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The effects of information type (features versus configuration) and location (eyes versus mouth) on the development of face perception

James W. Tanaka[1], **Paul C. Quinn**[2], **Buyun Xu**[1], **Kim Maynard**[1], **Natalie Huxtable**[1], **Kang Lee**[3], and **Olivier Pascalis**[4]

[1] University of Victoria, Canada

[2] University of Delaware, USA

[3] University of Toronto, Canada

[4] Université Pierre Mendès France, FR

Abstract

The goal of the present study was to investigate the development of face processing strategies in a perceptual discrimination task. Children ages 7 to 12 years and young adults were administered the Face Dimensions Task. In the Face Dimensions Task, participants were asked to judge whether two simultaneously presented faces were the “same” or “different”. For the “same” trials, the two faces were identical. For the “different” trials, the faces differed either in the spacing between the eyes, the spacing between the nose and the mouth, the size of the eyes or the size of the mouth. The main finding was that 7- to 10-year-old children showed no difference in their ability to discriminate differences in eye size and eye spacing but showed a poor ability to discriminate differences in nose and mouth spacing and to a lesser extent, mouth size. The developmental lag between nose-mouth discriminations and the other featural and configural discriminations was reduced in older children and eliminated by young adulthood. These results indicate that the type of the face information (i.e., configural versus featural) and its location (i.e., eye versus mouth) jointly contribute to the development of face perception abilities.

In the first thirty minutes of life, neonates attend to face-like stimuli over non-face stimuli (Johnson, Dziurawiec, Ellis, & Morton, 1991). In childhood, 6-year-olds begin a steady linear improvement in their face recognition abilities that plateaus at about age 10 and then accelerates during adolescence (Lawrence, Bernstein, Pearson, Mandy, Campbell, & Skuse, 2008), finally peaking at about 30 years of age (Germine, Duchaine, & Nakayama, 2010). Although human face abilities are impressive, it is less clear whether age-related gains in face processing reflect the maturation of general cognitive abilities or whether they signal a developmental shift in the nature of face processing (Crookes & McKone, 2009; Mondloch, Maurer, & Ahola, 2006; Tanaka, Meixner, & Kantner, 2011).

Several accounts have been offered to explain the changes in face processing strategies that occur across development. The configural hypothesis argues that the critical developmental change in face processing occurs when the child attends not only to the features of a face, but becomes increasingly sensitive to the spatial distances that separate the features (e.g., Mondloch, Le Grand, & Maurer, 2002). In contrast, the location hypothesis maintains that the critical shift in face processing development occurs when the child begins to attend equally to information in eyes, nose and mouth regions (e.g., Ge, Anzures, Wang, Kelly, Pascalis, Quinn, et al. , 2008). The aim of the Face Dimensions Task is to provide a psychophysics measure to evaluate the independent contributions of information type (configural versus featural) and location (eye versus mouth) to the development of face processing abilities. Face stimuli were designed such that featural information (i.e., size of the eyes, size of the mouth) and configural information (i.e., distance between the eyes, distance between the nose and mouth) were independently manipulated. In the current study, children ages 7 to 12 years of age and young adults were administered the Face Dimensions Task. The results revealed that both the type of information (featural versus configural) and the location of information (eyes versus mouth loci) were important factors for explaining the developmental shift in face processing.

The featural-configural processing view

From a perceptual standpoint, the human ability to perceive and distinguish identities of individual faces is truly exceptional. Faces constitute a structurally homogeneous class of objects in which all faces share the same features of two eyes, a nose, and mouth that are arranged in a similar configuration (i.e., the eyes are located in the upper half of the face above the midline nose and mouth features). Thus, recognition of a particular face must depend on the ability to perceive subtle differences in the size and shape of the facial features and the configural distances that separate the features. A longstanding issue in the face processing literature is the role that featural and configural processes play in face recognition abilities and how these processes unfold over the course of development.

Based on looking paradigms, infants show an early ability to detect featural and configural differences in a face. By 3 months of age, infants are sensitive to faces that differ in their featural information and by 5 months, they are able to discriminate faces that differ in the spatial distances between the eyes (Bhatt, Bertin, Hayden, & Reed, 2005; Leo & Simion, 2009; Simion, Leo, Turati, Valenza1 & Barba, 2007). The infants' awareness of featural and configural changes seems to be biased toward information in eye location over information in the mouth location (Quinn and Tanaka, 2009).

In contrast to the good configural abilities of infants, children seem impaired in their ability to use configural information in face recognition tasks. For example, 7-year-olds fail to detect configural changes of eyes and mouth in a familiarized face (Mondloch et al., 2006), in the face of a familiar peer (Mondloch & Thomson, 2008) and even in their own face (Mondloch, Leis, & Maurer, 2012). Six-, eight- and ten-year-old children have more difficulty encoding configural changes than featural changes in a face presented either in its upright or inverted orientation (Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Grand, & Maurer, 2002). Studies of cataract patients who experience early visual deprivation show that they are differentially impaired in their ability to detect spacing differences relative to featural differences (LeGrand, Mondloch, Maurer, & Brent, 2001). According to the *configural processing hypothesis*, the ability to discern the spatial distances between the features of a face is what distinguishes a developing face processing system from a fully mature "expert" system (Mondloch et al., 2002). The disparity in results between the relatively good configural abilities of infants and the relatively poor configural abilities of children might reflect differences in the type of methods and tasks used to test the two age groups (Keen, 2003). Alternatively, the contrasting results might reflect important differences in face strategies where infants employ a more configural approach and young children employ a more featural approach.

However, findings from other studies question whether configural processing is the behavioral milestone of an adult face system. In a series of experiments, McKone and colleagues (Gilchrist & McKone, 2003; McKone & Boyer, 2006) created a set of distinctive-looking faces either by manipulating its featural attributes (e.g., bushy eye brows, thick lips) or by manipulating its configural attributes (e.g., small or large inter-ocular and nose-mouth distances). When the manipulations were matched for overall distinctiveness with adult participants, 4-year-old children were equally sensitive to the featural and configural manipulations of distinctiveness (McKone & Boyer, 2006). On a recognition memory test, 6-7 year old children, like adults, exhibited a recognition advantage for faces that were either featurally distinctive (e.g., bushy eye brows, thick eyes) or configurally distinctive (e.g., close inter-ocular and nose-mouth distances) compared to the non-distinctive faces (Gilchrist & McKone, 2003). Based on these results, the authors concluded that featural and configural face processes mature at a relatively early age of 7 years and follow a similar developmental trajectory. According to Gilchrist and McKone (2003), young children and adults are equally competent in their featural and configural abilities.

The locus of face processing

It might not be the *type* of information (configural versus featural), but the *location* (eye region versus mouth region) of face information that distinguishes a developing face system from a fully mature one. Neurophysiological evidence shows that the sensitivity to eye information begins at an early age and matures faster than processing of other facial features (Taylor et al., 2001). Eye tracking studies indicate that young infants show greater fixation times on the eye area than on other areas of the face (Haith, Bergman, & Moore, 1977; Oakes & Ellis, 2013; Wheeler, Anzures, Quinn, Pascalis, Omrin, & Lee, 2011). At 3 months, infants are more sensitive to featural size changes in the eyes relative to featural size changes in the mouth (Quinn & Tanaka, 2009) and by 8 months of age, infants start looking at the mouth and less at the eyes (Oakes & Ellis, 2013). Whether the eye preference reflects a bias for eye information or a general bias for information in the upper visual field (Simion, Valenza, Cassia, Turati, & Umiltà, 2002; Turati, Simion, Milani, & Umilta, 2002) has been hotly contested in the literature. However, in a recent study, 3- to 5.5-month-old infants did not display a consistent preference for top-heavy configurations of geometric stimuli indicating the preference for the eyes might be face-specific (Chien, 2011).

Children also rely more on eye features than nose or mouth features for purposes of recognition (Hay & Cox, 2000; Pellicano, Rhodes, & Peters, 2006). When asked to identify familiar classmates based on individual features, young children and adolescents performed best when shown eye and eye-brow features relative to mouth and nose features (Ge, Anzures, Wang, Kelly, Pascalis, Quinn, et al., 2008). Critically, adolescent participants showed marked improvement in their ability to recognize schoolmates from just mouth and nose features compared to 8-year-old and 4-year-old children (Ge et al., 2008). For newly familiarized faces, 13- to 14-year olds performed as well as adults when asked to recognize faces based on isolated eyes. When presented with only the mouth features, thirteen- to fourteen-year olds showed better recognition than eight- to nine-year olds, but were poorer recognition than adults (Liu, Anzures, Ge, Tanaka, & Lee, 2013). These findings indicate that young children show a preference for the eyes in face recognition, but over the course of development, they incorporate nose and mouth features in their face memories (Ge et al., 2008; Liu et al., 2013).

The Face Dimensions Task

The collective developmental findings indicate that sensitivity to the configural and featural information in the eyes and mouth regions are essential for achieving adult-like competency in face processing. Although the configural and location hypotheses are not necessarily contradictory, it is unclear whether the two types of face information follow the same or different developmental trajectories. The goal of the Face Dimensions Task is to independently evaluate the observer's perceptual sensitivity to featural and configural changes in the eye and mouth locations of the face. In this task, two faces are presented side by side and participants are asked to respond whether the faces appear “same” or “different.” Configural information was manipulated by varying distance between the eyes or distance between the nose and mouth (see Figure 1). Differences in featural information were manipulated by varying the size of the eyes or the size of the mouth. As noted by Sergent (1984), changes to the features of the face (e.g., shape or size) produce simultaneous changes in the configural distances between the features (e.g., altering the shape of the eyes produces subtle changes in the distance between the nose and mouth features). In the Face Dimensions Task, the confounding effects of feature adjustments on configural information are minimized by systematically scaling the size of the features. The manipulation of feature size has the advantage of preserving the feature's shape, its centroid, and absolute location while only minimally affecting edge-to-edge distances between features.[1]

Unlike face processing measures employed in other studies (Mondloch et al., 2006; Mondloch & Thomson, 2008; Mondloch et al., 2004; Yovel & Kanwisher, 2004), type (i.e., featural versus configural) and location (i.e., eyes versus mouth) of face information are independently manipulated in the Face Dimensions Task. In the full version of the task,

[1]Changing the size of the eyes altered the spatial distance between the internal edge of the left eye to the internal edge of the right eye by 4 pixels. Changing the size of the mouth altered the distance between the philtrum of the mouth and the bottom of the nose by 2 pixels.

featural and configural differences in the eye and mouth locations are parametrically manipulated to produce three levels of discrimination difficulty (easy, medium, hard) and the dimensions were equated for difficulty with adult participants. The Face Dimensions Task has been successfully applied to examine the face perception strategies of individuals with autism (Wolf, Tanaka, Klaiman, Cockburn, Herlihy, Brown et al., 2009), patients with prosopagnosia (Bukach et al., 2008; Rossion, Le Grand, Kaiser, Bub, & Tanaka, 2009) infants (Quinn & Tanaka, 2009; Quinn, Tanaka, Lee, Pascalis, & Slater, 2013) and healthy adults viewing inverted faces (Tanaka, Kaiser, Pierce & Hagen, in press).

In the current experiment, we administered an abbreviated version of the Face Dimensions Task involving the easy level of difficulty to groups of 7- to 8-, 9- to 10-, 11-to 12-year-old children, and young adults. According to the configural processing hypothesis, young children should show an advantage in their ability to detect featural changes over configural changes regardless of its face location. In contrast, the location hypothesis predicts young children should show an advantage for discrimination in the eye region over the mouth region regardless of the type of configural or featural change. Finally, if configural and location information interact in face perception, location should influence the discriminability of configural changes for young children (e.g., configural eye differences should be easier to detect than configural mouth differences), but location should have no effect on featural discriminations (e.g., featural eye and featural mouth differences should be equivalent in their discriminability).

Method

Participants

There were a total of 104 participants: 24 children in the 7 to 8-year-old category (10 males, mean age = 7.64 years, range = 6.70 − 8.45 years); 36 children in the 9- to 10-year-old category (14 males, mean age = 9.39 years, range = 8.67 − 10.49 years); 17 children in the 11- to 12-year-old group (7 males, mean age = 11.23 years, range = 10.61− 12.18 years); and 27 undergraduate students in the adult category (3 males, mean age = 19.30 years). Children were recruited through flyers posted at various community centers and local public schools. The child participants were compensated with a free day of activities and games for their participation. Both parental and child consent were obtained prior to the study in accordance with the University of Victoria's Human Research Ethics Committee. The adults were university students who received course credit for their participation in the study.

Stimuli

Facial photographs for the present study were adapted from Bukach and colleagues’ face dimension stimuli (Bukach et al., 2008, for a detailed description). The images were high-quality grey-scale photographs of eight unfamiliar young individuals, approximately 12 years of age (four males and four females) whose faces were digitally modified to remove identifying traits such as make-up, freckles, moles, and jewelry. For each of the 8 faces, information about the configural eyes, featural eyes, configural mouth, and featural mouth was manipulated (see Figure 1). Using the graphics software program Adobe Photoshop™, the eyes or mouth of each original face was modified either featurally or configurally to create four dimensions of change: featural eyes, featural mouth, configural eyes, and configural mouth. For the “different” faces in the configural eye condition, the eyes of the original face were moved further apart by 15 pixels and closer together by 15 pixels. For the “different” faces in the configural mouth condition, the distance between the nose and the mouth of the original face were moved closer together by 15 pixels and further apart by 15 pixels. For the “different” faces in the featural eye condition, the size of eyes of the original face was increased by 30% in one face and decreased by 30% in the other face. For the “different” faces in the featural mouth condition, the mouth size of the original face was increased by 30% in one face and decreased by 30% in the other. The discriminability between the configural eye, featural eye, configural mouth, featural mouth conditions was equated with adults in a previous study (Bukach et al., 2008). The size and spacing manipulations were within the normative range of Caucasian face morphology as specified by Farkas, Katic and Forrest (2005). The images measured 6 cm in width and subtended a visual angle of 3 degrees and 8.5 cm in height and subtended a visual angle of 5 degrees.

There were a total of 128 trials in the experiment, 64 “same” trials and 64 “different” trials. For the 64 “same” trials, the identical faces were selected from the set of 32 faces. The 64 “different” trials were composed of 16 different configural eye trials, 16 different configural mouth trials, 16 different featural eye trials, and 16 featural different mouth trials.

Procedure

Participants were tested individually on a computer using the E-Prime software program. At the beginning of the experiment, the participant was told that their task was to detect differences in faces and the faces could vary in their features (i.e., eyes and mouths) or the spacing between the features. Next, the participant was given eight practice trials of the same/different task (4 “same” trials, 4 “different” trials), depicting cartoon faces presented side-by-side on a computer screen. For the “different” trials, the faces differed in either their configural or featural information in the eye or mouth locations. If the participant responded incorrectly on a “different” practice trial, the research assistant pointed to the feature or spacing difference on the cartoon faces. Following the practice trials, each participant completed 128 trials with pairs of faces that were either identical or varied in their featural or configural information in the eye or mouth location of the face. The pairs of faces were simultaneously presented on the computer screen in a pseudo-randomized order. Participants indicated the response using a mouse and the face stimuli remained on the screen until a response was made. For the test trials, no feedback was given. Participants were instructed to respond as quickly and as accurately as possible. Proportion correct and reaction time were recorded.

Results

Discrimination Accuracy

Discrimination was computed as a *d*’ score in which a “hit” was a correct different response for a different trial and a “false alarm” was an incorrect “different” response for a same trial. A 4 × 2 × 2 mixed ANOVA were performed with Age (7-to 8-year-old, 9-to 10-year-old, 11-to 12-year-old, adults) as a between-subject factor and Type (configural, featural) and

Location (eyes, mouth) as within-subject factors. A reliable main effect of Age, $F(3, 100) = 22.11$, $p < .001$, partial eta^2 = .40, showed that sensitivity to differences in the face stimuli improved with age. Information Type, $F(1, 100) = 37.50$, $p < .001$, partial eta^2 = .27 was also significant showing that overall, featural differences were more accurately detected than configural differences (see Figure 2). The significant Type x Location interaction, $F(1, 100) = 17.92$, $p < .001$, partial eta^2 = .15, showed that whereas featural eye and featural mouth judgments did not differ in their accuracy, configural eye judgments were reliably more accurate than configural mouth judgments. Critically, the three-way interaction between Age, Type, and Location was reliable, $F(3,100) = 3.44$, $p = .020$, partial eta^2 = .09, demonstrating that nose-mouth spacing judgments showed larger gains in discrimination with age relative to eye spacing, eye size and mouth size judgments.

Analysis by Age Group—To investigate the source of the three-way interaction, separate ANOVA's were conducted for the 7- to 8-year-old, 9- to 10-year-old, 11- to 12-year-old, and adult age groups. See Table 1 for *d'* means, standard deviations and sample size for the configural eyes, featural eyes, configural nose-mouth and featural mouth conditions by age group.

For the 7- to 8-year-old group, featural discriminations were superior to configural discriminations and eye differences were more accurately discriminated than mouth differences, as shown by the reliable main effect of Type, $F(1,23) = 5.69$, $p = .026$, partial eta^2 = .19, and Location, $F(1,23) = 6.82$, $p = .016$, partial eta^2 = .18. The critical Type x Location interaction was reliable, $F(1,23) = 6.67$, $p = .010$, partial eta^2 = .22. Follow-up direct comparisons showed that differences between configural mouth and featural mouth discriminations, $p = .002$ and differences between configural eyes and configural mouth discriminations, $p < .001$, were reliable. However, the differences between featural and configural discriminations in the eye location were not reliable, $p > .10$.

For the 9- to 10-year-old children, featural discriminations were superior to configural discriminations, $F(1,35) = 25.36$, $p < .001$, partial eta^2 = .94, but eye discriminations were not superior to mouth discriminations, $F(1,35) = 1.42$. Importantly, the Type x Location interaction was reliable, $F(1,35) = 12.02$, $p = .001$, partial eta^2 = .29, demonstrating configural discrimination of the inter-eye distance was better than discrimination of nose-mouth distance. The discrimination between featural and configural differences in the mouth location was reliable, p <001, whereas the difference between featural and configural discriminations in the eye location was not, $p > .10$,

For the 11- to 12-year-old children, neither the main effect of Type, $F(1,16) = 1.79$, nor the main effect of Location, $F(1,16)=.59$, were reliable, $p > .10$. However, the Type x Location interaction was significant, $F(1,16) = 9.93$, $p = .006$, partial eta^2 = .25. The difference between configural and featural discriminations in the mouth location was reliable, $p = .008$, but not featural and configural differences in the eye location, $p > .10$. In contrast to the younger age groups, the difference in configural discrimination between the nose-mouth distance and eye distance was not reliable, $p > .10$,

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For adults, the main effect of Type, $F(1, 26) = 16.72$, was reliable, $p < .001$, partial eta^2 = .34, demonstrating an advantage for featural judgments over configural judgments. Neither the main effect of Location, $F(1, 26) = .25$, nor the Type x Location, $F(1,26) = .20$, reached significance, $p > .10$.

Featural versus Configural Analysis—To examine their developmental trajectories, we performed separate ANOVA's for the configural dimension and featural dimension with Age (7- to 8-year-old, 9- to 10-year-old, 11- to 12-year-old, adults) as a between-group factor and Location (e.g., eye, mouth) as a within-group factor. For the configural dimension (i.e., configural eyes and configural nose-mouth trials), there was a reliable main effect of Age, $F(3,100) = 20.51$, $p < .001$, partial eta^2 = .38. The main effect of Location, $F(1,100) = 10.08$, $p = .002$, partial eta^2 = .09,was also reliable, demonstrating superior discrimination of eye spacing over discrimination of nose-mouth spacing. Critically, the Age by Location interaction was reliable, $F(3,100) = 2.94$, $p = .04$, partial eta^2 = .08, where differences in nose-mouth discriminations observed in the young age groups (i.e., children ages 7 and 8, children ages 9 and10), these differences were absent in older children (ages 11-12) and adults.

The ANOVA for the featural trials showed a reliable effect of Age, $F(3,100) = 21.57$, $p < .001$, partial eta^2 = .39. The main effect of Location, $F(1,100) = .82$, $p > .10$, was not reliable. The interaction between Location and Age approached reliable level, $F(3,100) = 2.23$, $p = .09$, partial eta^2 = .06.

Correlational Analysis—To better understand the contributions of face location (mouth versus eye) and face type (featural versus configural) to the development of perceptual face processing, we performed a correlational analysis using age as a continuous variable. In this analysis, we omitted participants from the adult group, leaving a total of 77 participants ranging in age from 6 years, 6 months to 11 years, 9 months.

We performed two types of correlational subtractions to isolate age-related effects. To examine development due to face location, we subtracted the *d'* of configural mouth condition from the *d'* of the configural eye condition and the *d'* of featural mouth condition from the *d'* of the featural eye condition and correlated both these differences with age. As showed in Figure 3a and 3b, age reliably correlated with the configural eye versus configural mouth differences (r=-0.23, p=0.02) and featural eye versus featural mouth differences (r=-0.27, p=0.01).

To examine development due to face type, we computed the difference in *d's* between configural eye and featural eye conditions and the difference in *d's* between configural and featural mouth conditions and correlated these differences with age. As showed in Figure 3c and 3d, age did not reliably correlate with the featural-configural difference in the eye location (r=-0.13, $p > 0.10$) or with the featural-configural difference in the mouth location (r=-0.02, $p > 0.10$).

To summarize the correlational analysis, we found an age-related effect for location where the difference between eye and mouth performance decreased with age, regardless of information type. In comparison, no age-related effect was found for information type where the difference between configural and featural discrimination did not correlate with age. The correlational results suggest that as children develop, they improve in their ability to detect changes in the mouth location of the face, but age was not associated with their ability to detect configural face changes.

Response Time

For the face dimension task, a 4 × 2 × 2 mixed ANOVA were performed on the correct different trials with Age (7- to 8-year-old, 9- to 10-year-old, 11- to 12-year-old, adults) as a between-subject factor and Type (configural, featural) and Location (eyes, mouth) as within-subject factors. The analysis of variance revealed a main effect of Age, $F(3, 104) = 6.22$, $p < .001$.Tukey's HSD test revealed that adults were significantly faster at the Face Dimensions task than 7- to 8-year-olds ($p < .001$) , 9- to 10-year olds ($p < .001$) and 11- to 12-year olds ($p = .02$). No other main effects or interactions were reliable.

Discussion

In this study, children 7 through 12 years of age and young adults were administered an abbreviated version of the Face Dimensions Task. Consistent with the configural processing view (Mondloch et al., 2004; Mondloch et al., 2002), spacing discriminations between nose and mouth features were slower to develop than featural discriminations involving eye size or mouth size. However, not predicted by the configural view, discrimination of inter-ocular distances was on par with the featural discrimination of the eye size and mouth size suggesting that horizontal spacing discriminations between the eyes develop at a faster rate than vertical discriminations separating the nose and mouth features. These results argue for a qualified interpretation of the configural processing hypothesis in which the ability to discriminate the spatial distances between features depends on the locus of the configural decision.

Evidence supporting this more restricted view of configural processing comes from the adult studies on the face inversion effect (i.e., the disproportionate effects of inversion on the recognition of faces compared to the recognition of non-face objects). Results from these experiments indicate that the perception of configural information is not equally distributed across an inverted face. In these studies, inversion differentially disrupts the perception of configural information between the nose and mouth features, but leaves the perception of the horizontal spacing between the eyes relatively intact (Malcolm, Leung & Barton, 2004; Sekunova & Barton, 2008). Other studies have shown that vertical discriminations of eyes and eye brows are more impaired by inversion than horizontal eye discriminations (Goffaux & Rossion, 2004) and this impairment is resistant to attentional cueing (Crookes & Hayward, 2012;). The collective message of the developmental and adult studies is that not all configural relations in a face are treated equivalently. Some relations are acquired early in development and are more immune to inversion (i.e., inter-ocular spacing), where other configural relations are acquired later in life and are more vulnerable to inversion (i.e., nose-mouth spacing) and vertical eye spacing (Goffaux & Rossion, 2004).

Results from the featural-configural ANOVA's and correlational analyses suggest that the "where" (i.e., the location) of face information might be more important than the "what" (i.e., the type) of face information. In the correlational analysis, configural and featural differences between eye and mouth locations diminished with age indicating that as children grow older, there is a face processing shift away from the eyes to a more distributed approach that encompasses the mouth region. This finding is consistent with the infant studies showing that the neonates (Quinn & Tanaka, 2009) and young children attend more to the eyes than the mouth in a face (Hay & Cox, 2000; Pellicano et al., 2006). As children mature, their face strategy encompasses information in the nose and mouth locations. This interpretation is consistent with the face recognition studies showing that compared to young children, adolescent participants improved in their ability to recognize schoolmates (Ge et al., 2008) and newly familiarized faces (Liu et al., 2013) from isolated nose and mouth features.

The emphasis on face location in the development of face processing contrasts with the featural-configural distinction made by other researchers (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002). Whether type (featural versus configural) or location (eyes versus mouth) of information is essential to the development of face processing may depend on the face stimuli, participant instructions and cognitive task. In their work, Mondloch and colleagues (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002) tested the "Jane" face stimuli in which distance between the eyes and the distance between the nose and mouth were altered to test configural processing or the shape of the eyes and the shape of the mouth were altered to test featural processing. With these stimuli, it is not clear whether configural and featural discriminations were mediated by differences at the eye location, at the mouth location, or at both locations. For the Face Dimension task, the differences in the eye and mouth locations were varied independently to localize the source of the configural and featural judgments. This approach showed that the configural eye discriminations of young children were superior to their configural nose-mouth discriminations. However, if young children are more sensitive to eye spacing differences than nose-mouth differences, this sensitivity should have been sufficient to drive configural judgments in Jane studies (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002) where the face stimuli varied in both their eye and mouth configurations. Thus, other stimulus and methodological differences must account for the divergent results of the current experiment and the results of Mondloch and colleagues (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002).

The two lines of research also employed different techniques to alter feature information. Featural information was modified by changing size in the Face Dimension task whereas the features were swapped for one another in the Jane studies (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002). Feature manipulations of size have the advantage of maintaining and local contrast relationships, but the disadvantage of altering edge-to-edge spatial distances between features. By comparison, feature substitutions generally preserve the edge-to-edge spatial relations between features, but alter the feature's centroid and its local contrast information (see a recent paper by Piepers & Robbins 2012 for further discussion). If children perceive size and shape information of features differently, it is not surprising that the two paradigms might produce divergent results.

The current study also employed different task instructions than previous experiments (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002). In the Face Dimensions experiment, participants were informed that the faces differed in their featural and configural information in the eyes and mouth locations. To reinforce their understanding of these differences, participants were given practice trials in each of the four conditions and provided with corrective feedback. By contrast, in previous studies, participants were told to look for differences between the target and test faces, but the exact nature of the differences (i.e., featural or configural) was left unspecified (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002). Without being informed of the type of changes, it is possible that children are perceptually less sensitive to configural changes than featural changes. Alternatively, children may employ a different decision criteria for configurally and featurally altered faces where a configural change may signal less of an identity change than a featural change.

Finally, whereas the Face Dimensions experiment tested face *perception*, the majority of the Mondloch studies examined face *recognition*. In the Face Dimensions task, faces are simultaneously presented and remain on the screen until a “same/different” decision is made. The direct matching paradigm might induce an analytic encoding approach allowing participants to systematically compare featural and configural differences at the eye and mouth locations. In comparison, most of the studies using the Jane stimuli required either immediate (Mondloch et al., 2002) or long-term (Mondloch et al., 2012) face memory. It is informative that 8-year-olds showed marked improvement in their discrimination abilities when the Jane stimuli were shown in a perceptual matching version of the task relative to the sequential version (Mondloch et al., 2004). Based on these findings, the authors speculated that age-related deficits in configural face processing are reduced by eliminating the memory demands of the task (Mondloch et al., 2004).

In summary, the role of featural and configural information during the development of face processes is likely to depend on several factors including: (1) the loci of the featural and configural information tested, (2) the nature of configural and featural manipulations, (3) the instructions administered to participants, and (4) the perceptual or memory requirements of the face task.

Given that the featural and configural conditions were equated for difficulty in the full version of the Face Dimensions Task (Bukach, Grand, Kaiser, Bub, & Tanaka, 2008), we were surprised that adults performed more poorly on configural trials than on featural trials. The featural-configural difference might be due to the abbreviated version of the Face Dimensions Task. Although the shortened version of the test was suitable for children, the test was relatively easy for adults and the featural advantage might be an artifact of their ceiling level performance. Importantly, unlike the adults, young children were only impaired in the nose-mouth configural decisions; their configural eye decisions did not differ from featural eye and mouth decisions. Thus, even at an early age, children are perceptually sensitive to the inter-ocular spacing between the eyes. The perceptual findings are consistent with the recognition memory research showing that children can identify familiar faces on the isolated eye features (Ge et al., 2008; Hay & Cox, 2000).

Our findings indicate that a shift occurs in face perception as a function of age. While the sensitivity to the configural distance between the nose and mouth lags behind sensitivity to other dimensions in early childhood, this gap is reduced in pre-adolescence and eliminated by young adulthood. As shown in Figure 4a, when viewing a face, young children have a fairly restricted perceptual window focusing primarily on the pair of eyes (Ge, Anzures, Wang, Kelly, Pascalis, Quinn, et al., 2008; Hay & Cox, 2000; Pellicano, Rhodes, & Peters, 2006) and to a lesser extent, the isolated mouth (current experiment). We speculate that the perceptual face window of young children is not broad enough to incorporate multiple features of a face (nose and mouth) and the spatial distance separating them. Because the eyes are processed as one unit, i.e., the left and right eye and their spatial distance (Cooper & Wojan, 2000), the spacing between the left and right eyes is preserved even in young children. Over the course of development, the size of the window expands to incorporate featural and configural information in the eye and mouth locations of face (See Figure 4b). In adults, inversion causes the size of the perceptual window to shrink thereby forcing the observer to focus on the eye features at the expense of other featural and configural face information (Crookes & Hayward, 2012; Rossion, 2008; Sekunova & Barton, 2008; Tanaka, Kaiser, Pierce, & Hagen, in press; Xu & Tanaka, 2013). Similar to our findings with young children, perception of inter-ocular distance is preserved in an inverted face because eyes and their distance are treated as a single unit (Crookes & Hayward, 2012; Sekunova & Barton, 2008; Tanaka et al., in press). In contrast, the configural spacing between the nose and the mouth is disrupted because the face processing system treats the nose and mouth as two separate features. Thus, there are striking similarities between the way young children perceive upright faces and adults perceive inverted faces.

It is open to speculation whether the age-related differences in this study reflect the young child's inability to perceive differences in the mouth region or a bias to attend to information in the eye region. For example, as a default strategy, adults tend to focus on the eyes in an inverted face, but can shift their attention to the mouth area when prompted to do so (Tanaka, Kaiser, Pierce & Hagen, in press). In a change detection task, eye-tracking studies have shown that the last fixation of adult participants prior to their response was predictive of correctly detecting mouth differences in upright faces (Xu & Tanaka, 2013). These results suggest that spatial attention plays a critical role in face processing (McKone, Davies, Darke, Crookes Wickramariyaratne, Zappia, et al. 2013). Following an attentional account, it should be possible to ameliorate the mouth deficits exhibited by young children by cueing them to this region of the face.

The current developmental results have important implications for treating people from clinical populations who experience severe problems with their face processing abilities. Not surprisingly, individuals who are impaired in the face recognition skills, such as people with acquired prosopagnosia (Caldara et al., 2005), developmental prosopagnosia (DeGutis, Cohan, & Mercado, 2012) and children with ASD (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Rutherford, Clements, & Sekuler, 2007; Wolf et al., 2008), demonstrate a tendency to encode information in the mouth location at the expense of information in the eye location. In order to circumvent this bias, face training programs that redirect visual attention to the eye location have been successful at improving face recognition abilities (Tanaka et al., 2010).

To summarize, consistent with the configural account of developmental face processing (Mondloch et al., 2004; Mondloch, Le Grand, & Maurer, 2002), the Face Dimensions Test results showed that young children displayed an ability to discriminate the individual features of the eyes and to a lesser extent, the mouth of the face. Although discrimination of the nose-mouth distance was developmentally delayed, young children were sensitive to the internal spacing separating the eyes. Hence, sensitivity to configural information follows different schedules of development depending on its location in the face. The configural relations involving inter-ocular distance may represent a special case in which the left and right eyes and their spatial distance are processed as an integrated whole unit relative to the distance separating the nose and mouth which are processed as individual features. As suggested by the results of the current Face Dimensions Test, development of face perception operations is jointly determined by the nature of the information (i.e., featural versus configural information) and its location (i.e., eye versus mouth) in the face.

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Highlights

- Young children are sensitive to the eye features and interocular distance
- Older children and adults are sensitive to eye and mouth features and their distances
- Development of face perception is influenced by face location

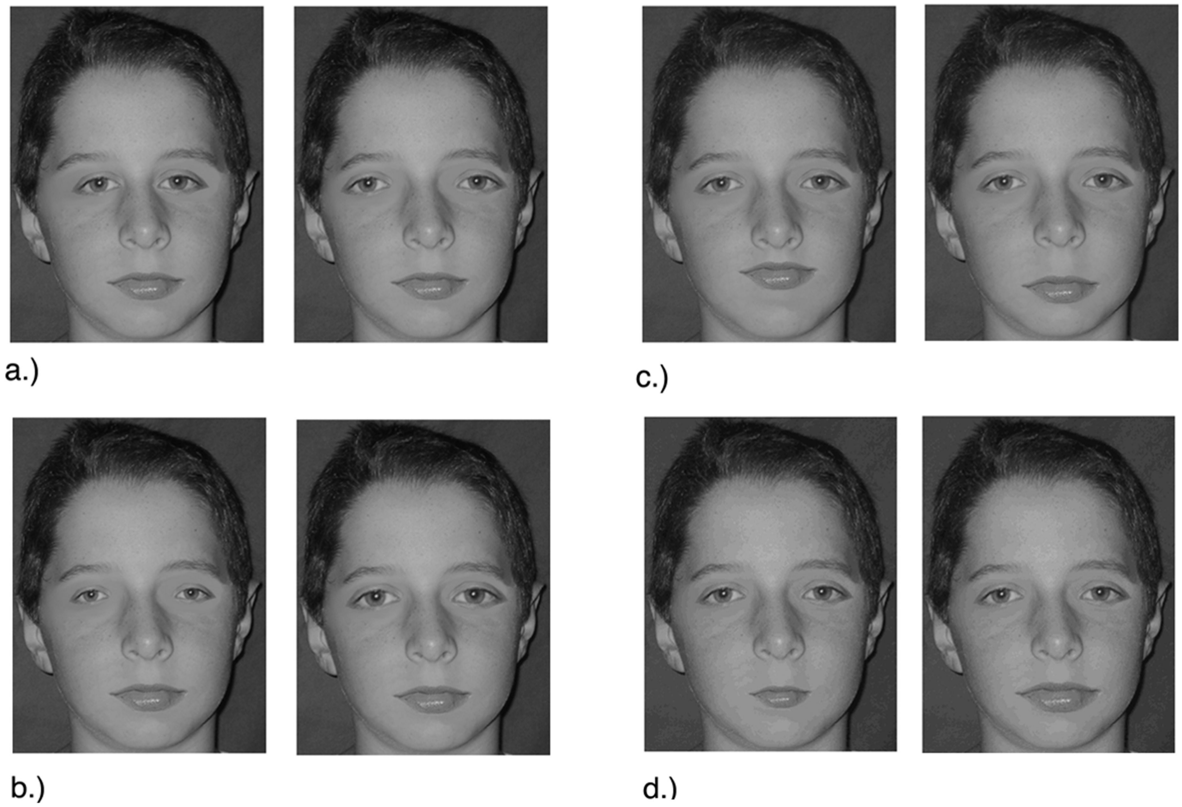

Figure 1.

Sample items from the Face Dimensions Task (Bukach et al., 2008) testing configural and featural discriminations in the eye and mouth locations of the face: (a) faces differ in the configural spacing of the eyes, (b) faces differ in the featural size of the eyes, (c) faces differ in the configural spacing between the nose and mouth, and (d) faces differ in the featural size of the mouth. In this study, the original child faces were not used for either the “same” or the “different” trials.

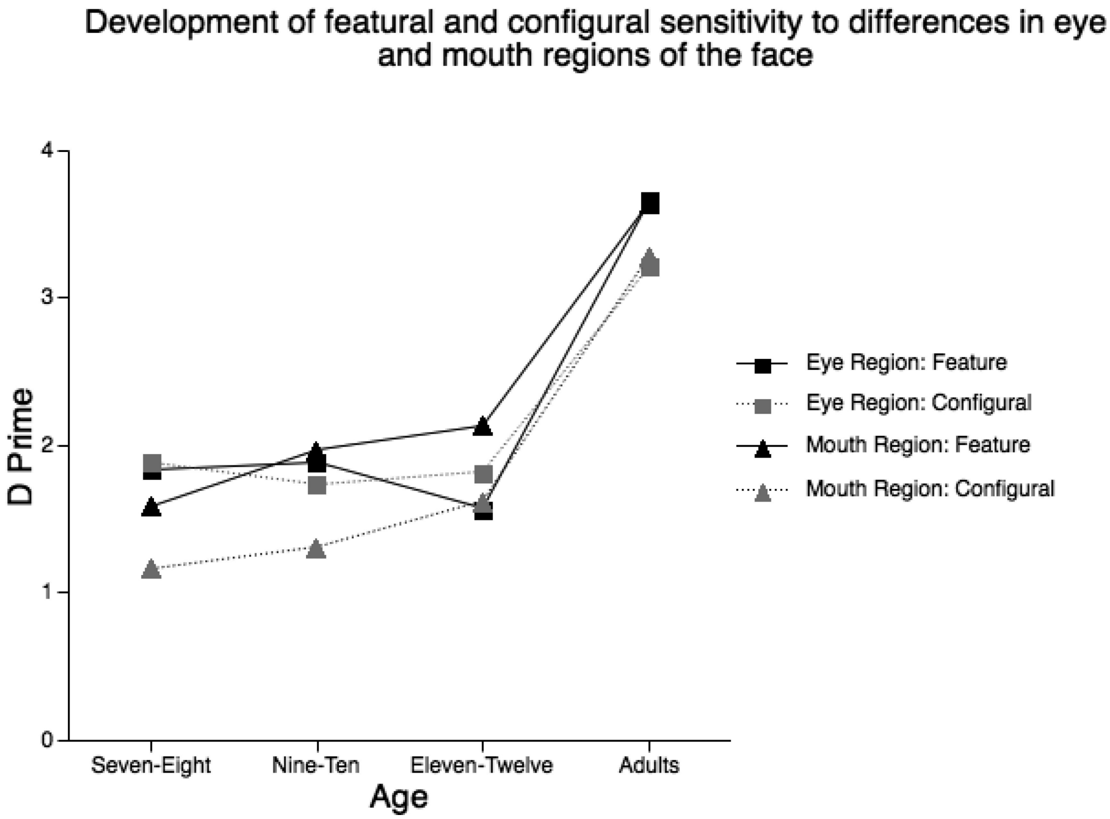

Figure 2.

Performance of 7- to 8-year-old, 9- to 10-year-old, 11- to 12-year-old, and adult groups on the discrimination of featural and configural information in the eye and mouth face locations.

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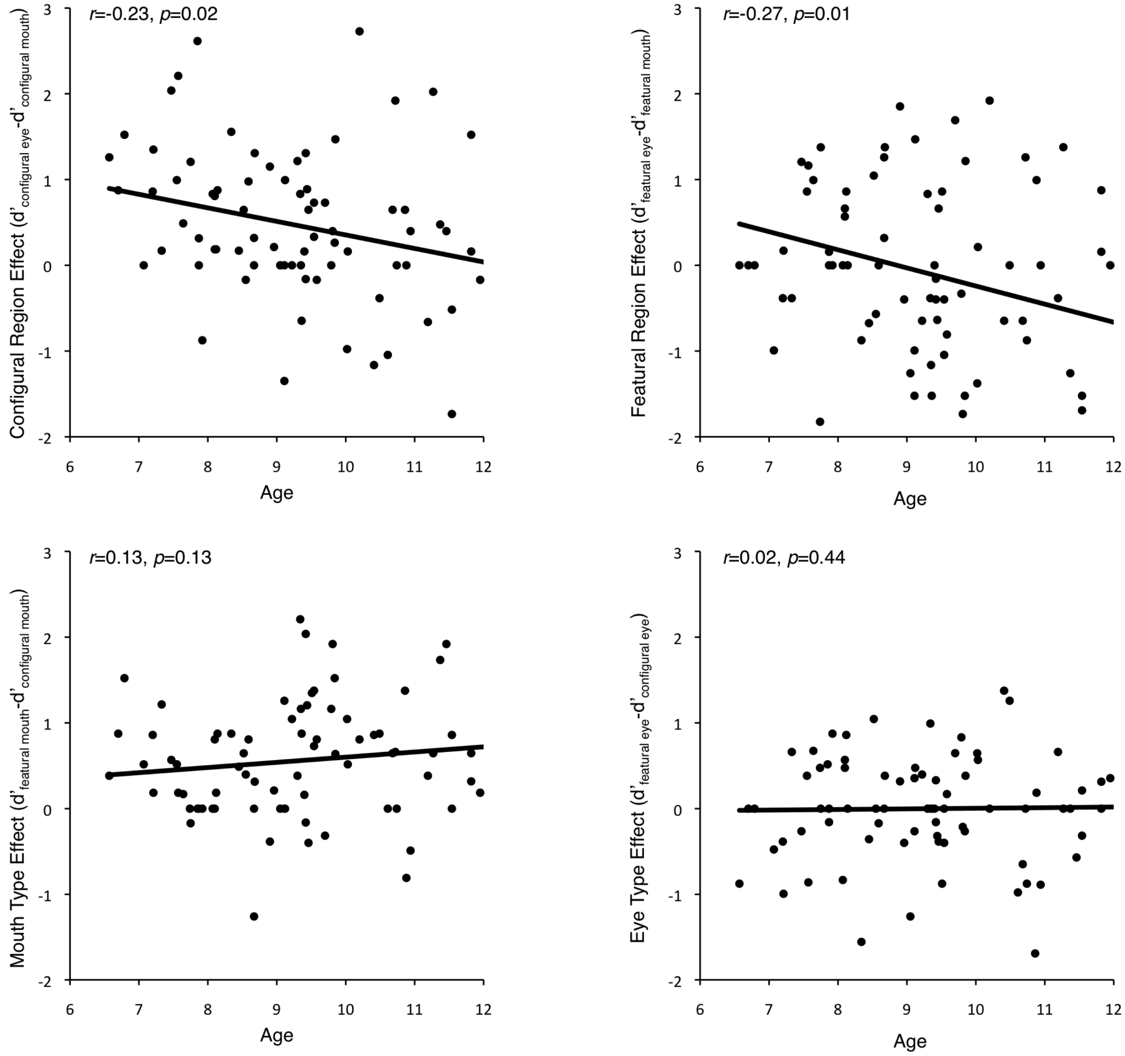

Figure 3.

The top left scatter plot illustrates the correlation between age and location for configural information. The top right scatter plot illustrates the correlation between age and location for featural information. The bottom left scatter plot illustrates the correlation between age and type in the mouth location. The bottom right scatter plot illustrates the correlation between age and type in the eye location.

Figure 4.

The developmental perceptual window. (a) Perceptual window of younger children (ages 7 to 10 years old) who show good discrimination of featural eye and configural eye information, moderate discrimination of featural mouth information and poor discrimination of configural nose-mouth information. (b) Perceptual window of older children and adults who show good discrimination of featural eyes, featural mouth, configural eyes, and configural nose-mouth.

Table 1

The average d' scores of 7- to 8-year-old, 9- to 10-year-old, 11- to 12-year-old, and adult groups on the discrimination of featural and configural information in the eye and mouth locations. Standard deviations are indicated in the parentheses.

Age Group	Eye Configural	Eye Featural	Mouth Configural	Mouth Featural
7-8 (n=24)	1.89 (1.39)	1.84 (1.37)	1.17 (1.16)	1.59 (1.37)
9-10 (n=36)	1.74 (1.10)	1.89 (1.01)	1.31 (1.15)	1.97 (1.35)
11-12 (n=17)	1.82 (0.90)	1.57 (1.14)	1.62 (0.95)	2.14 (1.13)
Adults (n=27)	3.22 (0.88)	3.67 (0.82)	3.29 (0.95)	3.65 (0.69)