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Are faces special to infants? An investigation of configural and featural processing for the upper and lower regions of houses in 3- to 7-month-olds

Paul C. Quinn[1], James W. Tanaka[2], Kang Lee[3], Olivier Pascalis[4], and Alan M. Slater[5]

[1]Department of Psychology, University of Delaware, Newark, DE, USA
[2]Department of Psychology, University of Victoria, Victoria, BC, Canada
[3]Institute of Child Study, University of Toronto, Toronto, Canada
[4]Laboratoire de Psychologie et Neurocognition, Universite Pierre Mendes, Grenoble, France
[5]School of Psychology, University of Exeter, Exeter, UK

Three- to 7-month-olds were administered a house version of the Face Dimensions Test in which the featural and configural properties of the upper and lower windows were systematically varied. The Dimensions Test has previously been used to study the processing of face features and their configurations by infants (Quinn & Tanaka, 2009). Just as was the case with faces, infants were shown to be sensitive to configural change in the upper and lower regions and to featural change in the upper region, but not to featural change in the lower region. The outcomes reflect either a face processing system that can generalize broadly to stimuli that are as different from faces as houses or a more general processing system with perceptual operations that can apply to both faces and houses.

Keywords: Face perception; Infancy; Object perception.

The question of whether faces are a special class of stimuli, with dedicated neural processing areas, has been a question of interest to contemporary

Please address all correspondence to Paul C. Quinn, Department of Psychology, University of Delaware, Newark, DE 19716, USA. E-mail: pquinn@udel.edu
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cognitive neuroscientists as well as developmentalists (Lee, Anzures, Quinn, Pascalis, & Slater, 2011). For example, in the adult literature, there is debate over whether a cortical region known as the fusiform face area (FFA) is specialized for face perception (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006) or whether it mediates specialized processing within domains of expertise (Bilalic, Langner, Ulrich, & Grodd, 2011; Gauthier, Skudlarski, Gore, & Anderson, 2000). The debate has led to developmental investigations targeted at determining when during ontogenesis the FFA responds to faces more than to nonface objects or places (Aylward et al., 2005; Gathers, Bhatt, Corbly, Farley, & Joseph, 2004; Golarai et al., 2007; Grill-Spector, Golarai, & Gabrieli, 2008; Johnston et al., 2011; Scherf, Behrmann, Humphreys, & Luna, 2007). This work has revealed generally that processing of different stimulus classes becomes more differentiated with age, although with different age estimates ranging from childhood to adolescence for when the FFA displays an adult-like pattern of activation, and recent evidence that what is developing during this time is the connectivity and efficiency (i.e., optimality) of function (Cantlon, Pinel, Dehaene, & Pelphrey, 2011; Cohen Kadosh, Johnson, Dick, R. Cohen Kadosh, & Blakemore, in press).

Two different lines of behaviourally based research in infants and children are also relevant to the debate over whether faces have a specialized processing machinery. One line concerns the preference that newborn infants display for schematic face-like stimuli (Goren, Sarty, & Wu, 1975; Johnson & Morton, 1991). Although this preference can be interpreted as evidence that specialized responding to faces is present at birth, others have argued that the preference is a byproduct of more general preferences for geometric properties of stimuli (i.e., top-heaviness, congruency) that are not exclusive to faces (Macchi Cassia, Valenza, Simion, & Leo, 2008; Turati, Simion, Milani, & Umilta, 2002). Moreover, there is debate over how well the nonface-specific account can explain the face preferences of older infants in the age range from 2 to 6 months (Turati, Valenza, Leo, & Simion, 2005), with some investigators arguing that the face preferences of infants in this age range can be better explained by a mechanism that is specifically tuned to faces (Chien, 2011; Chien, Hsu, & Su, 2010).

In an additional line of work relevant to the question of when during development face processing might become specialized, researchers have been studying how sensitivity develops to the shape and size of the individual features of the face (i.e., featural processing), and to the metric or second-order relations that separate the features (i.e., configural processing). Featural and configural processing have been distinguished from holistic processing (i.e., gluing the features together into a Gestalt), which may have its own pattern of development (Cohen & Cashon, 2001; Maurer, Le Grand, & Mondloch, 2002; Schwarzer, Zauner, & Jovanovic, 2007). Investigations conducted with children that compared the emergence of sensitivity to face parts versus their configural arrangement have reported a lengthier development for configural sensitivity (Mondloch, Le Grand, & Maurer, 2002; see also Carey & Diamond, 1977). In particular, children more rapidly developed the ability to discriminate faces (i.e., Jane and her sisters) that differed in the identity of the eyes and mouth versus faces that differed in the vertical height of the eyes and mouth and the horizontal spacing of the eyes. Thus, it has been suggested that adult face processing requires full development of sensitivity to second-order relations that follows an extended course of development lasting into adolescence, and that this protracted development is a key behavioural signature of specialized face processing (Mondloch, Le Grand, & Maurer, 2003).

The argument that sensitivity to spacing differences in faces lags behind that for featural differences as assessed by the "Jane and her sisters" task has met with the critique that the spacing and featural differences were not equated for difficulty level and that this developmental result may reflect differences in task difficulty, i.e., the spacing discrimination task was harder than the featural discrimination task (McKone & Boyer, 2006; McKone & Yovel, 2009; Yovel & Kanwisher, 2004; Zhang & Cottrell, 2004). This observation raises questions with the idea that the development of configural sensitivity proceeds more slowly than that of featural sensitivity, and that such an index can be used as a behavioural marker for the distinctiveness of face processing.

Research with children has also considered how information from different regions of the face (i.e., eyes vs. mouth) may affect processing. For example, processing of the eyes begins and matures earlier than for other individual facial features (Liu et al., in press; Taylor, Edmonds, McCarthy, & Allison, 2001). In addition, studies conducted with children generally suggest that the eyes are more easily recognized than the nose or mouth regions (Ge et al., 2008; Goldstein & Mackenberg, 1966; Hay & Cox, 2000; Pellicano & Rhodes, 2003; Pellicano, Rhodes, & Peters, 2006; but see Schwarzer & Massaro, 2001). This evidence is consistent with the top-heavy preference (i.e., preference for longer looking at patterns with a greater number of high-contrast areas in the upper rather than lower visual field) shown by newborns (Turati et al., 2002), and findings that young infants show greater fixation on the eyes than other face regions (Haith, Bergman, & Moore, 1977; Maurer & Salapatek, 1976). The child findings are moreover consistent with behavioural studies in adults indicating that eye features are relied on more heavily than nose or mouth features for face recognition (Sergent, 1984; Tanaka & Farah, 1993; Walker-Smith, 1978), and image-based computational analyses suggesting that the eye region is the most diagnostic region for extracting face identity (Sekuler, Gaspar, Gold, & Bennett, 2004; Vinette, Gosselin, & Schyns, 2004).

Given (1) uncertainties over whether the standard developmental account positing a late emergence for configural face processing might reflect differential task difficulty for processing featural versus configural information, and (2) evidence for a processing advantage for the upper versus lower face region, Quinn and Tanaka (2009) undertook an investigation to determine how infants would process featural versus configural manipulations to the face that were centred about the eye versus mouth regions. In particular, 3- to 7-month-olds were administered an infant version of the Face Dimensions Test. The advantages of the Dimensions Test are that the featural and configural changes in the eye and mouth regions are separately manipulated and their discrimination difficulty has been psychophysically equated in a population of healthy adults (Bukach, Le Grand, Kaiser, Bub, & Tanaka, 2008). Each infant was familiarized with one face and then preference tested with the familiar face paired with a novel face that differed in the (1) distance separating the eyes (a configural change in the eye region), (2) distance between the nose and mouth (a configural change in the mouth region), (3) size of the eyes (a featural change in the eye region), or (4) size of the mouth (a featural change in the mouth region).

The results of Quinn and Tanaka (2009) were that the infants processed configural change around the eyes and mouth, and featural change around the eyes, but not featural change around the mouth. Thus, when infants were presented with featural and configural changes that generated equivalent discrimination performance in adults, sensitivity to configural manipulations was more readily in evidence (present for both the eye and mouth regions) than sensitivity to featural manipulations (present only for the eye region). That sensitivity around the eyes was present for both configural and featural change, whereas sensitivity around the mouth was present only for configural change, suggests that region of change may be as important to consider as type of change when investigating development of face processing. The finding that infants as young as 3 months of age are sensitive to configural change in the eye region is additionally consistent with reports that young infants are responsive to faces that differ in the distances between the eyes (Bhatt, Bertin, Hayden, & Reed, 2005; Leo & Simion, 2009).

In the current study, we examined whether the sensitivity pattern observed in Quinn and Tanaka (2009) would extend to nonface objects (i.e., houses). Each house stimulus consisted of two second-floor (upper region) windows and one first-floor (lower region) window. Two age groups of infants, 3- to 4-month-olds and 6- to 7-month-olds, were randomly assigned to one of four discrimination tasks, each consisting of familiarization with one stimulus and then a preference test between the familiar stimulus and a novel stimulus that differed in: (1) Horizontal distance separating the upper windows (a configural change in the upper region of the stimulus), (2) vertical distance between the upper and lower windows (a configural change in the lower region), (3) size of the upper windows (a featural change in the upper region), and (4) size of the lower window (a featural change in the lower region). The conditions are depicted in Figure 1. Importantly, the discrimination difficulty of the featural and configural changes in the upper

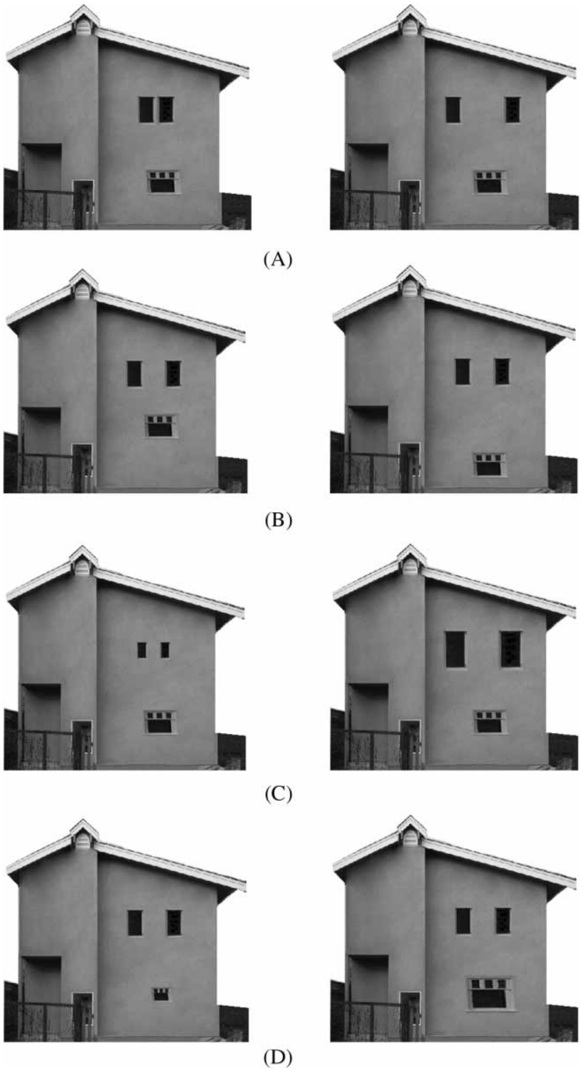

Figure 1. Stimuli used in the four different conditions: (A) Configural upper, (B) configural lower, (C) featural upper, and (D) featural lower.

and lower regions was psychophysically equated in a population of healthy adults (Bukach et al., 2008; Tanaka, Kaiser, Hagen, & Pierce, 2012).

METHOD

Participants

The participants were 64 infants, 32 3- to 4-month-olds (16 females) with a mean age of 113.28 days ($SD = 12.29$) and 32 6- to 7-month-olds (20 females) with a mean age of 192.19 days ($SD = 12.47$). Two additional 3- to 4-month-olds were tested, but one did not complete the procedure because of fussiness, and one was excluded from the data analysis because of looking at only one of the test stimuli over the two trials. Also, three additional 6- to 7-month-olds were tested, but one did not complete the procedure because of fussiness, and two were excluded from the data analysis because of sibling interference ($n = 1$) or failure to compare the test stimuli ($n = 1$). The infants were predominantly Caucasian and from middle-class backgrounds.

Stimuli

The stimuli were taken from Tanaka et al. (2012) and consisted of a grayscale 7.5 cm high (subtending 13.82° of visual angle) × 7.9 cm wide (14.53°) image of a house in which either (1) the distance between the upper windows was decreased or increased by 20 pixels, (2) the distance between the upper and lower windows was decreased or increased by 20 pixels, (3) the size of the upper windows was decreased or increased by 20 pixels, or (4) the size of the lower window was decreased or increased by 20 pixels. These manipulations are reflected in Figure 1 (going from the top to bottom rows): Configural upper region condition, configural lower region condition, featural upper region condition, and featural lower region condition.

Apparatus

All infants were tested in a visual preference apparatus, modelled after the one described by Fagan (1970). The apparatus has a display panel onto which were attached two compartments to hold the poster board stimuli. The stimuli were illuminated by a fluorescent lamp that was shielded from the infant's view. The centre-to-centre distance between compartments was 30.5 cm and on all trials the display panel was situated approximately 30.5 cm in front of the infant. The stimuli were thus viewed from a distance of 30.5 cm. There was a 0.62 cm peephole located midway between the two display compartments that permitted an observer to record the infant's visual fixations. A second peephole, 0.90 cm in diameter, was located directly below the first peephole, and permitted a Pro Video CVC-120PH pinhole camera and a Magnavox DVD recorder to record infants' gaze duration.

Procedure

All infants were brought to the laboratory by a parent and seated in a reclining position on the parent's lap. There were two experimenters, both of whom were naive to the hypotheses under investigation. The first experimenter positioned the apparatus so that the midline of the infant's head was aligned with the midline of the display panel. The experimenter selected the appropriate stimuli and loaded them into the compartments of the display panel. The experimenter then closed the panel, thereby exposing the stimuli to the infant. The parent was unable to see the stimuli, being blocked from viewing them by the top of the apparatus. During each familiarization trial, the first experimenter observed the infant through the peephole and recorded visual fixations to the left and right stimuli by means of two electronic stop watches, one of which was held in each hand. The second experimenter timed the fixed duration of the trials and signalled the end of each trial. The first and second experimenters changed places for the preference test trials. The experimenter who presented the stimuli and measured infants' fixations during the familiarization trials now measured trial duration and signalled the end of the test trials, whereas the second experimenter presented the test stimuli and measured the left/right fixations. This ensured that the second experimenter was naive with respect to the familiar stimulus. The two experimenters changed roles across infants.

Interobserver agreement, as determined by comparing looking times measured by the experimenter using the centre peephole, and an additional naive observer measuring looking times offline from DVD records, was calculated for the preference test trials of eight randomly selected infants in each age group. Average level of agreement for the novelty preference scores of the 16 infants was 97.88% ($SD = 1.49$).

The infants in each age group were randomly assigned to each of four experimental groups that were defined by the type of difference between the familiar and novel house: CU (configural upper region), CL (configural lower region), FU (featural upper region), and FL (featural lower region). For each age group, familiarization consisted of six 15 s trials, each of which presented two identical copies of the familiar house. There were two 10 s preference test trials, each of which paired the familiar house with a novel house. Which stimulus member from a given pair (i.e., for CU: Upper windows near vs. far; for CL: Upper and lower windows near vs. far; for FU: Small vs. large upper windows; for FL: Small vs. large lower window) served as familiar versus novel was counterbalanced across infants within an age group. The left/right positioning of the two test stimuli was also counterbalanced across infants within an age group on the first test trial and reversed on the second test trial.

Preliminary analyses indicated that familiar stimulus (short distance or small size vs. long distance or large size) did not impact looking times during familiarization or novelty preferences, nor did it interact with any of the other factors to influence these performance measures.

RESULTS

Familiarization trials

Individual looking times were summed over the left and right copies of the stimulus presented on each familiarization trial and then averaged across the first three trials and last three trials. An analysis of variance (ANOVA), Trial block (1–3 vs. 4–6) × Age of participant (3–4 months vs. 6–7 months) × Region of change (upper vs. lower) × Type of change (featural vs. configural), performed on the individual looking time scores revealed only main effects of trial block, $F(1, 56) = 38.16$, $p < .001$, and age, $F(1, 56) = 30.83$, $p < .001$. Both the trial block and age effects were also observed with the face stimuli in Quinn and Tanaka (2009). The trial block effect indicates that the infants displayed a reliable decrement in looking time from the first to the last half of familiarization (*M* trials 1–3 = 7.17, *SD* = 3.04; *M* trials 4–6 = 4.85, *SD* = 3.62) that is consistent with the presence of habituation (Cohen & Gelber, 1975). The age effect shows that the younger infants looked more at the house stimuli than did the older infants (*M* 3–4 months = 7.74, *SD* = 2.98; *M* 6–7 months = 4.28, *SD* = 1.75). Longer looking by younger participants in this same age range has previously been observed for infants who were presented with other nonface visual patterns (Quinn, Bhatt, Brush, Grimes, & Sharpnack 2002).

An additional ANOVA was conducted to compare looking times for the house stimuli in the present study with the face stimuli in Quinn and Tanaka (2009). Specifically, an ANOVA, Trial block (1–3 vs. 4–6) × Age of participant (3–4 months vs. 6–7 months) × Region of change (upper vs. lower) × Type of change (featural vs. configural) × Stimulus category (face from Quinn & Tanaka vs. house from the present study), revealed only main effects of trial block, $F(1, 112) = 60.03$, $p < .001$ (*M* trials 1–3 = 7.47, *SD* = 3.07; *M* trials 4–6 = 5.35, *SD* = 3.54), and age, $F(1, 112) = 56.03$, $p < .001$ (*M* 3–4 months = 8.01, *SD* = 2.69; *M* 6–7 months = 4.82, *SD* = 2.17), thereby confirming the decreased looking in the second trial block and in the older infants that was observed separately for the house stimuli in the present study and previously for the face stimuli in Quinn and Tanaka.

Preference test trials

Each infant's looking time to the novel stimulus was divided by the looking time to both test stimuli and then converted to a percentage score. The data are reported in percentage scores rather than looking times because the duration of the test trials (i.e., 10 s) is shorter than the duration of the fixation trials (i.e., 15 s). Test trials were kept to a short duration to capture a presumed burst of differential responsiveness towards the novel versus familiar stimulus. If test trials had been made longer, any initial advantage in responsiveness to the novel stimulus could have conceivably begun to subside because that stimulus was now becoming familiar.

An ANOVA, Age of participant (3–4 months vs. 6–7 months) × Region of change (upper vs. lower) × Type of change (featural vs. configural), performed on the individual preference scores did not reveal any reliable effects, $F(1, 56) < 1.69$, $p > .19$, in each instance. Given the null effect of age, the mean novelty preferences for the four conditions (configural upper, configural lower, featural upper, featural lower) collapsed across the two age groups were computed. The means, *SDs*, 95% confidence intervals, and relation to chance performance are shown in Table 1. As can be seen there, *t*-tests versus the chance preference of 50% revealed that the mean novelty preference was above chance in the CU, $t(15) = 2.63$, $p < .01$, CL, $t(15) = 2.27$, $p < .05$, and FU conditions, $t(15) = 2.59$, $p < .01$; however, the mean novelty preference did not differ from chance in the FL condition, $t(15) = 0.69$, $p > .20$. These results reveal that infants in the configural upper, configural lower, and featural upper conditions all preferred the novel stimulus, whereas infants in the featural lower condition divided attention between the familiar and novel stimuli. The findings indicate that the infants showed sensitivity to configural changes around both the upper and lower windows, but responded to featural changes only when they were around the upper windows.

TABLE 1
Mean novelty preference scores (percentages), *SD*s, and 95% CIs in the different conditions for houses (current study) and faces (from Quinn & Tanaka, 2009)

	Houses			*Faces*		
Condition	*M*	*SD*	*95% CI*	*M*	*SD*	*95% CI*
Configural upper	62.10*	18.54	[52.28, 71.92]	66.73*	13.15	[59.73, 73.73]
Configural lower	58.45*	14.86	[50.54, 66.36]	62.12*	14.18	[54.57, 69.67]
Featural upper	57.20*	11.13	[51.27, 63.13]	59.21*	15.51	[50.95, 67.47]
Featural lower	52.92	17.03	[43.85, 61.99]	47.49	14.69	[39.67, 55.31]

*Mean preference score significantly different from chance performance of 50%.

A further ANOVA was conducted to compare novelty preferences for the featural and configural changes in the upper and lower regions of the houses in the present study with the featural and configural changes in the eye and mouth regions of the faces in Quinn and Tanaka (2009). In particular, an ANOVA, Age of participant (3–4 months vs. 6–7 months) × Region of change (upper vs. lower) × Type of change (featural vs. configural) × Stimulus category (face from Quinn & Tanaka vs. house from the present study), revealed only main effects of type of change, $F(1, 112) = 8.97$, $p = .003$, and region of change, $F(1, 112) = 4.98$, $p = .026$. These two main effects matched those reported in Quinn and Tanaka for sensitivity to featural and configural manipulations in eye (upper) and mouth (lower) regions for infants in the same age range. The type of change effect indicated that the infants displayed a higher novelty preference for the stimuli containing configural change relative to the stimuli containing featural change (*M* configural = 62.35, *SD* = 15.21; *M* featural = 54.20, *SD* = 15.09). The region of change effect was such that infants showed higher novelty preference scores for change in the upper (eye) region relative to change in the lower (mouth) region (*M* eyes = 61.31, *SD* = 14.90; *M* mouth = 55.25, *SD* = 15.88). Notably, the mean novelty preferences for the four conditions collapsed across the two age groups and stimulus categories again revealed that infants in the configural upper (*M* = 64.41, *SD* = 15.94), $t(31) = 5.11$, $p < .001$, configural lower (*M* = 60.29, *SD* = 14.41), $t(31) = 4.04$, $p < .001$, and featural upper conditions (*M* = 58.20, *SD* = 13.32), $t(31) = 3.48$, $p < .002$, all performed at above-chance levels, whereas infants in the featural lower condition (*M* = 50.21, *SD* = 15.89), $t(31) = 0.07$, $p > .20$, performed at chance. The mean novelty preferences for the four conditions collapsed across the two age groups for the face stimuli in Quinn and Tanaka, along with their *SD*s, 95% confidence intervals, and relation to chance performance are provided in Table 1. The table reveals the close correspondence in performance for houses and faces.

DISCUSSION

In the current study, 3- to 7-month-old infants were found to be sensitive to configural changes in the upper and lower regions of house stimuli. However, the infants were found to be sensitive to featural changes only in the upper region (and not in the lower region) of the house stimuli. These findings parallel those reported for face stimuli in Quinn and Tanaka (2009). In the earlier study, infants were shown to be sensitive to configural changes around both the eye and mouth region, but sensitive to featural changes only around the eye region (and not in the mouth region). Taken together, both sets of results are consistent with the idea that configural and featural processing of face stimuli in the first 6 to 7 months of life are not mediated by a system that is specialized for processing just faces. Given that the same pattern of preferences was found for both face and house stimuli, the outcomes are more in accord with either a face processing system that can generalize broadly to stimuli that are as different from faces as houses, or from general perceptual processing operations that apply to both faces and houses (Simion, Macchi Cassia, Turati, & Valenza, 2003). The first account is consistent with the intriguing possibility that infants may process nonface objects like faces until experience with nonface objects increases to the point where a different system is developed to process them.

In addition to comparing infants tested on houses in the current study with infants tested on faces in Quinn and Tanaka (2009), one may also compare the performance of infants tested on both faces and houses with the performance of adults tested on both faces and houses (Bukach et al., 2008; Tanaka et al., 2012). As mentioned, for adults, both the house and face stimuli were designed such that the discrimination difficulty of the featural and configural changes in the upper (eyes) and lower (mouth) regions was psychophysically equated. Moreover, the stimulus differences presented to the infants were those that produced maximum discriminability in adults. Thus, a difference between infant and adult performance is the difficulty that the infants had with the featural change to the lower region in the present study and with the featural change to the mouth in Quinn and Tanaka.

A possible critique of the current study is the strong similarity between the house stimuli and the face stimuli used in Quinn and Tanaka (2009). The similarity is derived from the fact that both the face and house stimuli include a configuration with "two eyes" above a "mouth". In response to this critique, we would observe that a key difference between the face and house stimuli is that the face stimuli have a nose, whereas the house stimuli have no central feature to which the lower window can be compared. A related issue is that for the face stimuli, configural change within the lower region is provided by the manipulation of the distance between the mouth and the nose, whereas for the house stimuli, configural change in the lower region resulted from the manipulation of the distance between the windows in the upper part of the stimulus and the window in the lower part of the stimulus. Although this is a valid observation, we would note that only the window in the lower part of the stimulus changed location in the configural lower condition; the location of the windows in the upper part of the stimulus did not change.

The findings of no specialized featural and configural processing for faces during the first half of the infancy period are consistent with accounts of infant *preference* for face stimuli that are based on more general preferences for geometric properties of stimuli that are not exclusive to faces (Macchi Cassia et al., 2008). Moreover, the particular pattern of preferences observed, with sensitivity to both featural and configural change in evidence for the upper region of houses, and sensitivity only to featural change in evidence for the lower region of houses, are specifically consistent with the idea that infants may be especially skilled at processing changes in the "top heavy" region of stimuli (Turati et al., 2002).

The data are further in accord with neuroimaging evidence suggesting that a fusiform face area which displays activity for faces that is differentiated from nonface objects or places is not in evidence until sometime after the infancy period, and emerges either during childhood or adolescence (Aylward et al., 2005; Gathers et al., 2004; Golarai et al., 2007; Grill-Spector et al., 2008; Johnston et al., 2011; Scherf et al., 2007). The outcomes are moreover in agreement with behavioural results suggesting that sensitivity to spacing changes in faces is not differentiated from sensitivity to spacing changes in nonface objects until sometime during childhood, with different estimates ranging from 4 to 8 years of age (Macchi Cassia, Turati, & Schwarzer, 2011; Robbins, Shergill, Maurer, & Lewis, 2011).

Overall, then, the results of the present study suggest that processing of the featural and configural changes of faces is not specialized for faces during the first half of the first year of life. It will be interesting to determine whether the performance of older infants for faces and houses will parallel that of younger infants, and converge with other behavioural and neuroimaging evidence to collectively suggest that divergence between the two sets of stimuli will not be observed until sometime after the infancy period.

REFERENCES

Aylward, E. H., Park, J. E., Field, K. M., Parson, A. C., Richards, T. L., Cramer, S. C., & Meltzoff, A. N. (2005). Brain activation during face perception: Evidence of a developmental change. *Journal of Cognitive Neuroscience*, *17*, 308–319.

Bhatt, R. S., Bertin, E., Hayden, A., & Reed, A. (2005). Face processing in infancy: Developmental changes in the use of different kinds of relational information. *Child Development*, *76*, 169–181.

Bilalic, M., Langner, R., Ulrich, R., & Grodd, W. (2011). Many faces of expertise: Fusiform face area in chess experts and novices. *Journal of Neuroscience*, *31*, 10206–10214.

Bukach, C. M., Le Grand, R., Kaiser, M. D., Bub, D. N., & Tanaka, J. W. (2008). Preservation of mouth region processing in two cases of prosopagnosia. *Journal of Neuropsychology*, *2*, 227–244.

Cantlon, J. F., Pinel, P., Dehaene, S., & Pelphrey, K. A. (2011). Cortical representations of symbols, objects, and faces are pruned back during early development. *Cerebral Cortex*, *21*, 191–199.

Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science*, *195*, 312–314.

Chien, S. H. (2011). No more top-heavy bias: Infants and adults prefer upright faces but not heavy geometric or face-like patterns. *Journal of Vision*, *11*, 1–14.

Chien, S. H., Hsu, H. Y., & Su, B. H. (2010). Discriminating "top-heavy" versus "bottom-heavy" geometric patterns in 2- to 4.5-month-old infants. *Vision Research*, *50*, 2029–2036.

Cohen, L. B., & Cashon, C. H. (2001). Do 7-month-old infants process independent features or facial configurations? *Infant and Child Development*, *10*, 83–92.

Cohen, L. B., & Gelber, E. R. (1975). Infant visual memory. In L. B. Cohen & P. Salapatek (Eds.), *Infant perception: From sensation to cognition* (Vol. 1, pp. 347–403). New York, NY: Academic Press.

Cohen Kadosh, K., Johnson, M. H., Dick, F., Cohen Kadosh, R., & Blakemore, S. J. (in press). Effects of age, task performance, and structural brain development on face processing. *Cerebral Cortex*.

Fagan, J. F. (1970). Memory in the infant. *Journal of Experimental Child Psychology*, *9*, 217–226.

Gathers, A. D., Bhatt, R., Corbly, C. R., Farley, A. B., & Joseph, J. E. (2004). Developmental shifts in cortical loci for face and object recognition. *NeuroReport*, *15*, 1549–1553.

Gauthier, I., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. *Nature Neuroscience*, *3*, 191–197.

Ge, L., Anzures, G., Wang, Z., Kelly, D. J., Pascalis, O., Quinn, P. C., . . . & Lee, K. (2008). An inner-face advantage in children's recognition of familiar peers. *Journal of Experimental Child Psychology*, *101*, 124–136.

Golarai, G., Ghahremani, D. G., Whitfield-Gabrieli, S., Reiss, A., Eberhardt, J. L., Gabrieli, J. D. E., & Grill-Spector, K. (2007). Differential development of high-level visual cortex correlates with category-specific recognition memory. *Nature Neuroscience*, *10*, 512–522.

Goldstein, A. G., & Mackenberg, E. J. (1966). Recognition of human faces from isolated facial features: A developmental study. *Psychonomic Science*, *6*, 149–150.

Goren, C. C., Sarty, M., & Wu, P. Y. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics*, *56*, 544–549.

Grill-Spector, K., Golarai, G., & Gabrieli, J. (2008). Developmental neuroimaging of the human ventral visual cortex. *Trends in Cognitive Sciences*, *12*, 152–162.

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. *Science*, *198*, 853–855.

Hay, D. C., & Cox, R. (2000). Developmental changes in the recognition of faces and facial features. *Infant and Child Development*, *9*, 199–212.

Johnson, M. H., & Morton, J. (1991). *Biology and cognitive development: The case of face recognition*. Oxford: Blackwell.

Johnston, P. J., Kaufman, J., Bajic, J., Sercombe, A., Michie, P. T., & Karayanidis, F. (2011). Facial emotion and identity processing development in 5- to 15-year-old children. *Frontiers in Psychology*, *2*, Art. 26. doi:10.3389/fpsyg.2011.00026

Kanwisher, N., McDermott, J., & Chun, M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for the perception of faces. *Journal of Neuroscience*, *17*, 4302–4311.

Kanwisher, N., & Yovel, G. (2006). The fusiform face area: A cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society of London*, *361B*, 2109–2128.

Lee, K., Anzures, G., Quinn, P. C., Pascalis, O., & Slater, A. (2011). Development of face processing expertise. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 753–778). Oxford: Oxford University Press.

Leo, I., & Simion, F. (2009). Face processing at birth: A Thatcher illusion study. *Developmental Science*, *12*, 492–498.

Liu, S., Anzures, G., Ge, L., Quinn, P. C., Pascalis, O.. Slater, A. M., . . . & Lee, K. (in press). Development of recognition of face parts from unfamiliar faces. *Infant and Child Development*.

Macchi Cassia, V., Turati, C., & Schwarzer, G. (2011). Sensitivity to spacing changes in faces and nonface objects in preschool-aged children and adults. *Journal of Experimental Child Psychology*, *109*, 454–467.

Macchi Cassia, V., Valenza, E., Simion, F., & Leo, I. (2008). Congruency as a non-specific perceptual property contributing to newborns' face preference. *Child Development*, *79*, 807–820.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, *6*, 255–260.

Maurer, D., & Salapatek, P. (1976). Developmental changes in the scanning of faces by young infants. *Child Development*, *47*, 523–527.

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

McKone, E., & Yovel, G. (2009). Why does picture-plane inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? *Psychonomic Bulletin and Review*, *16*, 778–797.

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

Mondloch, C. J., Le Grand, R., & Maurer, D. (2003). Early visual experience is necessary for some—but not all—aspects of face processing. In O. Pascalis & A. Slater (Eds.), *The development of face processing in infancy and early childhood: Current perspectives* (pp. 99–117). Hauppauge, NY: Nova Science Publishers.

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

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

Quinn, P. C., Bhatt, R. S., Brush, D., Grimes, A., & Sharpnack, H. (2002). Development of form similarity as a Gestalt grouping principle in infancy. *Psychological Science*, *13*, 320–328.

Quinn, P. C., & Tanaka, J. W. (2009). Infants' processing of featural and configural information in the upper and lower halves of the face. *Infancy*, *14*, 474–487.

Robbins, R. A., Shergill, Y., Maurer, D., & Lewis, T. L. (2011). Development of sensitivity to spacing versus feature changes in pictures of houses: Evidence for slow development of a general spacing detection mechanism. *Journal of Experimental Child Psychology*, *109*, 371–382.

Scherf, K. S., Behrmann, M., Humphreys, K., & Luna, B. (2007). Visual category-selectivity for faces, places and objects emerges along different developmental trajectories. *Developmental Science*, *10*, F15–F30.

Schwarzer, G., & Massaro, D. W. (2001). Modeling face identification processing in children and adults. *Journal of Experimental Child Psychology*, *79*, 139–161.

Schwarzer, G., Zauner, N., & Jovanovic, B. (2007). Evidence of a shift from featural to configural face processing in infancy. *Developmental Science*, *10*, 452–463.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., & Bennett, P. J. (2004). Inversion leads to quantitative, not qualitative, changes in face processing. *Current Biology*, *14*, 391–396.

Sergent, J. (1984). An investigation into component and configural processes underlying face perception. *British Journal of Psychology*, *75*, 221–242.

Simion, F., Macchi Cassia, V., Turati, C., & Valenza, E. (2003). Non-specific perceptual biases at the origins of face processing. In O. Pascalis & A. Slater (Eds.), *The development of face processing in infancy and early childhood* (pp. 13–25). Hauppauge, NY: Nova Science.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology*, *46A*, 225–245.

Tanaka, J. W., Kaiser, M. D., Hagen, S., & Pierce, L. J. (2012). Losing face: Impaired discrimination of featural and configural information in the mouth region of an inverted face. *Manuscript submitted for publication*.

Taylor, M. J., Edmonds, G. E., McCarthy, G., & Allison, T. (2001). Eyes first! Eye processing develops before face processing in children. *Cognitive Neuroscience and Neuropsychology*, *12*, 1671–1676.

Turati, C., Simion, F., Milani, I., & Umilta, C. (2002). Newborns' preference for faces: What is crucial? *Developmental Psychology*, *38*, 875–882.

Turati, C., Valenza, E., Leo, I., & Simion, F. (2005). Three-month-olds' visual preference for faces and its underlying mechanisms. *Journal of Experimental Child Psychology*, *90*, 255–273.

Vinette, C., Gosselin, F., & Schyns, P. G. (2004). Spatio-temporal dynamics of face recognition in a flash: It's in the eyes. *Cognitive Science*, *28*, 289–301.

Walker-Smith, G. J. (1978). The effects of delay and exposure duration in a face recognition task. *Perception and Psychophysics*, *24*, 63–70.

Yovel, G., & Kanwisher, N. (2004). Face perception: Domain specific, not process specific. *Neuron*, *44*, 889–898.

Zhang, L., & Cottrell, G. W. (2004). When holistic processing is not enough: Local features save the day. In F. Forbus, D. Gentner, & T. Regier (Eds.), *Proceedings of the 26th annual Cognitive Science conference* (pp. 1506–1511). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

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