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PAPER

Developing cultural differences in face processing

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Abstract

Perception and eye movements are affected by culture. Adults from Eastern societies (e.g. China) display a disposition to process information holistically, whereas individuals from Western societies (e.g. Britain) process information analytically. Recently, this pattern of cultural differences has been extended to face processing. Adults from Eastern cultures fixate centrally towards the nose when learning and recognizing faces, whereas adults from Western societies spread fixations across the eye and mouth regions. Although light has been shed on how adults can fixate different areas yet achieve comparable recognition accuracy, the reason why such divergent strategies exist is less certain. Although some argue that culture shapes strategies across development, little direct evidence exists to support this claim. Additionally, it has long been claimed that face recognition in early childhood is largely reliant upon external rather than internal face features, yet recent studies have challenged this theory. To address these issues, we tested children aged 7–12 years of age from the UK and China with an old/new face recognition paradigm while simultaneously recording their eye movements. Both populations displayed patterns of fixations that were consistent with adults from their respective cultural groups, which 'strengthened' across development as qualified by a pattern classifier analysis. Altogether, these observations suggest that cultural forces may indeed be responsible for shaping eye movements from early childhood. Furthermore, fixations made by both cultural groups almost exclusively landed on internal face regions, suggesting that these features, and not external features, are universally used to achieve face recognition in childhood.

Introduction

The ability to accurately remember and identify conspecifics is a requisite skill for all social species. Humans primarily achieve this feat through face recognition, which requires rapid scanning of facial features in order to encode a new identity or to recognize whether an individual has been encountered previously or not. The pioneering work of Yarbus (1965) first demonstrated that adults display a distinct and ordered pattern of eye movements during face encoding and recognition with fixations primarily landing on the eyes and mouth forming a triangular scanpath. Further studies replicated this finding (Groner, Walder & Groner, 1984; Henderson, Williams & Falk, 2005), which leads to the presumption that a triangular scanpath represents a universal strategy employed by all individuals and is the most efficient way to extract individuating information. However, this hypothesis was challenged by Blais, Jack, Scheepers, Fiset and Caldara (2008) who found that in contrast to adults from Western societies (e.g. the USA), individuals from Eastern (e.g. China) cultural backgrounds predominantly fixate the centre of the face and almost completely avoid fixating the eyes, a finding recently corroborated by another group in Japanese observers (Kita, Gunji, Inagaki, Kaga, Nakagawa & Hosokawa, 2010).

The strategy used by Eastern populations is particularly intriguing as available evidence suggests that the information required to accurately recognize faces is contained in the eye region (e.g. Gosselin & Schyns, 2001; Caldara, Schyns, Mayer, Smith, Gosselin & Rossion, 2005). Furthermore, there is insufficient variation within the central nose region to achieve reliable face recognition (Goldstein, 1979a, 1979b; Caldara & Abdi, 2006). Caldara, Zhou and Miellet (2010) explored this paradox by testing East Asian (EA) and Western Caucasian (WC) adults using a gaze-contingent moving aperture method. In their study, the visual information available to participants was restricted by Gaussian apertures (termed *spotlights*) sized 2°, 5° or 8°. In both the 2° and 5° conditions, the aperture was large enough for any single facial feature (e.g. eye or nose) to be viewed, but it was not large enough for the eyes and mouth to be visible

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when fixating the nose. In the larger 8° condition, however, the aperture was sufficiently large for participants to fixate centrally on the nose region and view the mouth and eyes simultaneously. As predicted by Caldara and colleagues, the differences reported by Blais *et al*. (2008) were abolished in the restrictive 2° and 5° aperture conditions. In both of these conditions, EA and WC participants predominantly directed their fixations to the eye region. By contrast, in the 8° condition the EA participants reverted to their preferred central landing position while the WC participants retained their familiar triangular scanpath. Thus, it appears probable that the cognitive mechanisms operating to reliably encode and subsequently recognize the faces of conspecifics are invariant, but the manner in which this information is extracted is subject to environmental modulation.

If this interpretation of events is correct, then one can predict that the distinct eye movement patterns displayed by adults should emerge at a currently unknown timepoint and subsequently strengthen across ontogeny. Furthermore, it seems reasonable to hypothesize that all individuals may initially attend to the same facial information early in life before culture-specific patterns emerge as environmental forces are exerted. Currently though, it is unknown which of the strategies observed in adults might be found in developing populations or whether such clear strategies even exist in infancy and childhood. However, understanding the developing visual system can provide clues that permit a certain degree of speculation.

Based on the properties of the human newborn visual system, we can speculate that the pattern of eye movements observed at this age is more likely to resemble a rudimentary WC adult scanpath than an EA adult scanpath. The visual system of newborn infants is extremely limited relative to adults. At birth, an infant's visual acuity is approximately 40 times poorer than adults and is limited to the processing of spatial frequencies no greater than 1cpd (cycle per degree). Furthermore, newborns' sensitivity to contrast is around 30 times poorer than adults'. Consequently, newborns' recognition of faces is achieved using low spatial frequency information (de Heering, Turati, Rossion, Bulf, Goffaux & Simion, 2008) and therefore their recognition of faces is dependent upon large-scale differences between faces as they are unable to exploit fine-grained information. Thus, early in life newborns and infants will be drawn to facial areas of high variation and high contrast, suggesting that they will be more attracted to the eye and mouth (if the teeth are visible) regions. The limited available data suggest that this is indeed the case, with infants increasing fixations directed at the face from the external contour to the eye region between 3 to 11 weeks of age (Haith, Bergman & Moore, 1977) and 4-month-old infants directing the majority of their looks towards internal face features (Gallay, Baudouin, Durand, Lemoine & Lécuyer, 2006). In Gallay *et al*.'s study, across a familiarization trial with a single face, infants appear to shift their gaze from the eye region to other facial features (i.e. nose and mouth) and then back again. Whether infants show greater interest in the nose or mouth area is not clear at present as Gallay and colleagues collapsed the fixation points from these two regions into a single area of interest for analysis. Regardless, it can still be stated that very early in life fixations are dispersed around the internal facial features when faces are displayed in their canonical upright orientation.

Alternatively, other properties of the infant visual system mean that a case can be made for potentially observing a central fixation landing position. Retinal cell density and visual acuity decrease steeply towards the peripheral visual field, which might make the centre of the face an optimal spatial position to capture facial feature information holistically. Currently, such a pattern of looking has only been reported in Chinese adults, making a WC adult-like pattern of eye movements more likely to be observed, but owing to the lack of developmental eye-tracking studies using faces, the possibility that similar behaviour might be seen in developing populations remains open to investigation. A way to straightforwardly address this issue is to test children across a range of age groups. If culture is responsible for shaping the reported differences in adults, then we can expect to observe them emerge across ontogeny.

A recent study conducted with Chinese infants aged 4 to 9 months of age has provided some clues concerning the origins of differential face scanning strategies. Liu, Quinn, Wheeler, Xiao, Ge and Lee (2011) sequentially presented videos of a Chinese or Caucasian adult female to 23 Chinese infants. Their analyses found no significant differences for fixations to the eyes or mouth between own- and other-race faces, but a significant race of face by age interaction was found for fixations to the nose. While the high frequency of fixations to the nose was maintained for own-race faces, they decreased with age for other-race faces. Although these findings might suggest that a predilection to fixate the central face region develops within the first year of life in Chinese infants, making this conclusion would be premature. As only one population was tested and the stimulus set used was relatively limited, we cannot be certain that the pattern of results reported by Liu *et al*. is evidence of the same strategic eye movement differences found in adults. Nevertheless, the results from Liu *et al*. warrant further investigation with different cultural and older age groups.

In addition to attempting to identify the emergence of cultural differences in eye movements, the current study will also enable us to explore more general aspects of face processing development. In particular, analysis of fixation locations will inform the inner/outer face feature debate. Earlier behavioural studies reported that children aged 5 to 13 years rely more on external face features relative to internal face features when recognizing famous faces (Campbell, Coleman, Walker, Benson, Wallace, Michelotti & Baron-Cohen, 1999) and 5- to 9-year-olds show the same external advantage for unfamiliar adult faces (Want, Pascalis, Coleman & Blades, 2003). However, later studies have reported an inner face advantage in children from 5 years of age when recognizing familiar adult faces (Wilson, Blades & Pascalis, 2007). In terms of children recognizing children's faces, the results are similarly mixed. While one study has reported an external face advantage at 7 years shifting to an internal face advantage at 9 years (Campbell, Walker & Baron-Cohen, 1995), a second study found an internal advantage from 7 years of age (Bonner & Burton, 2004). A recent study further explored this issue by testing children with their classmates' faces and found an internal advantage in 4-year-old children. The authors conclude that previous reports of a reliance on external face features are attributable to experience with faces rather than ontogenetic shifts in processing strategy (Ge, Anzures, Wang, Kelly, Pascalis, Quinn, Slater, Yang & Lee, 2008). However, it is notable that in contrast to all the other studies described above, Ge and colleagues tested a non-Western (Chinese) population. This raises the possibility that strategic differences in face processing may exist between Eastern and Western cultural groups and that the findings of Ge *et al.* are attributable to cultural differences rather than experiential differences. The current study will add clarity to this issue by testing both Eastern and Western children across a range of age groups with unfamiliar faces from both races.

To begin to explore the origins of cultural differences in eye movements when encoding and recognizing human faces and potential cultural divergence in general face processing strategies, we recruited children aged 7 to 12 years of age from the UK and China. Children were tested with East Asian and Western Caucasian adult faces with an old/new face recognition paradigm, analogous to the adult study (Blais *et al.*, 2008), while we simultaneously recorded their eye movements. With this balanced design, we predicted that the patterns of eye movements displayed in both cultural groups might be different in even the youngest children (based on the findings of Liu *et al.*, 2011), but will further diverge to more fully resemble their respective adult cultural norms in older age groups.

Methods

Participants

In total, 42 WC children and 42 EA children comprised the final sample. Within each cultural population, there were three separate age groups: 7–8 years, 9–10 years and 11–12 years. There were 14 children of each cultural group in each age group: 7–8 years (WC: eight female, age range = 7.2–8.8; EA: six female, age range = 7.4–8.6), 9–10 years (WC: seven female, age range = 9.1–10.9; EA: seven female, age range = 9.4–10.10), 11–12 years (WC: seven female, age range = 11.2–12.11; EA: six female, age range = 11.3–12.9).

The WC participants were recruited from local schools near to the University of Glasgow. Letters providing information about the study were distributed to the schools and subsequently sent home for parents. Parents were then able to contact us to arrange a convenient testing time. Written consent was obtained from parents and testing only occurred if the child was willing to participate. Remuneration comprised travel expenses for parents and gift vouchers for children.

The EA participants were recruited from schools in Hangzhou, PR China. Testing took place in the schools where parents had already provided consent for their children to participate in studies affiliated to Zheijiang Sci-Tech University. Children were reimbursed for their participation with stationary sets. All participants from both populations had normal or corrected to normal vision.

Materials

Face stimuli were obtained from the KDEF (Lundqvist, Flykt & Öhman, 1998) and AFID (Bang, Kim & Choi, 2001) databases and consisted of 12 East Asian and 12 Western Caucasian identities holding neutral facial expressions and contained equal numbers of adult males and females. The images were 390×382 pixels in size, subtending 15.6° degrees of visual angle horizontally and 15.3° degrees of visual angle vertically, which represents the size of a real face (approximately 19 cm in height). All images were cropped around the face to remove clothing and were devoid of distinctive features (scarf, jewellery, facial hair, etc.). All images were mounted on a white background and viewed at a distance of 70 cm. This reflects a natural distance during human face-to-face interaction (Hall, 1966) and has been successfully used in previous studies (Blais *et al.*, 2008; Caldara *et al.*, 2010; Kelly, Miellet & Caldara, 2010). Luminance was normalized for all images and they were presented on a 800×600 pixel grey background displayed on a 19″ CRT monitor with a refresh rate of 170 Hz.

Eye tracking (UK)

Eye movements were recorded at a sampling rate of 1000 Hz with the SR Research Desktop-Mount EyeLink 2K eyetracker (with a chin/forehead-rest), which has an average gaze position error of about 0.25°. Only the dominant eye of each participant was tracked although viewing was binocular. The experiment was implemented in Matlab (R2006a), using the Psychophysics (PTB-3) and EyeLink Toolbox extensions (Brainard, 1997; Cornelissen, Peters & Palmer, 2002). Calibrations of eye fixations were conducted at the beginning of the experiment using a nine-point fixation procedure as implemented in the EyeLink API (see EyeLink Manual) and initiated using Matlab software. Calibration was validated with the EyeLink software and repeated when necessary until the optimal calibration criterion was reached.

Eye tracking (China)

Binocular eye movements were recorded at a sampling rate of 60 Hz with a Tobii T120 eyetracker which has an average gaze position error of about 0.5°. The experiment was implemented using Tobii Studio software. Calibration of eye fixations was conducted at the beginning of the experiment using a nine-point fixation procedure in Tobii Studio software. Calibration was validated and repeated when necessary until the optimal calibration criterion was reached.

Eye tracking – hardware differences

Naturally, it would have been preferable for all participants to have been tested with identical eye-tracking systems. To combat this difference, prior to testing we defined fixations so they were comparable across systems and subsequently analyzed all data using custom written code with an independent platform (MATLAB 2006a) to ensure that all data output was treated equally. Furthermore, we also administered a control task to demonstrate that any differences observed between populations were not an artifact resulting from hardware differences. For the control task, we selected six new faces (three EA, three WC) from the face database described above and presented them sequentially for 5 seconds each to five children from each population while eye movements were recorded. For half the face trials, children were asked to look at the eyes and the mouth and for the remaining trials children were instructed to fixate centrally on the nose. Eye movements were analyzed separately for the 'eye/mouth' and 'nose' conditions and revealed no differences between cultural groups (see Figure S1 in Supplementary Materials). Thus, any differences observed between cultural groups are a consequence of genuine strategic variations and not attributable to the different hardware devices used.

Procedure

All participants completed both EA and WC face stimulus conditions. The order of conditions was counterbalanced across participants. Participants began each stimulus condition with a training session, which comprised four examples of the images that would be displayed in that condition. Importantly, these images were obtained from the original databases from which the final stimulus sets were taken, but they did not form part of the final sets and were not displayed again subsequently. The purpose of the training session was simply to familiarize the participants with the stimuli, but they were not required to perform any behavioural task during this phase and eye movements were not recorded.

Participants were informed that they would be presented with a series of images to learn and subsequently recognize. They were also told that they would complete two testing blocks in total. In each block, participants were required to learn six images. After a 30 second pause, a series of 12 images (six targets from the learning phase plus six foils) were presented and participants were asked to indicate as quickly and as accurately as possible whether each stimulus was a target or foil by pressing designated keys (a, l) on the keyboard with the index fingers of their left and right hands. Response buttons were counterbalanced across participants.

Each test trial started with the presentation of a central fixation cross that was displayed until the participant held a stable fixation on the cross. Following this, a stimulus was presented on the computer screen. All stimuli were presented for 5 seconds' duration in the learning phase and until the participant made a key press response in the recognition phase. To prevent anticipatory strategies, images were randomly presented at different locations of the computer screen. Each stimulus was subsequently followed by the fixation cross, as described above, which preceded the next stimulus.

Data analyses

Analysis was conducted using *i*Map (Caldara & Miellet, in press) methods and other custom written MATLAB software. Fixation distribution maps were computed individually for WC and EA participants, for each stimulus condition and separately for the learning and recognition phases. The fixation maps were computed by summing, across all (correct) trials, the fixation location coordinates (x, y) across time. Since more than one pixel is processed during a fixation, we smoothed the resulting fixation distributions with a Gaussian kernel with a sigma of 15 pixels. Then, the fixation maps of all the participants belonging to the same cultural group were summed together separately for each face condition, resulting in group fixation maps.

We Z-scored the group fixation maps by assuming identical WC and EA eye movement distributions for a particular face race as the null hypothesis. Consequently, we pooled the fixation distributions of participants for both groups and used the mean and the standard deviation for each stimulus condition to separately normalize the data. Finally, to clearly reveal the difference of fixation patterns across participants of different cultures, we subtracted the group fixation maps of the EA participants from the WC participants and Z-scored the resulting distribution. To establish significance, we used a robust statistical approach correcting for multiple comparisons in the fixation map space, by applying a two-tailed *Pixel test* (Chauvin, Worsley, Schyns, Arguin & Gosselin, 2005; $Z_{crit} > |4.64|$; $p < .05$) on the *differential* fixation maps.

Results

Accuracy

A 2 (*Culture of Observer*: British or Chinese) × 2 (*Race of Face*: WC or EA) × 3 (*Age*: 7–8 years, 9–10 years or 11–

12 years) ANOVA was conducted on participants' recognition accuracy. The ANOVA yielded a main effect of *Race of Face* ($F(1, 82) = 11.550$, $p < .001$, $\eta_p^2 = .069$) and a main effect of *Age* ($F(2, 81) = 6.510$, $p < .002$, $\eta_p^2 = .077$). Post-hoc analysis revealed that accuracy was superior for WC faces (86.41%) relative to EA faces (80.46%) ($t(83) = 3.691$, $p < .001$) and that recognition accuracy increased with age (7–8 years: 79.61%; 9–10 years: 83.33%; 11–12 years: 87.35%) with a significant difference between 7–8-year-olds and 11–12-year-olds ($t(55) = 3.702$, $p < .001$). Furthermore, WC participants were significantly more accurate at recognizing WC faces relative to EA faces ($t(41) = 3.954$, $p < .001$), whereas EA participants' recognition accuracy did not differ between face categories. Accuracy results are displayed in Figure 1a.

Reaction time

A 2 (*Culture of Observer*: British or Chinese) × 2 (*Race of Face*: WC or EA) × 3 (*Age*: 7–8 years, 9–10 years or 11–12 years) ANOVA was conducted on participants' recognition reaction times. The ANOVA yielded a main effect of *Culture of Participant* ($F(1, 82) = 10.724$, $p < .001$, $\eta_p^2 = .064$) only. Post-hoc analysis revealed that WC children responded faster (1.932 secs) than EA children (2.196 secs) ($t(83) = 3.242$, $p < .002$). Reaction time results for correct trials are displayed in Figure 1b.

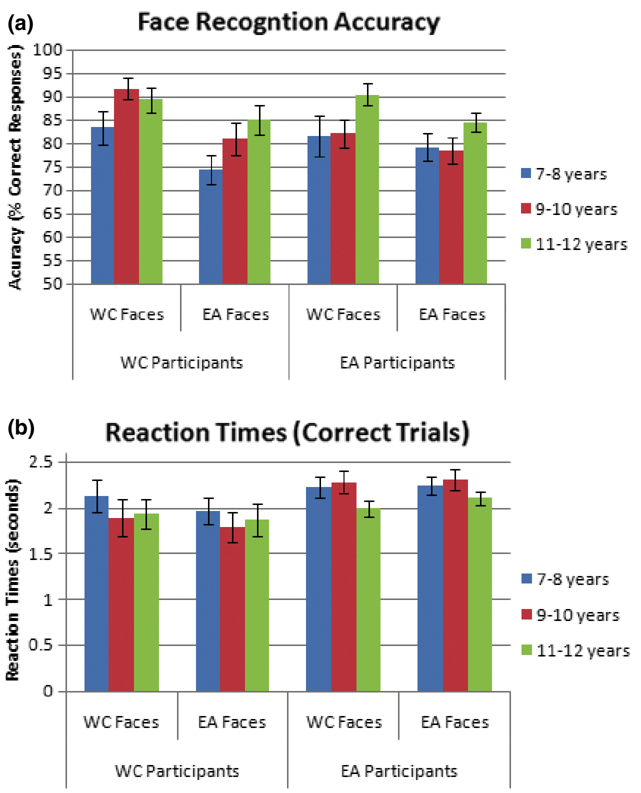

Figure 1 *(a) Accuracy (% correct responses) with standard error bars from the recognition phase of the old/new task for Western Caucasian (WC) and East Asian (EA) faces in all age groups from both populations. (b) Reaction Times for correct trials only with standard error bars from the recognition phase of the old/new task for all age groups for Western Caucasian (WC) and East Asian (EA) faces in all age groups from both populations.*

Number of fixations

A 2 (*Culture of Observer*: British or Chinese) × 2 (*Condition*: Learning or Recognition) × 3 (*Age*: 7–8 years, 9–10 years or 11–12 years) ANOVA was conducted on the number of fixations made by participants. The number of fixations made increased with age (7–8 years: 8.31; 9–10 years: 9.353; 11–12 years: 10.450) with a significant difference between 7–8-year-olds and 11–12-year-olds ($t(55) = 2.836$, $p < .006$). A main effect of *Condition* ($F(1, 82) = 10.431$, $p < .002$, $\eta_p^2 = .063$) was also found with more fixations made during learning (mean = 10.45) than recognition (mean = 8.45).

Eye movements

Children from the UK predominantly direct their fixations toward the eyes and mouth regions whereas children from China fixate more centrally on the nose region. These strategic group differences, as qualified by a two-tailed pixel test ($Z_{crit} > |4.64|$, $p < .05$), are clearly illustrated in Figure 2. Areas fixated above chance are delimited by white borders and depict the relative fixation biases following map subtraction (WC – EA).

Classifier

In order to measure any strategic changes in fixation patterns across development, we classified children's fixation maps by contrasting these with adults' fixation maps obtained from a previous study, Kelly *et al.* (2010). Critically, the materials and methods used by Kelly and colleagues were identical to the current study, making the data templates perfectly suited for comparison with the

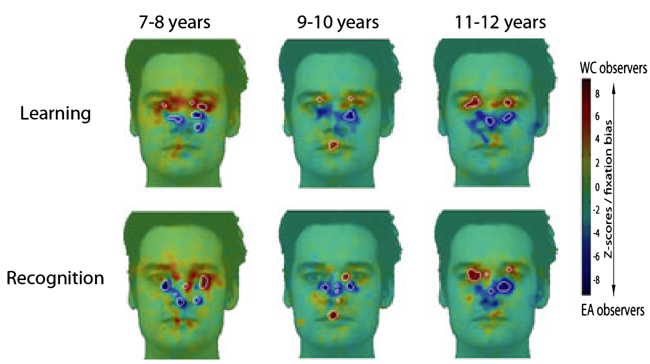

Figure 2 *Fixation maps: group differences. Maps display Western Caucasian (WC) participant fixation strategies minus East Asian (EA) fixation strategies at each age group. Areas of significance are delimited by white borders (red indicates Western Caucasian bias, blue indicates East Asian bias).*

current results. We used the Z-scored EA and WC participants' group fixation maps from Kelly *et al.* (2010) as 'Eastern' and 'Western' templates. Subsequently, each child's fixation map was compared against each of the templates. Four comparisons were computed separately for each individual participant, which comprised the learning and recognition phases for each race of face (i.e. EA faces and WC faces). A correlation coefficient was then computed for each comparison to determine which of the adults' strategies the participants' strategy was closest to. Since correlation coefficients are not additive, they were then Z-normalized (Chung, Kim, Kelley, Robbins, Evans & Davidson, 2005), using Fisher's transform $Z = 0.5 \cdot \log_e\left|\frac{1+r}{1-r}\right|$. A 2 (*Culture of Observer*: British or Chinese) × 2 (*Condition*: Learning or Recognition) × 3 (*Age*: 7–8 years, 9–10 years or 11–12 years) ANOVA was conducted to assess eye movement strategy differences between groups and across development. The ANOVA yielded a main effect of *Culture of Observer* only ($F(1, 82) = 43.778$, $p < .001$, $\eta_p^2 = .219$), demonstrating that significant strategic differences exist between the two populations. Although a main effect of *Age* was not found ($F(1, 82) = 2.092$, $p = .130$, $\eta_p^2 = .051$), we did observe a non-significant trend in the predicted direction. Figure 3 displays the Z-normalized WC template comparison values minus the Z-normalized EA template comparison values. Inspection of these values reveals that for both cultural groups, older children's fixation strategies more closely resemble their respective adult fixation patterns.

Inner/outer fixations

In order to assess the number of fixations directed towards internal and external features, two Areas of Interest (AOIs) were established. One AOI covered the internal facial features only and the second AOI comprised the rest of the pixel space. The number of fixations that fell within each of these two AOIs was then calculated individually for each participant. A 2 (*Culture of Observer*: British or Chinese) × 2 (*Condition*: Learning or Recognition) × 3 (*Age*: 7–8 years, 9–10 years or 11–12 years) × 2 (AOI: Internal or External) ANOVA was conducted on the number of fixations made by participants yielding a main effect of AOI only ($F(1, 82) = 24235.06$, $p < .0001$, $\eta_p^2 = .987$). Inspection of the mean number of fixations showed that participants almost exclusively directed their fixations towards internal features (98.56%) rather than external features (1.44%).

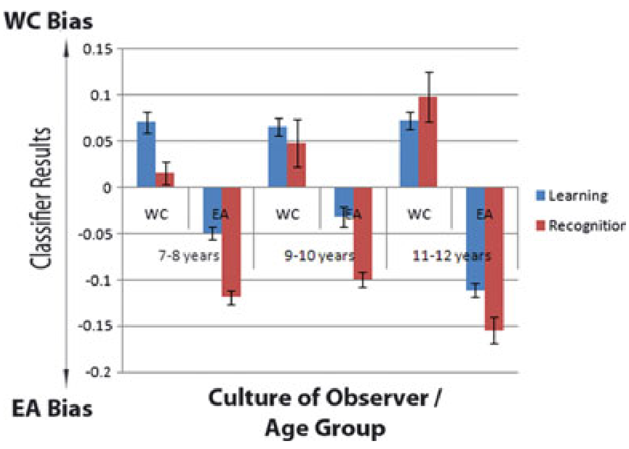

Figure 3 *Results from classifier analysis. Z-normalised Western Caucasian template comparison values minus the East Asian template comparison values with standard error bars. Positive values indicate 'Western-like' fixation strategies. Negative values indicate 'Eastern-like' fixation strategies.*

Discussion

The subtracted group fixation maps show that the patterns of fixations displayed by children in all age groups are highly similar to those of adults from their respective cultural groups reported in previous studies (Blais *et al.*, 2008; Caldara *et al.*, 2010; Kelly *et al.*, 2010) when encoding and recognizing human faces. The culture-specific patterns observed in EA and WC adults were even present in the youngest age group tested. This observation was qualified by the classification procedure conducted using templates from Kelly *et al.* (2010). Furthermore, fixation strategies appear to become more 'adult-like' across development, although this trend failed to reach statistical significance. Our findings clearly show that culture-specific fixation strategies are present by 7 years of age and are maintained throughout later childhood. The non-significant trend observed for culture-specific strategies to become more 'adult-like' across childhood implies that these cultural differences may increase with age, although the current data do not provide definitive support for this conclusion. In relation to the study of Liu *et al.* (2011), the findings from the present study demonstrate that the 'tuning' of culture-specific eye movement patterns continues long after infancy. Furthermore, Liu and colleagues found that a tendency to fixate the nose region decreased for other-race faces. In our study culture-specific strategies were present for both own- and other-race faces (see Figure S2 in Supplementary Materials), which might indicate that the face system has reached a more robust calibration in the eye movement strategy used to process faces. Further eye-tracking studies with infants and young children are necessary to identify the precise changes that occur in early childhood, and precisely identify when similar eye movement strategies are deployed for all human faces.

A slightly unexpected auxiliary finding is that EA children did not display an own-race bias in face recognition, while the WC children did. We cannot fully account for this result as previous studies have found evidence for the other-race effect emerging during infancy (e.g. Kelly, Quinn, Slater, Lee, Ge & Pascalis, 2007; Kelly, Liu, Lee, Quinn, Pascalis, Slater & Ge, 2009). EA children did take significantly longer to respond relative to WC children, which could account for their high accuracy. Alternatively, the increase in exposure to Western media such as Hollywood movies and the internet in China could have eradicated the effect in this population. Future studies may well shed light on this finding.

As cultural differences in fixation strategies were observed during development, it is critical to question what aspect of culture is responsible for producing distinct strategies during face processing tasks. At present, the *analytical* versus *holistic* cultural framework of perceptual and attentional processing styles by Nisbett and Miyamoto (2005) provides the most plausible explanation for the pattern of results observed. According to their work, individuals from Western cultural backgrounds display a tendency to process information *analytically* by focusing on salient objects and using categorical rules when organizing their visual environment. People from Eastern cultures, on the other hand, seem to process information in a more *holistic* manner by showing interest in context and grouping objects according to relationships. Miyamoto, Nisbett and Masuda (2006) have argued that the reported variations have arisen as a consequence of the physical environment and historical differences between these distinct societies (e.g. individualist versus collectivist; see Miyamoto *et al*., 2006, for a fuller account and Kelly *et al*., 2010, for further discussion on this issue). The critical, but as yet unanswered, question that remains is whether it is these same forces that impact face recognition and whether a direct link between cultural upbringing and strategies to extract information from the environment can be established. The suggestion that such a link might exist would have been considered controversial until quite recently; however, as evidence from the cultural framework of perception and attention increases we are challenged to reconsider this position.

In a recent review of cross-cultural studies, Henrich, Heine and Norenzayan (2010) endorse the view that much of what we consider to be universal in psychology, including 'classic' effects with visual illusions, is in fact culture specific. Perhaps counter-intuitively to members of the Western psychology community, Henrich *et al.* claim that not only do pronounced differences in thought, behaviour and perception exist between cultural groups, but the most commonly tested population (i.e. white, middle-class, psychology students) might be the outliers in relation to most other populations. However, Henrich and colleagues also emphasize that cultural differences are not always found, and highlight areas where universality prevails (e.g. mate preferences and personality structure). It is necessary to be mindful of this fact and rather than seeking out cultural differences alone, we should also attempt to understand what differences exist and how to account for them. In the present study, cultural variations were clearly demonstrated in eye movements at the individual feature level (i.e. looking at eyes versus nose), but no differences were found at the internal/external features level. This result adds further weight to the argument proposed by Caldara *et al*. (2010), who suggested that the cognitive mechanisms involved in face processing are identical across all peoples, but the strategies employed for information extraction vary across populations. Future developmental work will be crucial to aid our understanding of how cultural differences arise across populations, which cognitive processes are subject to environmental modulation and when they occur. For example, testing children younger than 7 years of age with age-appropriate methods is likely to provide significant insights into early development of these processes.

In relation to the internal/external feature debate, the findings from this study offer strong support for the reliance of internal feature use for face encoding and recognition during childhood as all age groups almost exclusively directed fixations towards the internal features. Although this finding is at odds with some early work in this area (Campbell *et al*., 1999; Want *et al*., 2003), the pattern of results is consistent with recent studies (Bonner & Burton, 2004; Ge *et al*., 2008; Liu *et al*., 2011; Wilson *et al*., 2007). It is important to emphasize that the current study can only inform on which facial information overt visual attention is directed towards during recognition and not how accurate recognition is achieved. On the basis of the fixations patterns observed it is clear that if external face information is being used to recognize faces, it is done using extrafoveal vision as fixations were not directed to these regions. Therefore, it seems probable that face recognition in childhood does not require the use of the detailed, foveated information that would be gained by landing fixations on external features. This reliance on internal feature information accords with recent studies that contrast with earlier evidence of internal/external information use biases and ontogenetic shifts. Notably, in the current study the face stimuli represented unfamiliar adults and were displayed as full faces. Based on the findings of earlier studies, one might have predicted that the unfamiliarity of faces would have led to an external feature advantage, at least in the younger age groups. But our data do not support this view. One possible explanation for the discrepancies between studies is that the typical method of displaying faces that have been divided into internal/external features induces artificial learning strategies. To establish whether this is correct, it will be important for future studies to consider this point and to use naturalistic full faces whenever possible. Nonetheless, we believe the current study provides an important contribution to this literature and demonstrates that external face features are not relied upon by children aged 7–12 years when encoding and recognizing unfamiliar faces.

In conclusion, cultural differences in eye movements were found in children as young as 7 years of age during face encoding and recognition. Furthermore, the strategies displayed by both WC and EA children were consistent with those previously reported in adults (Blais *et al*., 2008; Caldara *et al*., 2010; Kelly *et al*., 2010). Although it cannot be definitively stated that cultural factors are responsible for shaping the distinct eye movement patterns observed, the culture-specific adult-like fixation strategies displayed at 7 years of age and the apparent strengthening of strategies across ontogeny implies that experiential factors influence the way information is extracted from the visual world.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1 *Fixations maps generated for Western Caucasian and East Asian children in the control task where explicit instructions to look to either the* '*eyes and mouth*' *or the* '*nose*' *were provided.*

Figure S2 *Fixation maps displaying fixation patterns separately for WC and EA faces in each age group. The subtracted maps show small but non-significant differences between fixation patterns for own- and other-race faces in both populations. Figure 2a displays Western Caucasian participants*' *fixation strategies. Figure 2b displays East Asian participants*' *fixation strategies.*

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