study and in the one previous study investigating this question in adults (Fox et al., 2008), children’s identity aftereffects were not reduced in the different-expression condition relative to the same-expression condition. These results suggest that, like adults, children’s representation of identity is expression invariant, a proposal that is consistent with Bruce and Young’s (1986) model. This is in contrast to evidence that both adults’ and 8-year-old children’s expression aftereffects are identity-dependent; expression aftereffects are smaller when the adapting and test stimuli have different identities than when they have the same identity (Fox & Barton, 2007; Vida & Mondloch, 2009). Collectively, these results provide evidence that the relationship between identity and expression representations is asymmetrical even in young children.

The fact that five children were excluded because they did not meet our inclusion criteria cannot be taken as evidence that a subset of 8-year-olds is unable to process identity independently of expression. In an identity aftereffects study in which a similar training procedure was used without variation in expression (Nishimura et al., 2008), 75% of children met the inclusion criterion within two training blocks (M. Nishimura, personal communication, July 14, 2011); 76% of children did so in our study (see Patel, Maurer, & Lewis, 2010; Spector & Maurer, 2008 for similar exclusion rates in studies of perceptual development). We note also that in the absence of time constraints in
the school environment, some or all of the four children excluded after being provided only two or three attempts may have reached criterion. Finally, although one child failed to meet our criterion in the 100% identity training procedure, so too did one adult.

Although low-level effects may partially account for these identity aftereffects, numerous studies have demonstrated that high-level effects can be isolated. Face aftereffects are evident despite changes in image size, contrast, orientation, and retinal location (reviewed in Webster, 2011). Furthermore, opposing aftereffects occur when oppositely distorted faces belong to two different categories (e.g., male/female), but not when they belong to the same category (e.g., female/hyper-female; Bestelmeyer et al., 2008; reviewed in Webster, 2011). In our study there were no systematic differences in luminance between the two adapting identities and the adapting stimuli, and test stimuli differed in size, enhancing the relative contribution of high-level effects. Furthermore, finding no difference in the magnitude of aftereffects between the same- and different-expression conditions supports our conclusion that, like adults, children are showing high-level effects.

One apparent difference between children and adults is that children appear to have become biased towards responding ‘Jen’ on adaptation trials relative to baseline trials (i.e., they made fewer ‘Sue’ responses), a trend for which we do not have an explanation. The proportion of ‘Sue’ responses did not differ as a function of age during preadaptation trials. Nonetheless, despite this potential bias during the adaptation phase, the magnitude of 8-year-olds’ identity aftereffects did not differ from that of adults and was independent of facial expression.

Evidence of expression-independent identity aftereffects in 8-year-old children refutes the hypothesis that children make more errors than adults on face recognition tasks because their representation of identity is not expression-invariant. Indeed, these data add to a growing body of evidence that many of the requisite skills underlying adult expertise are present by 8 years of age, including holistic processing (e.g., de Heering et al., 2007), norm-based coding (e.g., Anzures et al., 2009; Jeffery et al., 2011) and expression-independent representations of identity (current study). Nonetheless, performance on a variety of face perception tasks continues to improve throughout childhood (see Jeffery et al., 2011 for a review) indicating that adult-like expertise is slow to develop. The results of the current study contribute to a growing body of evidence that it may be most prudent to view the development of face perception during childhood as a process of refinement. For example, although infants and young children show sensitivity to feature shape and spacing (e.g., Hayden, Bhatt, Reed, Corbly, & Joseph, 2007; Gilchrist & McKone, 2003), they are less sensitive than adults to variations in these characteristics (Baudouin et al., 2010; Gilchrist & McKone, 2003; Mondloch et al., 2002). Likewise, although 8-year-old children seem to represent faces in a multi-dimensional face space, they are less sensitive than adults to variation within dimensions (Anzures et al., 2009; Jeffery et al., 2010), and they rely almost exclusively on a single dimension.
(eye color) when judging face similarity (Nishimura et al., 2009). Likewise, it is quite possible that despite having an expression-independent representation of identity as revealed in the current study, children have difficulty ignoring changes in expression in identity tasks. Children are less able than adults to selectively attend to identity when expression varies in a Garner interference task (Baudouin et al., 2008; but see Spangler et al., 2010). They also make more errors than adults when asked to recognize facial identity across changes in expression (Mondloch, Geldart et al., 2003; see also Bruce et al., 2000). Our results suggest that these findings cannot be attributed to children failing to form an expression-independent representation of identity. Rather, Garner interference effects may reflect a failure of selective attention, something that may be augmented when children are asked to recognize unfamiliar faces across changes in expression in a delayed match-to-sample task.

Our findings should also be considered in the context of models of face recognition that propose separable (e.g., Bruce & Young, 1986) versus overlapping (e.g., Calder & Young, 2005) representations of facial identity and expression. Bruce and Young’s (1986) classic and influential model of face perception suggests that stable (e.g., identity, age, sex) and transient (e.g., eye gaze, facial speech, emotional expressions) cues are processed in parallel and independently of one another. This model is supported by evidence from numerous studies in cognitive psychology (Calder, Young, Keane, & Dean, 2000; Campbell, Brooks, de Haan, & Roberts, 1996; Young, McWeeny, Hay, & Ellis, 1986) and cognitive neuropsychology (Tranel, Damasio, & Damasio, 1988; Young, Newcombe, de Haan, Small, & Hay, 1993; reviewed in Vida & Mondloch, 2009). For example, adults’ accuracy in recognizing the identity in the top half of a face decreases when the top half is aligned with the bottom half of a different identity; those same judgments are not further impaired when the bottom half also differs in emotional expression (Calder et al., 2000). Likewise, adults’ accuracy in recognizing the expression in the top half of a face is impaired when the top half is aligned with a bottom half displaying a different expression; those same judgments are not further impaired when the bottom half also differs in identity. The independent processing of stable versus transient facial characteristics is consistent with evidence that facial identity is processed in the lateral fusiform gyrus (LFG), whereas facial expression and other changeable facial characteristics are processed in the superior temporal sulcus (STS) (see Haxby et al., 2000 for a review).

However, Calder and Young (2005) argue that the evidence supporting Bruce and Young’s (1986) model is not extensive; rather, researchers in the field of face perception have assumed its accuracy, and both research design and interpretation have been heavily guided by its underlying principles. Recent fMRI data suggests that the clear distinction of LFG (or fusiform face area, FFA) processing identity and STS processing expression may be unwarranted. In a Garner interference task, activation in the FFA and in the STS was higher when participants were judging expression than when they were judging identity; in addition, activation in both areas was higher when participants were judging identity while expression varied than while expression was held constant (Ganel, Valyear, Goshen-Gottstein, & Goodale, 2005). Processing of identity appeared to be more localized; activation in the FFA was higher when participants were instructed to judge expression while identity varied than while identity was held constant, a pattern that was not observed in STS. Likewise, in a study by Narumoto, Okada, Sadato, Fukui, and Yonekura (2001), activation in both STS and FFA was higher when participants were instructed to match faces based on emotion than when they were instructed to match faces based on contour. In contrast, only the FFA showed increased activation when participants were instructed to match identity.

Adaptation aftereffects provide additional insight about underlying neural representations and the extent to which identity versus expression processing is separable. Expression-independent identity aftereffects are thought to indicate that the neural populations that represent facial identity (e.g., FFA) form a representation that is expression invariant (Fox et al., 2008). In contrast, identity-dependent expression aftereffects are thought to indicate that the neural populations that represent facial expression (e.g., STS) form a representation of expression that includes identity (Fox & Barton, 2007; Vida & Mondloch, 2009). Identity-dependent expression aftereffects in both adults (Fox & Barton, 2007; Vida & Mondloch, 2009) and 8-year-old children (Vida & Mondloch, 2009) may reflect the same process that causes increased activation in the FFA when identity varies throughout an expression task (Ganel et al., 2005). Likewise, expression-independent identity aftereffects in both adults (Fox et al., 2008; current study) and 8-year-old children (current study) is consistent with evidence that STS activation does not increase in response to variation in identity (Ganel et al., 2005; see also Narumoto et al., 2001). Of course, activation in FFA increases in response to variation in both expression and identity (Ganel et al., 2005); one can speculate that such processing allows the brain to extract an expression-independent representation of identity.

fMRI studies suggest that face-specific neural activity is slow to develop. Three studies have reported a lack of face-specific activity in the FFA prior to 10 years of age (Aylward et al., 2005; Gathers, Bhatt, Corbly, Farley, & Joseph, 2004; Scherf, Behrmann,
Humphreys, & Luna, 2007; see also Passarotti et al., 2003), and in the one study reporting face-specific activity (Golarai et al., 2007) the right FFA was three times larger in adults than in children aged 7 to 11 years. Furthermore, accuracy on a face memory task was correlated with the size of the FFA (Golarai et al., 2007). The results of the current study suggest that although face-specific neural activity is slow to develop, by 8 years of age there is an expression-independent representation of identity.

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