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Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults

Gizelle Anzures
University of Toronto

Catherine J. Mondloch
Brock University

Christine Lackner
Queen's University

A novel method was used to investigate developmental changes in face processing: attractiveness aftereffects. Consistent with the norm-based coding model, viewing consistently distorted faces shifts adults' attractiveness preferences toward the adapting stimuli. Thus, adults' attractiveness judgments are influenced by a continuously updated face prototype. To investigate the development of this process, a novel method was developed for 8-year-olds. After reading a storybook composed of faces with either compressed or expanded features, 8-year-olds' ratings of faces distorted in the direction of the adapting stimuli increased. Nonetheless, they required larger distortions than adults to rate undistorted faces as most attractive preadaptation. Thus, although 8-year-olds' attractiveness preferences are influenced by a continuously updated prototype, their face space is less refined than that of adults.

Adults' remarkable ability to discriminate and recognize hundreds of faces based on small differences in both featural and spatial cues has been attributed to their encoding individual face exemplars relative to a face prototype (Valentine, 1991). Faces vary continuously on multiple dimensions (e.g., eye size and distance between the nose and mouth), each of which is represented as a vector in "face space." Individual faces are represented as single points in this multidimensional space. The *direction* of the vector joining each individual face to the prototype represents how that face differs from the average face (the identity trajectory); the *distance* between each individual face and the prototype represents how typical/distinctive that face is. According to Valentine's (1991) norm-based coding model, faces near the prototype (i.e., "typical" faces) should be harder to recognize than distinctive faces because there is greater exemplar density near the face prototype than there is further away. This prediction has received support from studies showing that caricatures are rated as less typical than unaltered photographs and that the identity of caricatures is more easily recognized than veridical line drawings (Lee, Byatt, & Rhodes, 2000; Rhodes, Brennan, & Carey, 1987; Rhodes & Tremewan, 1994). More importantly for the purposes of the present study, faces near the prototype are also rated as more attractive than faces that are farther away (Langlois & Roggman, 1990; Rhodes, Sumich, & Byatt, 1999; Rubenstein, Kalakanis, & Langlois, 1999; Valentine, Darling, & Donnelly, 2004)—a pattern that is evident by 6 months of age (Rubenstein et al., 1999).

Adaptation and Aftereffects

Further evidence for norm-based face coding comes from studies using adaptation and aftereffects. In many visual domains, adults' perception of a stimulus is influenced by previously viewed stimuli. For example, following adaptation to a visual pattern tilted in one direction (e.g., clockwise), a vertically oriented pattern appears tilted in the opposite direction (i.e., counterclockwise). Likewise, following adaptation to a waterfall, a stationary pattern appears to move upward (reviewed in Leopold & Bondar, 2005). These adaptation aftereffects have been attributed to reduced neural activation following repeated stimulation and serve to increase sensitivity to environmental change (Ibbotson, 2005). Similar adaptation effects have been observed for other visual

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Correspondence concerning this article should be addressed to Catherine Mondloch, Department of Psychology, Brock University, St. Catharines, Ontario, Canada L2S 3A1. Electronic mail may be sent to cmondloch@brocku.ca.

characteristics including luminance, contrast, and direction of motion (reviewed in Ibbotson, 2005). Considering its usefulness in increasing sensitivity to environmental changes, aftereffects provide a useful context for examining how our perception of faces is influenced by experience with certain faces.

Face aftereffects. Recent studies have demonstrated face aftereffects in adults. Face aftereffects were first observed for facial distortions. Following adaptation to a series of consistently distorted faces (e.g., with very compressed features) unaltered faces appear distorted in the opposite direction (Webster & MacLin, 1999). These attractiveness aftereffects occur because the adapting stimulus changes the prototype (or norm), which is constantly updated. For example, viewing a series of faces with very compressed features moves the norm toward the "compressed" side of the previous average face. As a consequence, unaltered faces no longer lie near the prototype but rather on the opposite (i.e., expanded) side. Adaptation and aftereffects have been observed for a variety of facial dimensions. After adaptation to a male face, an androgynous face appears female, whereas after adaptation to a female face that same androgynous face appears male (Webster, Kaping, Mizokami, & Duhamel, 2004). Similar aftereffects have been observed for gender, race, and emotional expression (Fox & Barton, 2007; Webster et al., 2004). The prevalence of aftereffects support the hypothesis that multiple dimensions of faces are encoded relative to a prototypical face (i.e., norm-based coding). This prototype is dynamically updated with each face encountered so that the adapting stimulus draws the prototype in its direction and places previously neutral faces in a new category. After adaptation to one face category (female, surprise, or Caucasian), previously ambiguous or neutral faces are perceived to belong to a new category (male, disgusted, or Asian, respectively; reviewed in Rhodes et al., 2005). For example, following adaptation to faces showing surprised expressions, a face composite that is comprised of a surprised expression morphed with a disgusted expression (i.e., a face showing 50% surprise and 50% disgust) would subsequently be perceived as showing disgust. Aftereffects following the same logic have been shown for specific facial identities (Anderson & Wilson, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006).

The Development of Adult-Like Expert Face Perception

Collectively, studies of adaptation and aftereffects in adults provide convincing evidence that norm-based coding underlies adults' ability to recognize hundreds of faces with ease. This methodology may provide a powerful tool for investigating the development of face processing. Adult-like expertise in face recognition is slow to develop (Bruce et al., 2000; Mondloch, Geldart, Maurer, & Le Grand, 2003), even when memory demands are eliminated. Several factors contribute to the slow development of expertise. Relative to adults, children are more easily fooled by paraphernalia (Baenninger, 1994; Carey & Diamond, 1977; Freire & Lee, 2001), and they are also less sensitive to variations in distinctiveness (McKone & Boyer, 2006; Mondloch, Dobson, Parsons, & Maurer, 2004) and to small differences among faces in the appearance of individual features and the spacing among features (Freire & Lee, 2001; Mondloch, Le Grand, & Maurer, 2002; Mondloch, Leis, & Maurer, 2006). One unifying explanation for this pattern of results is that children may rely less than adults on norm-based coding of faces. Children may differ from adults in multiple ways: their representation of the norm, the number of dimensions represented in face space, the dimensions they use, or their sensitivity to differences in values within some dimensions of face space (Rhodes et al., 2005).

Perceptions of Attractiveness

To examine norm-based coding in children, we elected to measure attractiveness aftereffects. As discussed earlier, the extent to which faces are perceived as typical or normal is indicative of the distance from one's face prototype, with typical/normal-looking faces closer to the prototype and distinctive and less attractive faces farther away from the prototype. Since the original study by Webster and MacLin (1999), several researchers have demonstrated shifts in perceived attractiveness/normality following adaptation to consistently distorted faces (MacLin & Webster, 2001; Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Watson & Clifford, 2003). Although some features that deviate from average (e.g., large eyes, McArthur & Apatow, 1983-1984; sexually dimorphic features, DeBruine, Jones, Unger, Little, & Feinberg, 2007; Perrett et al., 1998; reviewed in Geldart, Maurer & Carney, 1999) can enhance facial attractiveness, adults typically rate averaged faces (i.e., a composite face created by combining a set of individual same-sex, same-race faces) as more attractive than most individual, nonaveraged faces (Langlois & Roggman, 1990; Rhodes et al., 1999; Rubenstein et al., 1999; Valentine et al., 2004). Attractiveness aftereffects provide evidence that the average face is updated with each new face encountered. After adaptation to faces with either compressed or expanded features, adults' ratings of both facial attractiveness and normality shift in the direction of the adapting stimuli such that faces with slight distortions are rated as more attractive and more normal than unaltered faces (Rhodes et al., 2003). Adaptation and attractiveness/normality aftereffects occur across different types of distortions (e.g., when internal features are pulled/pushed toward the center of the face; Watson & Clifford, 2003) and are maintained across changes in size (Jeffery, Rhodes, & Busey, 2006), orientation (e.g., when adapting faces are presented at 45 ° clockwise and rating stimuli are presented at 45 ° counterclockwise as demonstrated by Rhodes et al., 2003) and point of view (Jeffery et al., 2006; Jiang, Blanz, & O'Toole, 2007). The survival of aftereffects across these transformations indicates the involvement of high-level nonretinotopic mechanisms (Rhodes et al., 2003). These studies indicate that what is average varies with the diet of faces to which each individual is exposed and that short-term shifts in the face prototype influence the perceived attractiveness of faces.

No previous study has investigated attractiveness aftereffects in children. There is evidence that even babies have one prerequisite skill—the ability to form a prototype after viewing faces in the lab. After being familiarized with four individual faces, 3-month-old infants treat a composite of those four faces as more familiar than any of the familiarized faces (de Haan, Johnson, Maurer, & Perrett, 2001; see Inn, Walden & Solso, 1993, for similar effects in children). Second, similar facial attractiveness preferences have been found among adults and infants, with infants showing longer looking times for adult-rated attractive faces over adult-rated unattractive faces (Langlois, Ritter, Roggman, & Vaughn, 1991; Langlois et al., 1987; Samuels & Ewy, 1985; Slater et al., 1998). Like adults (see above), infants prefer averaged faces; 6-month-olds look longer at a 32-face averaged composite when paired with a nonaveraged, adult-rated unattractive face (Rubenstein et al., 1999; but see Rhodes, Geddes, Jeffery, Dziurawiec, & Clark, 2002). Studies with infants, therefore, suggest that the cognitive mechanisms that underlie the perception of facial attractiveness and norm-based coding may already be present very early in development.

In addition, there is evidence that children's perception of facial attractiveness is influenced by their face prototype: Age-related changes in perceived attractiveness reflect age-related changes in experience. Maurer and colleagues created a set of female faces that differed only in the height of facial features and obtained attractiveness preferences from infants (via measurements of looking time and smiling, with greater fixations and more smiling interpreted as greater preference for one stimulus relative to another) and attractiveness ratings from adults (Geldart, Maurer, & Henderson, 1999) as well as children aged 3, 4, 9, and 12 years (Cooper, Geldart, Mondloch, & Maurer, 2006). Infants show a slight preference for high-placed features, presumably because that is how features appear from their vantage point when held in an adult's arms. Preferences for low/medium-placed features emerge as children begin to interact with peers, who have low-placed features, and a preference for medium-placed features over low-placed features emerges at puberty when children attain adult height and their peers' faces take on adult proportions. In summary, which position of facial features is rated as most attractive varies with age, but each age group rates the height of features with which they are most familiar as most attractive.

Collectively, these studies suggest that, like adults, children rate faces that are near their prototype as most attractive and that long-term changes in perceived attractiveness can be attributed to their prototype changing with experience. However, previous developmental work provides only indirect evidence of children's perception of attractiveness being influenced by a face prototype. Furthermore, no previous study has investigated whether children's perceptions of attractiveness are dynamically updated as they encounter new faces. The present study provides the first test of attractiveness aftereffects in children. We studied 8-year-old children because they show (nearly) adult-like performance on several aspects of face perception including holistic processing (Carey & Diamond, 1994; de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Le Grand, Maurer, & de Schonen, 2007; Pellicano & Rhodes, 2003; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998), sensitivity to the shape of individual features and the external contour (Mondloch et al., 2002), and expertise for human, but not monkey faces (Mondloch, Maurer, & Ahola, 2006). However, other aspects of their face perception are immature: sensitivity to differences among faces in the spacing of features (Mondloch et al., 2002) and recognition of faces from a new point of view (Mondloch et al., 2003). If 8-year-olds do not show attractiveness aftereffects, then we can conclude that one source of their immaturity in face processing may be that they do not use norm-based coding.

To measure attractiveness aftereffects in adults, Rhodes et al. (2003) asked participants to rate 110 faces pre- and postadaptation. Some of these rated faces had internal facial features compressed toward the center of the face (as a face would appear in a concave mirror) and some had internal features that were expanded from the center (as a face would appear in a convex mirror); the degree of distortion varied in six equal steps. During the adaptation phase, adults viewed each of 10 distorted faces that were presented repeatedly for 5 min; each face was presented for 4 s and adults were asked to maintain their attention on the screen. For each participant, all of the adapting faces were distorted in the same way (i.e., compressed or expanded) at a fixed level. We made several modifications to this procedure to ensure that our method was child friendly: (a) all of the stimuli were color photographs of children's faces, (b) participants rated the attractiveness of a small set ($n = 5$) of test faces rather than 110 faces as in Rhodes et al. (2003), (c) we used more exaggerated distortions because children rate spatially altered and Thatcherized faces (i.e., eyes and mouth inverted within an upright face) as less bizarre than do adults (Mondloch et al., 2004), and (d) the adapting faces were presented in a storybook so as to better maintain participants' interest. Brace et al. (2001) and Mondloch, Leis, et al. (2006) successfully used storybooks to maintain children's attention. It was especially important to do so in the present study because participants were required to maintain attention on the computer screen throughout testing and were not allowed to look at the experimenter whose (undistorted) face might have disrupted adaptation. In Experiment 1, we tested adults to ensure that this novel method was sensitive to adaptation and attractiveness aftereffects; in Experiment 2, we tested 8-year-olds. We predicted that both adults and 8-year-old children would rate unaltered faces as more attractive than both expanded and contracted faces prior to adaptation. We predicted that after adaptation to compressed faces, adults' ratings of slightly compressed faces would increase relative to their ratings of unaltered faces; conversely, we predicted that after adaptation to expanded faces, adults' ratings of slightly expanded faces would increase relative to their ratings of unaltered faces. The postadaptation data from 8-year-old children were used to explore whether they show evidence of norm-based coding.

Experiment 1

Method

Participants. Forty-eight undergraduates (41 female, 45 Caucasian) from Brock University participated. An additional six adults were tested but excluded from the final analysis because they did not pass the preadaptation criterion (see Procedure, $n = 2$) or because they rated all ($n = 3$) or all but one ($n = 1$) of the pretest faces identically.

Stimuli. The adaptation procedure consisted of three phases. In the preadaptation phase, adults rated five photographs of 4-year-old children. In the adaptation phase, adults were shown a series of faces with either compressed or expanded features. In the postadaptation phase, adults rated five additional photographs. The adapting stimuli consisted of 10 colored photographs of 4-year-old Caucasian children (five girls). Using the spherize function in Adobe Photoshop, these faces were either compressed (for half of the participants) or expanded using a 60% distortion level. Rhodes et al. (2003) used ±50 distortions as adapting stimuli; we used ±60 distortions because children are less sensitive than adults to the spacing of internal features (Mondloch, Leis, et al., 2006; Mondloch et al., 2002). The rating stimuli consisted of photographs of ten 4-year-old Caucasian children (five girls). As shown in Figures 1A and 1C, we divided these photographs into two sets of five faces comprised of one face at each distortion level (i.e., +60, +40, 0, −40, and −60). One set of faces consisted of two boys and three girls, and the other set of faces consisted of three boys and two girls. Faces from one set were shown individually prior to adaptation and the participant rated each on the 5-point scale; the remaining five faces were shown after adaptation. The order in which the two sets of faces were presented (i.e., preadaptation vs. postadaptation) was counterbalanced across all participants.

Like Rhodes et al. (2003), we asked participants to rate stimuli with the same distortion level as the adapting stimuli (±60) and an undistorted face. Rhodes et al. also asked participants to rate faces at eight intermediate levels of distortion. We chose one intermediate value (±40) to simplify the task for children. The faces presented before and after adaptation were also matched on distinctiveness based on adult ratings obtained from a previous study (Mondloch, Leis, et al., 2006). Thus, the original undistorted versions of the two sets of faces did not differ significantly in distinctiveness ($p > .05$). Controlling for variations in distinctiveness also ensured that the faces could only become *more* distinctive, rather than *less* distinctive, after distortion. All of these faces were presented in the context of a storybook about a surprise birthday party (Figure 1B). A Canon Ultrasonic digital camera was used to take pictures of color drawings on a 14 × 22 in. background. These drawings served as the backgrounds for the storybook. We created the storybook by superimposing the faces onto these backgrounds.

Procedure. The procedure was approved by the Research Ethics Board at Brock University. After

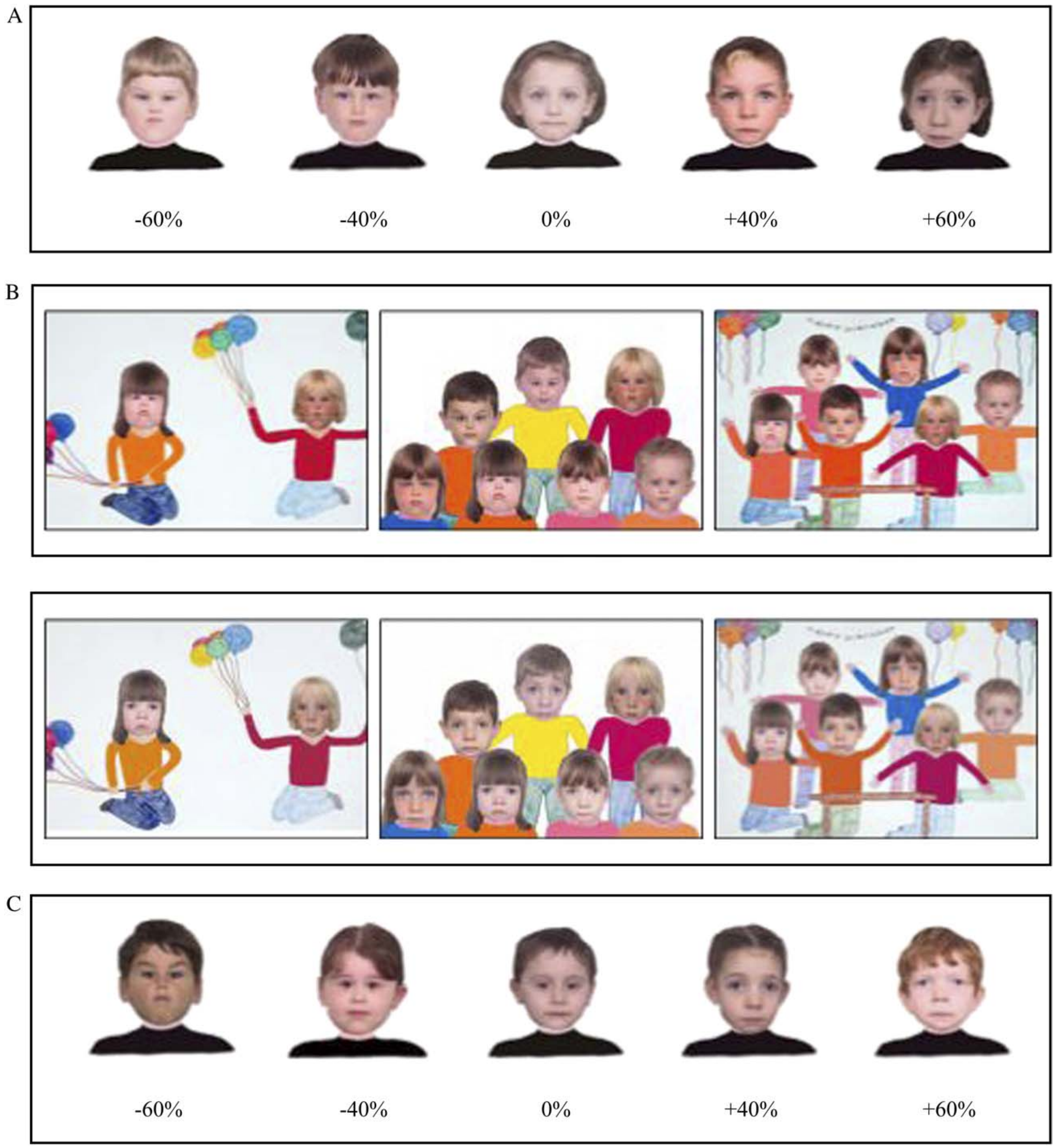

Figure 1. Examples of preadaptation test faces (A), adaptation pages from the −60% (top panel) and +60% (bottom panel) storybook (B), and postadaptation test faces (C) used with adults in Experiment 1.
Note. We distorted faces using the spherize function in Adobe Photoshop. Each participant was adapted to one of the most extreme distortions (−60% or +60%). The test faces were presented on a white background and all original clothing was replaced with a black shirt so as to minimize nonface differences that may have impacted attractiveness ratings. The order of the two sets of test faces used in pre- and postadaptation was counterbalanced across participants. All test faces were 19 cm high from chin to hairline.

providing informed consent, each adult sat 60 cm from a computer monitor and was read a storybook about a surprise birthday party. The first page of the book contained an unaltered picture of a 4-year-old child used to introduce the theme. Adults then received two sets of practice trials. In the first set, adults were shown three presents that varied in attractiveness. After viewing the three presents simultaneously, they viewed each present individually and rated each one on a 5-point cup-rating scale in which the largest cup meant *very, very pretty* and the smallest cup meant *not at all pretty.* In the second set of practice trials, adults rated three balloons using the same protocol. Participants were excluded from the analysis if they made more than one reversal, defined as rating a less attractive item (e.g., a paper bag) as more attractive than the next most attractive item (i.e., a green present with polka dots). They also were excluded if they rated the least attractive item as most attractive (e.g., the brown bag as more attractive than both the green present and the blue present with bows and streamers). Exclusion was based on the assumption that the participant was not being attentive or not using the rating scale consistently.

After rating the balloons and presents, participants were told that they would see five guests arriving at the party and that they would be asked to use the 5-point scale to rate each face on attractiveness. Which set of rated faces was presented preadaptation varied across participants to ensure that differences in preversus postadaptation ratings could not be attributed to the individual faces being rated. The order in which faces was presented varied across participants with two constraints: The unaltered face was always presented first and the direction of distortion alternated after that (i.e., the +60 face was followed by either the −40 or the −60 face). The experimenter then read the storybook to the adult. Adults were instructed to look at the 23-in. computer screen throughout the entire story. The adapting portion of the book consisted of 20 pages containing a total of 42 distorted faces (10 faces each repeated several times); each face was shown in different sizes, ranging from 19 to 71 cm high. For half of the participants, the internal features of every face in this portion of the storybook were compressed toward the center of the face and for half of the participants the features of every face were expanded. The storybook was designed to maintain children's attention throughout the adaptation phase. In the book, the host takes the birthday boy, Dan, to the park to play hide-and-go-seek. The remaining children are shown preparing the party and then the host discovers that Dan is lost. Throughout the rest of the book, the children are looking for Dan. As new characters are introduced during the search, participants were asked "Is that Dan?" to ensure that they were attending to the distorted faces as is required for adaptation to occur.

Dan is found at the end of the story, but just as he is about to open his present the doorbell rings and five new guests arrive. Once again, the participants viewed one face at each distortion level and rated each face on the 5-point scale. These faces had not been seen prior to their being rated (i.e., they were different than the faces rated preadaptation and they did not appear earlier in the storybook). To maintain adaptation, these postadaptation faces were presented only briefly (approximately 2 s) and then a blank screen was presented until the adult responded. In addition, we presented an adapting face from the storybook after each response; these faces were paired with words such as "Good job!" or "I think so too" so as not to raise suspicions about their purpose. After rating the five faces, the book ends with Dan opening his gift, a new bike.

Results and Discussion

Prior to adaptation, adults rated the undistorted faces as more attractive than the distorted faces; after adaptation, peak attractiveness ratings shifted in the direction of the adapting stimuli (Figure 3). A 2 (adapting condition) × 5 (distortion level) × 2 (test time: preadaptation/postadaptation) analysis of variance (ANOVA) revealed a significant three-way interaction, $F(4, 92) = 16.61$, $p < .001$, $\eta_p^2 = .27$. We used a 2 (test time) × 5 (distortion level) ANOVA to look at adaptation aftereffects in the two groups separately. The Test Time × Distortion Level interaction was significant in adults adapted to both the +60 faces, $F(4, 92) = 11.61$, $p < .001$, $\eta_p^2 = .34$, and the −60 faces, $F(4, 92) = 6.44$, $p < .001$, $\eta_p^2 = .22$. To examine the effect of test time at each level of adaptation, we conducted a series of one-tailed single-sample t tests. Ratings of the +40 test face, $t(23) = 2.81$, $p < .05$, $d = .48$, and +60 test face, $t(23) = 4.04$, $p < .001$, $d = .53$, increased in the +60 group, whereas ratings of the −40 face decreased, $t(23) = 3.43$, $p < .05$, $d = .50$. That is, participants who were adapted to faces at the +60% distortion level rated faces at the +60% and +40% distortion levels as significantly more attractive after adaptation relative to preadaptation ratings. These participants also rated faces that were slightly distorted in the opposite direction of the adapting stimuli (i.e., faces at the −40% distortion level) as significantly less attractive after adaptation relative to preadaptation ratings. In contrast, ratings of the −40 face, $t(23) = 3.33$, $p < .05$, $d = .33$, and −60 face, $t(23) = 2.41$, $p < .05$, $d = .28$, increased in the −60 group, whereas ratings of the +40 face decreased, $t(23) = 2.50$, $p < .05$, $d = .28$. That is, participants who were adapted to faces at the −60% distortion level rated faces at the −60% and −40% distortion levels as significantly more attractive after adaptation relative to preadaptation ratings. These participants also rated faces that were slightly distorted in the opposite direction of the adapting stimuli (i.e.,

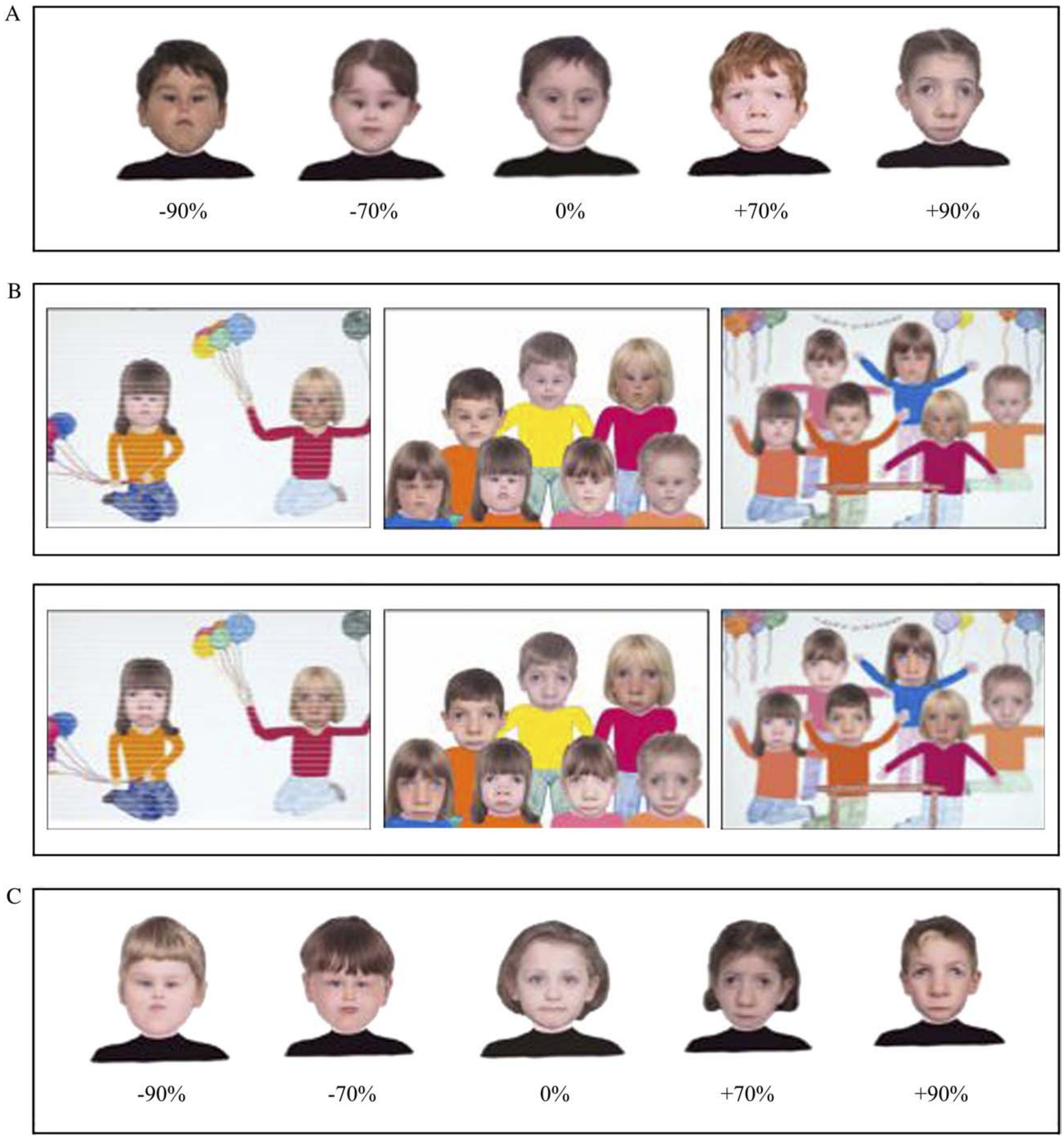

Figure 2. Examples of preadaptation test faces (A), adaptation pages from the −90% (top panel) and +90% (bottom panel) storybooks (B), and postadaptation test faces (C) used with 8-year-olds in Experiment 2.
Note. The order of the two sets of test faces used in pre- and postadaptation was counterbalanced across participants.

faces at the +40% distortion level) as significantly less attractive after adaptation relative to preadaptation ratings. Ratings of the undistorted face did not change in either group, $p > .05$, nor did ratings of the ±60 face that was opposite the adapting stimuli, $p > .05$.

Although ratings of the undistorted faces did not change, Figure 3 shows that there was a shift in peak attractiveness ratings. To analyze this shift we conducted a 2 (test time) × 2 (distortion level) ANOVA. We entered attractiveness ratings for the undistorted face and for the ±40 faces that were in the direction of adapting stimuli (e.g., the −40 faces for the group adapted to the −60 distortion). There was a significant interaction between test time and distortion level,

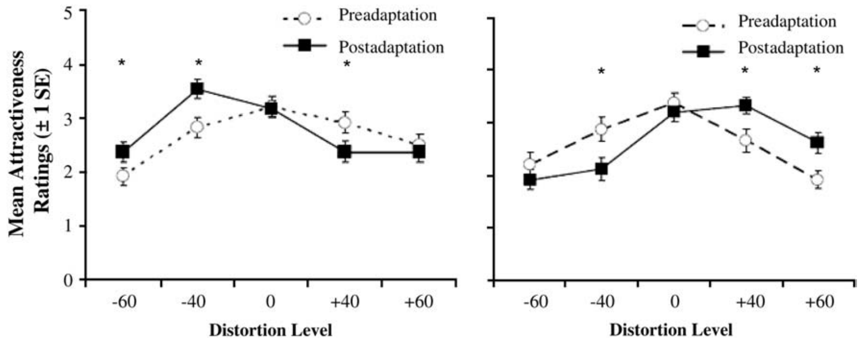

Figure 3. Adults' attractiveness ratings and standard error across conditions before and after adaptation to −60 distortions (left) and +60 distortions (right).
*A significant difference between pre- and postadaptation ratings.

$F(1, 47) = 19.66$, $p < .001$, $\eta_p^2 = .30$. Prior to adaptation, undistorted faces were given higher ratings (M = 3.29, SE = 0.14) than ±40 faces (M = 2.75, SE = 0.14), t (47) = 3.38, $p < .001$, d = .57 (mean difference score = 0.54, SE = 0.16). After adaptation, ±40 faces were given higher ratings (M = 3.44, SE = 0.12) than undistorted faces (M = 3.19, SE = 0.11), $t(47) = 2.00$, $p < .05$, d = .31 (mean difference score = 0.25, SE = 0.12).

These results indicate that our novel child-friendly method yields attractiveness aftereffects like those previously reported for adults (Rhodes et al., 2003; Watson & Clifford, 2003). This is impressive given that adults rated only five faces at each test time, in contrast to the much higher number (> 100) that is typical of adult studies. Because each individual face served as a pretest stimulus for some participants and a posttest stimulus for others, differences in ratings cannot be attributed to the attractiveness of unaltered stimuli. We reduced the number of rated faces to ensure that children would not become bored, especially during postadaptation ratings. These results are consistent with published studies (Rhodes et al., 2003; Watson & Clifford, 2003) and the prototype theory: Presumably adults' prototype shifted toward the adapting stimuli, resulting in increased attractiveness ratings of faces distorted in that direction relative to unaltered faces. In Experiment 2, we tested 8-year-olds on the same task to see whether their attractiveness ratings would shift as a function of adaptation. Evidence of attractiveness aftereffects in children would be consistent with their use of norm-based coding for faces.

Experiment 2

Method

Participants. Forty-eight 8-year-olds (±6 months; 24 female, 47 Caucasian) participated. Prior to testing, children's parents provided written informed consent and children provided verbal assent. An additional nine children were tested but excluded from data analysis because they did not pass the preadaptation criterion (n = 5; see Procedure) or because there was no variability either in their pretest or posttest ratings (n = 4).

Stimuli. We had initially planned on testing 8-year-olds with the same distortion levels used with adult participants, but pilot data suggested that 8-year-olds did not systematically rate the unaltered faces as more attractive than the ±40 faces; therefore, we used ±70 and ±90 faces as pre- and postadaptation faces (Figures 2A and 2C) and children were adapted to either +90 or −90 faces (Figure 2B).

Procedure. The procedure used to test children was identical to that described for adults with two exceptions. To explain the cup-rating scale to children in a way that was fun and that helped develop a positive rapport between each child and the experimenter, children were asked to rate foods that they liked very much versus foods that they did not like at all using the cup scale. Children then received further training in using the cup scale with presents and balloons that differed in attractiveness (i.e., the same training given to adult participants). This method of using cups to help children with the ordinal nature of the scale has been validated by Cooper et al. (2006). We also added one page to the storybook. It displayed the 10 faces to be rated pre- and postadaptation. Children were encouraged to be honest about their attractiveness ratings. The experimenter explained, "Here are all of the children who are coming to today's birthday party. They've spent a long time getting ready for the party. . . . Remember, these aren't real children. They are only pretend, so it's OK if you think that some of them are really pretty and others aren't pretty at all." Children were tested in a quiet room and the experimenter sat behind the child and held a clipboard in front of her face to ensure that the child would not turn around and be exposed to an undistorted face in the midst of adaptation.

Results and Discussion

Like adults, children rated the undistorted faces as most attractive prior to adaptation but there was a shift in peak attractiveness ratings following adaptation (Figure 4). The 2 (adapting condition) × 5 (distortion level) × 2 (test time) ANOVA revealed a significant three-way interaction, $F(4, 184) = 5.55$, $p < .001$, $\eta_p^2 = .11$. The 2 (test time) × 5 (distortion level) ANOVA revealed a significant interaction both for children adapted to the +90 face, $F(4, 92) = 5.05$, $p < .05$, $\eta_p^2 = .18$ and the −90 face, $F(4, 92) = 4.93$, $p < .05$, $\eta_p^2 = .18$. Single-sample *t* tests confirmed that after adaptation to +90 faces, ratings of both the +90 face, $t(23) = 3.36$, $p < .05$, $d = .61$, and the +70 face increased, $t(23) = 3.21$, $p < .05$, $d = .42$; ratings of −70 faces decreased, $t(23) = 2.10$, $p < .05$, $d = .25$. Ratings of the remaining faces remained unchanged ($p > .05$). After adaptation to −90 faces, ratings of the −90 face, $t(23) = 3.25$, $p < .05$, $d = .37$, and the −70 face, $t(23) = 3.05$, $p < .05$, $d = .72$, increased, whereas ratings of undistorted faces decreased, $t(23) = 3.60$, $p < .001$, $d = .42$. Ratings of +70 and +90 faces remained unchanged ($p > .05$). Our analysis of the shift in peak attractiveness ratings revealed a significant Test Time × Distortion Level interaction, $F(1, 47) = 12.11$, $p < .05$, $\eta_p^2 = .21$. Prior to adaptation, undistorted faces were given higher ratings ($M = 3.33$, $SE = 0.16$) than ±70 faces ($M = 2.10$, $SE = 0.16$), $t(47) = 5.36$, $p < .001$, $d = 1.14$ (mean difference score = 1.23, $SE = 0.23$). After adaptation, ratings of the ±70 faces ($M = 2.88$, $SE = 0.16$) did not differ from those of the unaltered faces ($M = 2.85$, $SE = 0.18$), $p > .05$ (mean difference score = 0.02, $SE = .020$).

Despite only rating one face at each of the five distortion levels, 8-year-old children showed attractiveness aftereffects. As predicted, prior to adaptation, 8-year-olds rated undistorted faces as more attractive than distorted faces; unaltered faces were no longer rated as most attractive after adaptation. After adaptation, ratings of faces distorted in the same direction as the adapting stimuli increased. Ratings of undistorted faces decreased following adaptation to compressed (−90) faces but remained unchanged after adaptation to expanded (+90) faces. These data suggest that children's perception of attractiveness is influenced by a face prototype and that this prototype is dynamically updated as new faces are encountered.

General Discussion

Using children's faces as stimuli, these results replicate previous findings of attractiveness aftereffects in adults (Rhodes et al., 2003) and are the first to show adaptation and attractiveness aftereffects for faces in children as young as 8 years of age. Like adults, children rated undistorted faces as more attractive than compressed or expanded faces prior to adaptation, a result that is consistent with a previous study in which 8-year-old children rated both spatially distorted faces and Thatcherized faces as more bizarre than unaltered faces (Mondloch et al., 2004; see also Gilchrist & McKone, 2003, for evidence of better recognition memory for distinctive faces in 7-year-olds). This initial preference for undistorted faces suggests that, like adults, children find faces nearer their prototype more attractive than faces that are farther away. After adaptation, both adults and children rated faces distorted toward the adapting faces as more attractive, whereas their ratings of unaltered

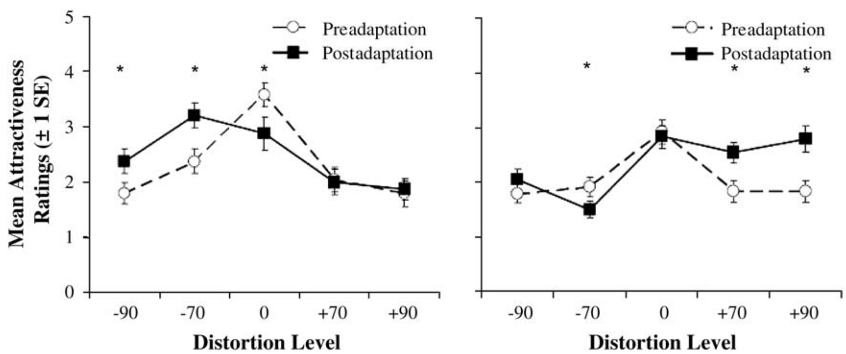

Figure 4. Eight-year-olds' attractiveness ratings and standard error across conditions before and after adaptation to −90 distortions (left) and +90 distortions (right).
*A significant difference between pre- and postadaptation ratings.

faces and faces distorted in the opposite direction of the adapting stimuli either decreased or remained unchanged. Like adults, children's shift in their perception of facial attractiveness at postadaptation was large enough to eliminate their preadaptation preference for undistorted faces. These aftereffects emphasize the role of experience in adults' and 8-year-olds' perception of facial attractiveness. That is, short-term adaptation to consistently distorted faces changes one's perception of attractive faces toward the adapting distortion, indicating the use of norm-based coding and the flexible nature of an experience-dependent facial prototype. This is consistent with previous results that show a developmental change in the preferred height of internal facial features as a function of experience (Cooper et al., 2006).

Although 8-year-old children showed adult-like attractiveness aftereffects, they differed from adults in one significant way. Prior to adaptation, they did not rate ± 40 faces or ± 60 faces as less attractive than undistorted faces (consequently we adapted them to ± 90 faces and asked them to rate ± 70 and ± 90 faces). This is consistent with previous studies showing that children are less sensitive than adults to differences in distinctiveness. Although 7-year-olds recognize distinctive faces more accurately than typical faces (Gilchrist & McKone, 2003), 8-year-olds' ratings of grotesque faces differ from those of adults. When asked to rate featurally distorted, spatially distorted, and Thatcherized (inverted features in an otherwise upright face) faces on a grotesqueness scale, 8-year-olds' ratings were adult like for featural distortions but they rated both spatially distorted and Thatcherized faces as less grotesque than adults (Mondloch et al., 2004). Younger children show little or no sensitivity to manipulations that increase distinctiveness. Four-year-olds are able to correctly choose the more distinctive face of a pair when differences between the unaltered face and the manipulated face are large, but their performance is at or near chance levels when the differences are smaller, unlike adults' performance that remains very accurate (McKone & Boyer, 2006; Mondloch & Thomson, 2008). Our finding that 8-year-olds show attractiveness aftereffects despite being less sensitive to differences among faces in distinctiveness suggests that although they use norm-based face coding their face space is not adult-like.

Similar patterns have been observed for facial identity. Adult-like sensitivity to two cues to facial identity, the appearance of facial features and the spacing among them, is slow to develop. Four-year-old children are able to recognize faces based on the appearance of individual features such as the eyes or mouth (Mondloch, Leis, et al., 2006); this sensitivity is nearly adult like by 6 years of age with no statistical difference by 10 years of age (Freire & Lee, 2001; Mondloch et al., 2002). Four-year-old children are unable to recognize even highly familiar faces based on differences in the spacing of facial features (Mondloch, Leis, et al., 2006; Mondloch & Thomson, 2008); this sensitivity emerges by 6 years of age but is not adult like until after 14 years of age (Mondloch et al., 2003). Likely as a result, children make more errors than adults when asked to recognize a face from a new point of view (Bruce et al., 2000; Mondloch et al., 2003). Despite the slow development of adult-like sensitivity to some cues to facial identity, a very recent study has shown adult-like identity aftereffects in 8-year-old children (Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008). Like adults, 8-year-old children recognize a previously neutral face (e.g., the average face) as having a particular identity (e.g., Bob) following adaptation to the computationally opposite face (i.e., anti-Bob).

The finding of attractiveness (our study) and identity (Nishimura et al., 2008) aftereffects in 8-year-old children in the context of immature sensitivity to differences among faces both in distinctiveness and in some cues to facial identity raises the question as to what develops between 8 years of age and adulthood. One possibility is that the dimensions used to discriminate individual faces become increasingly specific to the population of faces encountered on a daily basis. However, several studies provide evidence that perceptual narrowing begins during infancy and that the dimensions used to recognize individual faces are specific to human/own-race faces by early childhood. Three-month-olds, but not newborns, look preferentially toward own-race faces (Kelly et al., 2005) and 6-month-olds, but not 9-month-olds, can recognize individual monkey faces (Pascalis, de Haan, & Nelson, 2002) unless they receive exposure to monkey faces between 6 and 9 months of age (Pascalis et al., 2005). By 3 years of age, like adults (reviewed in Meissner & Brigham, 2001), children recognize own-race faces more accurately than other-race faces (Hayden, Bhatt, Joseph, & Tanaka, 2007; Sangrigoli & de Schonen, 2004a, 2004b). Furthermore, by 8 years of age, children are more sensitive to small differences among faces in the spacing of features in human faces than in monkey faces: Like adults, 8-year-olds were 9% more accurate when discriminating human faces that differed only in the spacing of facial features than monkey faces that differed in exactly the same way (Mondloch, Maurer, et al., 2006). Valentine (1991) explains this "other-race effect" in terms of a prototype model; he argues that the dimensions used to distinguish individual faces are shaped by experience and reflect those facial characteristics that best discriminate among typical exemplars. Because other-race faces differ from the face prototype in the same way, they will be clustered together in face-space far from the average face. Given evidence of perceptual narrowing during infancy and early childhood, it is unlikely that increasing specificity of the face prototype makes a significant contribution to increased sensitivity to facial distinctiveness and facial identity after 8 years of age.

Rhodes et al. (2005) suggest several aspects of norm-based coding that might continue to develop during childhood including the number of dimensions represented in face space and the ability to discriminate small differences within any one dimension. There is evidence in the literature that both the average face and the dimensions used to distinguish among faces remain plastic throughout childhood. Sangrigoli, Pallier, Argenti, Ventureyra, and de Schonen (2006) showed that Korean individuals adopted into French families between 3 and 9 years of age (i.e., after developing superior recognition of Korean faces) were more accurate when asked to recognize Caucasian faces than Asian faces when tested as adults. In contrast, Korean individuals who moved to France as adults were more accurate when asked to recognize Asian faces, even after residing in France for 11 years. Likewise, preferences based on height of facial features continue to develop until the child reaches puberty, with adult-like preferences emerging when children attain adult height and their peers' faces take on adult proportions (i.e., between 9 and 12 years of age; Cooper et al., 2006). Collectively, these studies indicate that face space remains plastic throughout childhood allowing for dramatic changes in organization following exposure to a new population of faces and for more subtle changes as a result of growth and physiognomic changes in peers' faces. Perhaps as a result, the number of dimensions represented or the perception of distances between faces changes with age (Pedelty, Levine, & Shevell, 1985). Adaptation and aftereffects for faces can occur within a relatively limited temporal context (as in the present study), but it can also occur over the lifespan. Thus, as we continue to experience certain types of faces (e.g., own-race faces), our face prototype becomes more refined for that particular group of faces with age. This might explain why adults are better at differentiating between own-race faces (which are closer to one's face prototype) relative to other-race faces (which are farther away from one's face prototype).

There is evidence that sensitivity to small differences within a dimension represented in face space increases after 8 years of age. Although 8-year-old children are more sensitive to differences in the spacing of facial features in human faces than in monkey faces (i.e., they show an adult-like pattern of expertise), their sensitivity is not adult like; adults' accuracy is 14% higher than that of 8-year-olds when tested on both human and monkey faces (Mondloch, Maurer, et al., 2006). This is consistent with the report that 8-year-olds rate Thatcherized and spatially distorted faces as less grotesque than adults (Mondloch et al., 2004) and with our current finding that 8-year-olds did not consistently rate ±40 and ±60 faces as less attractive than unaltered faces. If 8-year-olds are less sensitive than adults to variability within a dimension, they may have a wider area of face space that they perceive as normal than do adults. If so, then they resemble adults after adaptation to distorted faces (MacLin & Webster, 2001); following adaptation to distorted faces, adults' perception of normality shifts in the direction of the adapting stimuli and they rate a wider range of faces as normal. This leads to the interesting hypothesis that adults would be similarly tolerant of distortions when tested with other-race faces; like children tested with own-race faces, they may show evidence of norm-based coding but be more tolerant of deviation around undistorted faces.

The hypothesis that 8-year-olds' face space is less refined than that of adults is consistent with several studies that report slow development of adult-like neural correlates of face processing. The neural correlates of norm-based face coding have only recently been examined in adults. Studies have shown that activation of the anterior inferotemporal cortex in monkeys (Leopold, Bondar, & Giese, 2006) and activation in the fusiform face area (FFA) in human adults (Loffler, Yourganov, Wilkinson, & Wilson, 2005) increase as a function of the distance from the average face. Loffler et al. (2005) also found that adapting adults to a particular facial identity decreased neural activity to other faces on the same identity trajectory but not to faces on a different identity trajectory. Functional magnetic resonance imaging (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 – 11 years. Furthermore, accuracy on a face memory task was correlated with the size of the FFA (Golarai et al., 2007).

The success of our novel, child-friendly method in generating attractiveness aftereffects in children and adults indicates that this is a promising approach to understanding the development of other aspects of adult-like expertise in face processing. Future studies need to investigate whether children are sensitive to other aftereffects (e.g., gender, emotions, and race) that have been found in adults (Rhodes et al., 2003; Webster et al., 2004). Future studies may also use attractiveness aftereffects as a tool to understand the nature of children's prototypes and their multidimensional face space (Valentine, 1991). Rhodes et al. (2004) adapted adults to compressed and expanded faces simultaneously; the two distortions were presented at different orientations (e.g., compressed upright faces and expanded inverted faces). They report orientation-contingent aftereffects such that adults rated compressed faces more attractive when faces were upright and expanded faces as more attractive when faces were inverted. Rhodes et al. concluded that different neural populations may process upright and inverted faces. Similar results have been reported when male and female faces are adapted in opposite directions (Little, DeBruine, & Jones, 2005). Adapting our storybook task would allow researchers to investigate whether distinct neural populations process upright/inverted faces in children. Likewise, male and female or own-race and other-race faces could be distorted in opposite directions to see whether children develop opposite preferences for the two categories, as is true for adults, or whether the effects of adaptation merely cancel each other out. In short, our new method provides a wealth of opportunity to investigate face processing in children. Slight modifications of our method will also allow us to probe the nature of developmental changes before 8 years of age.

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