# Social experience does not abolish cultural diversity in eye movements

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**Abstract**

Adults from Eastern (e.g., China) and Western (e.g., USA) cultural groups display pronounced differences in a range of visual processing tasks. For example, the eye movement strategies used for information extraction during a variety of face processing tasks (e.g., identification and facial expressions of emotion categorization) differs across cultural groups. Currently, many of the differences reported in previous studies have asserted that culture itself is responsible for shaping the way we process visual information, yet this has never been directly investigated. In the current study, we assessed the relative contribution of genetic and cultural factors by testing face processing in a population of British Born Chinese (BBC) adults using face recognition and expression classification tasks. Contrary to predictions made by the cultural differences framework, the majority of BBC adults deployed 'Eastern' eye movement strategies, while approximately 25% of participants displayed 'Western' strategies. Furthermore, the cultural eye movement strategies used by individuals were consistent across recognition and expression tasks. These findings suggest that 'culture' alone cannot straightforwardly account for diversity in eye movement patterns. Instead a more complex understanding of how the environment and individual experiences can influence the mechanisms that govern visual processing is required.

**1.1 Introduction**

It has long been considered that many aspects of human cognition are culture invariant. This assumption arises from the fact that the neural substrates underlying cognitive processes are thought to be principally identical across all people and cultures. However, studies conducted over the past decade have begun to systematically challenge the notion of cognitive universality, forcing reconsideration of long standing beliefs about how humans process information, particularly from their visual world. At the forefront of current literature is the assertion that culture itself is responsible for shaping the way we perceive the world.

According to a popular framework, adults from collectivist societies in East Asian countries (e.g., China, Japan etc.) process visual information *holistically* whereas adults from individualist Western countries (e.g., U.S.A., Britain etc.) employ *analytical* processing strategies, resulting in fundamental differences in thought, behavior and perception. Adults from Western societies are inclined to focus on focal objects, make causal attributions and group objects based on categorical rules. By contrast, Easterners are more likely to display interest in context, make situational attributions and group objects according to relationships (see Nisbett & Miyamoto, 2005 for a review). It has been argued by Nisbett & Masuda (2003) that the origins of these divergent strategies are deep-rooted, originating from distinct geographical and philosophical/ideological factors. In terms of geography, favorable farming conditions in the West permitted the pursuit of individual farms and thus autonomy and emphasis on personal goals. By contrast, farming conditions in the East were harsh with limited arable land available, which demanded the collective effort of many people in order to produce a good yield. The history of farming can be traced back approximately 10,000 thousand years in both Greece (Montgomery, 2007) and China (Bray, 1984). Coupled with geographical factors that served to structure fledgling societies are the socio-political ideologies and philosophies that are responsible for shaping thought and action. For example, in ancient Greece, Aristotle focused his explanation of the world on individual objects: a rock sank in water because it had the property of 'gravity' and wood floated because it had the property of 'levity.' However, the Chinese perceived that actions occurred in a field of forces (i.e. the water), allowing them to understood concepts such as tidal flows and magnetism long before thinkers in the West.

Culture's potency for shaping thought and behavior is still acutely evident when visiting foreign countries today. Within Europe, for example, every individual country has a long and rich history which has created distinct and varied cultural groups divided only by relatively arbitrary dividing points (i.e. international borders). Cultural differences are even more marked when crossing continental boundaries. Indeed, the differences can be so profound that travelers regularly suffer from what is known as 'culture shock;' the feeling of surprise, uncertainty, disorientation, etc., which is felt when people need to function in an unfamiliar cultural environment. While claims of intense cultural diversity are not controversial, linking cognitive processes to the physical environment could be considered somewhat speculative. However, an alternative account of the observed differences has not yet emerged. Furthermore, in addition to the cultural differences found at the behavioral level described above, cultural diversity has also been shown in studies of eye movements.

Adults who have been raised in different cultural backgrounds, namely Western Caucasian (WC) and East Asian (EA), display dissimilar patterns of fixations during face processing tasks (Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Consistent with a multitude of prior reports (e.g., Groner, Walder, & Groner, 1984; Henderson, Williams, & Falk, 2005; Janik, Wellens, Goldberg, Dell'Osso, 1978; Kleinke, 1986; Yarbus, 1965), Blais and colleagues found that WC adults primarily fixate the eyes and mouth region during face learning, recognition and race categorization tasks. However, EA adults did not display this well documented strategy and instead directed the majority of their fixations towards the central region of the face, which represents the optimal location for the visual system to process information *holistically*. These divergent strategies are consistent across face race categories (Caucasian and Asian), time (i.e. stimulus presentation duration) and are equally reliable strategies as both populations achieved comparable face recognition and race categorization accuracy. Furthermore, differences in the distribution of fixations persist across non-human face stimuli (sheep) and non-face objects (*greebles*) and are thus not stimulus specific (Kelly, Miellet, & Caldara, 2010). Together, these data show fundamental differences in visual processing between cultural groups.

Studies using a variety of techniques, such as behavioral (Davies, Ellis, & Shepherd, 1977), response classification (Gosselin & Schyns, 2001) and computational modeling (Rowley, Baluja, & Kanade, 1998; Viola & Jones, 2004) have revealed that the critical information required to accurately individuate faces is located in the eye region, but not the nose (see also Caldara, Zhou, & Millet, in press). Fixations towards the mouth are functional during communication with conspecifics as they serve to facilitate speech comprehension (Reisberg, McLean, & Goldfield, 1987), making such fixations habitual and likely to account for their occurrence when viewing static images. Strategies similar to those reported in WC adults have also been observed in rhesus macaques (*Macaca mulatta*), emphasizing the biological pertinence of information contained in the eye region for identity recognition (Dahl, Wallraven, Bülthoff, & Logothetis, 2009) and mouth region for facilitating the comprehension of vocalizations (Ghazanfar, Nielsen, & Logothetis, 2006). When considering these findings collectively, it is puzzling that East Asian adults are able to fixate an essentially redundant facial feature (i.e. the center of the face) in terms of individuation, yet still achieve face recognition accuracy comparable to that of WC adults, who fixate information known to be diagnostic for face identification.

Caldara, Miellet and Zhou (2010) recently clarified the apparent underuse of eye region information in East Asian observers by using a gaze-contingent moving aperture paradigm. Western Caucasian and East Asian observers explored faces while their extrafoveal vision was dynamically restricted by apertures sized 2°, 5° and 8° visual angle, termed '*Spotlights*.' Critically, in the most restrictive conditions (i.e. 2° and 5°), the eyes were not visible when fixations landed on the center of the face. By contrast, in the most permissive condition (i.e. 8° visual angle) the eyes were simultaneously visible during central fixations. In both the 2° and 5° conditions, East Asian observers adapted their usual strategy by fixating the eyes in an identical manner to the Western observers. However, in the 8° condition, when the eyes and mouth were simultaneously visible from the center of the face, East Asian observers reverted to their preferred strategy by directed fixations to the center of the face. These results suggest that although East Asian observers rely on the same facial information (i.e. the eyes) as Western observers, they process this information using extrafoveal vision. When vision is restricted, East Asian observers are forced to modulate their preferred central fixation strategy to one that mirrors the Western fixation pattern in order to access the eye region.

In the current study we directly explored the impact of cultural environment on eye-movement strategies during face learning and recognition. The studies described above support the notion of environmental or cultural influence, but none have directly tested this hypothesis. To address this shortfall, we identified a population of British Born Chinese (BBC) adults. The BBC population is genetically Chinese, but they were born in a Western country (U.K.) and have lived their entire lives there. We hypothesized that if culture, rather than genetic factors, is responsible for shaping eye movement strategies, then the BBC population will display the triangular series of fixations commonly reported in Western populations (e.g., Henderson et al., 2005).

## 2.1 Experiment 1

### 2.1.1 Methods

***Participants.*** Twenty British Born Chinese (BBC; 14 females) adults (mean = 25.23 years) participated in this study. All participants had been born in the UK (Scotland), had spent their entire lives in the U.K. and were all living in Glasgow at the time of testing. We recruited participants through a Chinese Community Development Partnership in Glasgow. All participants had normal or corrected vision and were paid £6 per hour for their participation. All participants gave written informed consent and the protocol was approved by the departmental ethical committee.

***2.1.2 Materials.*** We sourced stimuli from the Karolinska Directed Emotional Faces (KDEF, Lundqvist, Flykt, & Öhman, 1998) database and Asian Face Image Database (AFID, Bang, Kim, & Choi, 2001), which consisted of 56 East Asian (EA) and 56 Western Caucasian (WC) identities with equal numbers of males and females. At 390x382 pixels in size, each image subtended 15.6° degrees of visual angle horizontally and 15.3° degrees of visual angle vertically, when viewed at a distance of 70 cm (a natural distance during human interaction; Hall, 1966). Thus, each image represented the size of a real face (approximately 19 cm in height). We cropped all images around the face to remove clothing and hair and were devoid of distinctive features (e.g. scarf, jewelry, facial hair etc.). The faces used were aligned on eye and mouth positions and luminance normalized for all images. We presented images on grey background on a 19" Dell P1130 CRT monitor with a refresh rate of 170 Hz and a screen resolution of 800 x 600 pixels and used a chin/forehead rest to maintain a constant viewing distance. We controlled stimulus presentation using MATLAB™ (The MathWorks, MA).

***2.1.3 Eye-tracking.*** We recorded eye movements using an SR Research Desktop-Mount EyeLink 2K eyetracker with a sampling rate of 1000 Hz and average gaze position error of approximately 0.25° visual angle, a spatial resolution of 0.01° visual angle and a linear output over the range of the monitor used. Only the dominant eye of each participant was tracked although viewing was binocular. We used MATLAB™ (R2006a) in conjunction with Psychophysics toolbox (PTB-3) and EyeLink Toolbox extensions (Brainard, 1997; Cornelissen, Peters, & Palmer, 2002) to execute the experiment. Prior to testing, we performed calibration using a nine-point fixation procedure as implemented in the EyeLink API (see EyeLink Manual) followed by validation with the EyeLink software. We repeated this procedure when necessary and until the optimal calibration criterion was reached. At the beginning of each trial, participants fixated a dot at the center of the screen to calculate drift correction. If the drift correction exceeded 1° of visual angle, we launched a new calibration procedure to insure an optimal recording quality.

***2.1.4 Procedure.*** Participants were informed that they would be presented with a series of faces to learn and subsequently recognize, which would be conducted during two separate sessions (EA and WC) with each race session containing two blocks. In each block, observers learned 14 face identities (7 females) each displaying either neutral, happy or disgusted facial expressions (presented in random order). After a 30 second pause, observers were presented with a series of 28 faces (14 faces from the learning phase – 14 new faces; 7 females), indicating whether each face was familiar or not. Participants were instructed to respond as quickly and as accurately as possible by pressing pre-allocated keys on the keyboard with the index fingers of their left and right hands. Faces of the two races were presented in separate blocks, with the order of presentation for same- and other-race blocks counterbalanced across observers. Response buttons were counterbalanced across participants.

Each trial started with the presentation of a central fixation cross, followed by a series of four crosses presented in each of the four quadrants of the monitor. This procedure allowed the experimenter to check the accuracy of the previous calibration procedure, thus validating the calibration between each trial. Finally, a central fixation cross that served as a drift correction measure was displayed, followed by a face presented in a random location on the monitor to prevent anticipatory strategies, all images were presented in random locations on the computer screen. Faces were displayed in a white frame for 5 seconds duration in the learning phase and until the observer responded in the recognition phase. Each face was subsequently followed by the 6 fixation crosses which preceded the next face stimulus.

***2.1.5 Data analyses.*** The data was analyzed with iMap (Caldara & Miellet, submitted). Only correct trials were analyzed. Fixation distribution maps were extracted individually for BBC participants for each face race and for the learning and recognition tasks separately. 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 10 pixels. Then, the fixation maps of all the observers were summed together separately for each face condition to produce group fixation maps.

To produce group fixation maps, we summed the fixation maps of all the individual observers for each face condition. We then Z-scored the resulting group fixation maps for learning and recognition phases and for both sets of face stimuli separately. Finally, we pooled the fixation distributions of observers, using the mean and standard deviation for WC and EA faces to normalize the data separately. To test for any differences in eye movements across face conditions, we subtracted the values for EA faces from WC faces, producing difference maps computed separately for both learning and recognition conditions. To establish significance, we used a robust statistical approach correcting for multiple comparisons in the fixation map space. We applied a two-tailed *Pixel test* (Chauvin, Worsley, Schyns, Arguin, &, Gosselin, 2005; $Z_{crit} > 4.38$; $p < .05$) on the difference maps and a one-tailed *Pixel test* on the group fixation maps.

### *2.2 Results*

***2.2.1 Accuracy**:* A one-way ANOVA conducted on participant's accuracy (*d'*) showed that participant's recognition accuracy did not differ between stimulus categories (F(1,19) = 0.76, $p$ = .783). A further one-way ANOVA revealed no differences in reaction time (F(1,19) = 2.674, $p$ = .102), indicating that participants responded with equal speed to both sets of faces (See figure 1).

**INSERT FIGURE 1 ABOUT HERE**

***2.2.2 Number of Fixations**:* A 2 (Race of Face: EA or WC) x 2 (Phase: Learning or Recognition) ANOVA conducted on the number of fixations yielded a main effect of Phase only (F(1,19) = 196.021, $p$<.001, $\eta_p^2$ = .721) with more fixations made during the learning than recognition phase. Participants made equal numbers of fixations for both EA and WC faces in both conditions (Number of fixations are show in Table 1).

**INSERT TABLE 1 ABOUT HERE**

**2.2.3 Eye Movements:** The two-tailed *Pixel test* conducted on the race of face differences map yielded no significant differences in eye movements across EA and WC face conditions. The one-tailed *Pixel test* ($Z_{crit}$ > 3.96; $p$ < .05) applied to the group fixation maps produced large areas of significance with fixations clustered around the nose region and spreading up towards the eyes for learning and recognition and both face categories (See figure 2).

**INSERT FIGURE 2 ABOUT HERE**

***2.2.4 Individual Participant Analysis***: Following this initial analyses, we turned our attention to the eye movement strategies used by individual participants. The group maps shown in figure 2 appear closer to the EA strategies reported in previous studies (e.g., Blais et al., 2008), but with significantly fixated areas falling closer to the eye region. A visual inspection of each participant's fixation maps showed that some individuals employed strategies that looked similar to those reported in EA adults, while others showed strategies more like those observed in WC adults. In order to robustly and objectively categorize each fixation map as Eastern or Western, we developed a data-driven classification procedure. We used the Z-scored EA and WC group fixation maps from Blais et al. (2008) as 'Eastern' and 'Western' templates (see figure 3) and subsequently compared every individual's fixation map with each of the templates. Critically, the materials and methods used by Blais and colleagues were identical to the current study making the data templates perfectly suited for comparison with the BBC results. Five comparisons were computed separately for each individual participant. These comprised the learning and recognition phases for each race of face (i.e. Asian faces and Caucasian faces), plus a comparison with fixation maps collapsed across all phases. We then computed a correlation coefficient for each comparison to determine whether each participant's strategy was closer to those previously observed in Eastern and Western adults. Since correlation coefficients are not additive, they were then Z-normalized (Chung, et al. 2005), before performing statistical analyses. We thus normalized the obtained correlation coefficient by using Fisher's transform $Z = 0.5 \cdot \log_e \left|\frac{1+r}{1-r}\right|$. Then, to estimate the average correlation coefficients for template comparisons, an inverse of Fisher's transform was applied on the mean of Z values ($Z_{mean}$) using the following formula: $r_{average} = \tanh(Z_{mean})$, in which tanh stands for the hyperbolic tangent.

The classifying method produced two main findings. First, strategies displayed by individual participants were consistent across all learning and recognition conditions. Second, the procedure classified 14 eye movement strategies as Eastern and only 6 as Western (See figure 4 and Table 2). We subsequently collapsed data across conditions, to produce two values for each individual: a similarity measure with East Asian strategies and a second measure with Western Caucasian strategies. A paired samples *t* test conducted on these values confirmed that as a group ($t(19) = 2.306$, $p < .033$), the BBC's eye movement strategies more closely resembled Eastern templates.

**INSERT FIGURES 3 & 4 AND TABLE 2 ABOUT HERE**

### 2.3 Discussion

The typical pattern of eye movements displayed by the BBC population was unequivocally more 'Eastern' with fixations principally clustered around the center of the face. However, inspection of fixation strategies at the individual level revealed greater within-group variance than previously reported in WC and EA populations (Blais et al., 2008; Kelly et al., 2010). According to our classification procedure, 70% of individual strategies are Eastern and

30% Western, which renders us unable to fully accept or reject our original hypothesis. Nonetheless, given the variability of the fixation strategies found within the BBC group, it is possible that this reflects the influence of both cultures upon these biological mechanisms, which presents a more complex picture than accounts that advocate the governance of a single, predominant cultural influence.

A small number of studies have tested Asian American participants, who are analogous to the BBC population as both groups are likely to embrace aspects of two different cultures. For example, Norenzayan and colleagues (2002) examined cultural differences in categorical perception. Participants were presented with a target object (e.g., a flower) and two groups/families, with each containing four unique members. The task was to decide to which group the target object most appropriately belonged. Critically, one group/family objectively possessed more features overall with the target, whereas the other group/family shared fewer features. However, all members of the group/family shared one common feature that was also found on the target object. As predicted, European Americans made more judgments according to the rule (i.e. all objects share a common feature) while Asian American participants typically placed the target object in the group that bore a greater family resemblance (i.e. more features in general). However, the judgments of the Asian American participants were distributed approximately evenly between 'Eastern' and 'Western' styles of categorization, with a slight inclination to categorize according to family resemblance (i.e. 'Eastern' style). Interestingly, these findings are line with the current study, which replicates the distribution of 'Eastern' and 'Western' styles. In both instances, a genetically EA population born and raised in a Western environment displayed perceptual strategies that do not entirely resemble the strategies reported in European/American or East Asian adults, but represent both cultures, with a leaning towards East Asian styles.

After consideration of the findings, further examination of the BBC population yielded information that could account for the distribution of styles between Eastern and Western. The vast majority of BBC participants attended the same activity/youth centre where they engaged in activities such as Mandarin lessons, calligraphy and cookery lessons etc. to continue to engage with Eastern cultural pursuits. In short, the BBC population represents a community that actively engages with its Chinese heritage. Following these reflections, we considered that the majority of the BBC population grew up in a home environment where Eastern culture was prominent or at least well represented. In addition to explicit engagement with Eastern cultural activities, it is clear that this population had also been exposed to Western culture within their schools and more general in their day-to-day lives outside of the home. Therefore, we conducted a second experiment in which we explored the consistency of individual's eye movement strategies across tasks.

**3.1 Experiment 2**

In order to help clarify the results from experiment 1, we conducted a second face processing task: the classification of facial expressions of emotion. Facial expressions of emotion are central to human communication and represent the physical manifestation of an individual's internal emotional state. Following Ekman (e.g., Ekman, 1994), it was generally accepted that facial expressions are universally produced and interpreted. However, Jack, Blais, Scheepers, Schyns, & Caldara (2009) recently showed that cultural differences in eye movements also extend to the categorization of emotionally expressive faces. In summary, Jack and colleagues reported that Western adults distributed fixations across the entire face allowing them to extract critical diagnostic information required to facilitate accurate categorical judgments. By contrast, Eastern adults primarily fixated the eye region across all facial expressions - a strategy inadequate to dependably distinguish between certain facial expressions, such as 'fear' and 'surprise', for example. These results question the universality of facial expressions, suggesting cultural diversity in the *transmission* of facial expression signals. The purpose of experiment 2 was to explore whether individual participants displayed 'Eastern' or 'Western' expression strategies and more pertinently, whether each individual's strategy was consistent across tasks (i.e. recognition (experiment 1) and expression tasks).

***3.2.1 Participants.*** We contacted the same 20 BBC participants who took part in Experiment 1 to enquire as to whether they would be willing to complete a further experiment. Nine of the 20 BBC group returned and participated in experiment 2. The final sample comprised 6 females and 3 males with an average age of 24.4 years.

***3.2.2 Materials.*** Stimuli consisted of fifty-six images displaying 6 Facial Action Coding System (FACS)-coded facial expressions of emotion ('Happy', 'Surprise', 'Fear', 'Disgust', 'Anger' and 'Sadness') plus 'Neutral' (Matsumoto and Ekman, 1988). Gender and race (East Asian and Western Caucasian) of faces was equally distributed across expressions. Images were cropped using Adobe™ Photoshop CS™ and aligned the eye and mouth positions using Psychomorph software. Images (280 x 380 pixels) were viewed on a 800 x 600 pixel white background using a

21” Iiyama HM204DTA monitor (refresh rate of 170 Hz) at a distance of 60 cm, and thus subtended 10° (horizontally) x 14° (vertically) of visual angle.

***3.2.3 Eye-Tracking*:** We followed the same procedures as in experiment 1 above.

***3.2.4 Procedure.*** Participants performed a 7-AFC facial expression categorization task using the following categorical labels: ‘Happy,’ ‘Surprise,’ ‘Fear,’ ‘Disgust,’ ‘Anger’ and ‘Sadness,’ plus ‘Neutral.’ Each participant completed 336 trials (48 trials per expression), divided into 6 blocks each containing 56 trials. As in experiment 1, we presented images in random locations on the monitor and each image remained visible until participants responded. Participants provided verbal responses to eliminate eye movements towards response keys and were recorded by the experimenter. Prior to testing, we established participants’ familiarity with the categorical labels by asking each participant to provide correct descriptions and synonyms of each emotion.

**3.2.5 Data analyses.** As in Experiment 1, we analyzed only correct trials. Similar to Jack et al. (2009), the patterns of fixations displayed by individual BBC participants were consistent across all 7 facial expressions. Owing to the lack of variability between fixation maps for individual expressions and our primary interest being the general strategy used by individual participants for classifying expressions, we collapsed the fixation maps across expressions for analysis.

**3.3 Results**

**3.3.1 Accuracy:** A 2 (Race of faces) x 7 (Expression) repeated measures ANOVA conducted on accuracy revealed a main effect of expression ($F(1,6) = 4.227$, $p<.001$, $\eta_p^2 = .185$). Post-hoc Bonferroni corrected comparisons revealed the following significant differences: Happy vs.

Neutral ($p$ < .017), Happy vs. Fear ($p$ < .006), and Happy vs. Anger ($p$ < .022). Inspection of the mean accuracy for individual expressions reveals that these significant differences are due to the near ceiling accuracy shown for Happy, as opposed to a deficit for other expressions.

As shown in Figure 5, behavioral performance for individual expressions suggests that BBC participants do not share the same deficit for fear and disgust that been previously reported by Jack et al. Using the data from Jack et al., a one-way ANOVA conducted on mean categorization accuracy revealed a significant difference between groups of participants ($F(2) = 11.282$, $p<.001$). Post hoc Bonferroni corrected comparisons verified that behavioral performance of BBC participants performed significantly more accurately than East Asian observers ($t(62) = 2.232$, $p < .029$), and comparably with Western Caucasian observers (($t(62) = 1.390$, $p = .169$).

**INSERT FIGURE 5 ABOUT HERE**

### 3.3.2 Eye Movements & Number of fixations

We conducted a 2(Race of Face) x 7(Expression) repeated measures ANOVA on the total number of fixations used by observers to correctly categorize each facial expression. Results showed a main effect of Expression only ($F(1,6) = 5.442$, $p<.001$) with post hoc Bonferroni corrected comparisons revealing significant differences between the following contrasts: Happy (7.81) vs. Anger (11.00), Happy vs. Sad (11.56) and Surprise (6.87) vs. Sad.

### 3.3.3 Eye movements: Individual Analysis

Given the findings from experiment 1, we did not perform a group analysis, but instead analyzed each participant's data separately. Using the data from Jack et al. (2009) as 'Eastern' and 'Western' templates, we compared each individual BBC participant's fixation map (collapsed across expressions) against both templates using the same procedure as described in Experiment 1. The materials and methods used by Jack et al. were identical to the current study again making the templates ideally suited for making this comparison. The classifying procedure revealed that 7 out of 9 BBC participants more closely matched the Eastern template (See figure. Then, looking at the consistency of individual participant strategies across the two experiments, we found that the 7 participants who completed both experiments displayed consistent 'Eastern' or 'Western' strategies across tasks. Of these 7 participants, 6 showed 'Eastern' strategies in both tasks and 1 showed a consistent 'Western' strategy.

**3.4 Discussion**

Similar to EA adults (Jack et al., 2009), the majority of BBC participants displayed 'Eastern-style' strategies with the majority of fixations clustered around the eye region. Strikingly, despite not directing fixations to the bottom half of the face like WC observers, their behavioral performance was not impaired unlike the EA participants in Jack et al. In their paper, Jack et al. provided two explanations for the behavioral deficit displayed by their EA participants. First, they showed that the overuse of the eye region prohibits reliable discrimination of certain expressions (e.g., fear vs. surprise), as demonstrated by the use of a model observer built to simulate the performance of the EA group. Second, they argued that FACS-coded faces may represent expressions that are based on Western norms and subsequently EA participants struggle to accurately classify certain facial expressions, most notably fear and disgust. The results from the current study are not consistent with the first of these explanations as the BBC participants performed as competently as WC adults despite deploying the same strategy as EA adults. However, the current results are consistent with their second account. As described above, the BBC population were born in the U.K. and have spent their entire lives there. Consequently, they are familiar with the *transmission* of 'Western facial expressions' and might have developed with experience effective representations allowing them to avoid a significant recognition *decoding* deficit.

**4.1 Questionnaires**

Although the consistency of strategies across tasks within the BBC group suggests that eye movements displayed in one task might be a good predictor of strategy in a second task, it is evident that the cultural strategy deployed by an individual cannot be simply predicted by the organization of society (i.e., individualist or collectivistic) in which they reside. We then considered the possibility that each individual's cultural outlook and behavior could be dynamically modulated by their environment. For example, in the case of the BBC participants, we reasoned that their life at home with their parents was likely to be quite 'Eastern,' whereas at school or work the environment will inevitably be more 'Western'. In order to formally investigate this hypothesis, we administered the individualism-collectivism scale (INDCOL) questionnaire (Hui, 1988) to each of the original BBC population. The INDCOL questionnaire assesses the individualist vs. collectivistic tendencies of a person within a variety of social settings, such as at home, at work or socializing with friends. In addition to the BBC population, we asked 10 European adults (5 male, 5 female) to complete the same questionnaire. The European adults selected for comparison were matched for age (mean =25.8 years) with the BBC population and had all spent their entire lives in European nations and were only informed about the eye-tracking experiments after completing the questionnaire.

Surprisingly and disappointingly, the questionnaires failed to reveal any significant differences between populations or within the BBC population itself or reveal any trend or pattern. Some participants scored highly for collectivist tendencies and others highly individualist, but none of these scores correlated with the fixation maps. Finally, we investigated whether Chinese language proficiency in speaking and writing was predictive of the fixation strategy deployed by the BBC observers, but once again we failed to identify a relationship between those variables (i.e., BBC subject with very poor Chinese speaking skills and no Chinese writing skills deploying an EA fixation pattern).

**5.1 General Discussion**

Contrary to our initial expectations, the eye movement strategies displayed by the BBC population in experiment 1 closely resembled Eastern Asian's fixation maps as reported by Blais et al. (2008). Furthermore, the strategies used in experiment 2 closely matched those reported in East Asian adults by Jack et al. (2009). However, inspection of fixation strategies at the individual level revealed that averaging across the population masked within-group variability, which was not observed previously within WC or EA populations. While the majority of participants used 'Eastern' eye movement strategies when completing identity and expression tasks, approximately 25-30% of the BBC population employed a 'Western' strategy. In addition, the type of strategy used by each individual (i.e. 'Eastern' or 'Western') was largely consistent across tasks. Despite variability in eye movement patterns, behavioral performance was comparable across individuals in both tasks. It appears that in terms of eye movements, there is more than one way to achieve successful face recognition and expression classification. Although the underlying reasons for such diversity are not fully apparent, when the results from the current study are considered collectively with previous findings, a clearer picture is beginning to emerge.

As described in the introduction, an ever growing body of literature is revealing profound differences in the way people from Eastern and Western cultures reason and process information in their visual world (Nisbett & Miyamoto, 2005). At the centre of this literature is the notion that *culture itself* plays a pivotal role in shaping the minds of the individuals it encompasses. Nonetheless, the leap from differing societal organization to eye movements and cognitive processing is substantial. Yet, the similarities between the observations made in the perceptual literature and those that we have reported here are difficult to dismiss out of hand. Furthermore, evidence for culturally modulated cortical activation as measured by fMRI is gradually building, with differences in active brain regions found for object processing (Gutchess, Welsh, Boduroglu, & Park, 2006) arithmetic processing (Tang et al., 2006), self-representation (Zhu, Zhang, Fan, & Han ,2007), emotion processing (Chiao et al., 2008) and perceptual judgments (Hedden, Ketay, Aron, Markus, & Gabrieli, 2008). Moreover, a recent study has provided evidence that the same gene can produce different behavioral outcomes as a function of cultural modulation. Kim et al. (2010) studied the serotonin (5-HT) system in Korean and European American adults, as it is known to be associated with attentional focus and cognitive flexibility. In particular, they explored the role of the C(-1019)G 5-HTR1A gene, which inhibits 5-HT release. The G allele of 5-HTR1A is associated with reduced cognitive flexibility whereas the C allele is not. The authors predicted that individuals (of both races) homozygous with the G allele would have a reduced ability to adapt cognitively and would therefore display their cultural mode of reasoning more robustly relative to those homozygous with the C allele. The mode of participant's reasoning was measured by the Analysis-Holism scale (Choi, Koo, & Choi, 2007) and genotyping assessed from saliva or cheek swabs. The author's predictions were fully supported, with both Koreans and European Americans homozygous for the G allele showing strong tendencies for their culture's mode of thought (i.e. Holistic for Korean and Analytical for Americans). By contrast, participants homozygous for the C allele did lean towards their cultural mode of thinking, but not to the same extent as the G allele group. This demonstration of a gene by culture interaction reveals social forces can shape the phenotypic expression (at least of some genes), which ultimately led to different cognitive processing styles.

Our data also suggest that cultural perceptual differences might be shaped by the early ontogenetic and social experience. It has been shown that Western and Eastern mothers are different in the way they interact with their children while playing (Bornstein, Toda, Azuma, Tamis-LeMonda, & Ogino, 1990; Fernald & Morikawa, 1993). Western mothers tend to label toys (e.g., "look at the rabbit") and focus the attention of their children towards attributes (e.g., the rabbit is white, has long ears etc.), whereas Eastern mothers emphasize the relationship of objects within a context (e.g., the rabbit eats carrots, jumps on the grass, etc.) and rely more on verbs than nouns (Tardif, Gelman, & Xu, F, 1999; Tardif, Shatz, & Naigles, 1997). From the interviews we performed after the experiments, it is apparent that the BBC population we have tested was not confronted with a Western culture before attending compulsory school classes. This observation supports the view that very early life experiences are a critical factor in forging cultural perceptual biases.

An auxiliary finding from experiment 1 is that the BBC population did not display any evidence of the 'other-race effect' (ORE). The ORE is a well documented phenomenon whereby people are typically more accurate at recognizing faces from their own-race relative to faces from other-races (see Hancock & Rhodes, 2008 for a review). The results from our study support the commonly help belief that the ORE arises from a lack of experience or exposure to other-race faces; this is known as the 'contact hypothesis' (Brigham & Malpass, 1985). Although support for the contact hypothesis has been mixed (see Meissner & Brigham, 2001 for a review), there is general consensus that experience with other-race faces facilitates accurate individuation. The BBC population has been heavily exposed to both Chinese and Caucasian individuals and confronted with the recognition of faces of both races at the individual level on a day-to-day basis. Therefore, their equal proficiency for face recognition with both categories of faces is not surprising.

As described above, previous studies (e.g., Norenzayan et al., 2002) have reported that Asian Americans, who are akin to the BBC population, do not display a clear analytical or holistic processing style, but instead fall in between these two strategies. The initial group analysis conducted in the current study revealed a similar ambiguous pattern of results, but individual participant analysis showed that in fact two distinct strategies existed within the population. This raises the possibility that when previous studies have only reported group effects for Asian

American participants and found a ‘middle-ground’ processing style; they may have inadvertently amalgamated two distinct strategies. Although this is not certain, the results from the current study invite caution when working with different cultural groups and highlight the importance of individual participant analysis, especially when working with particular populations, such as the BBC.

It is critical to understand the relationship between eye movements and the underlying cognitive processes involved in identity and expression recognition. More importantly, the variance in eye movements reported in the current and previous studies coupled with near identical behavioral performance between- and within-populations demonstrates that there is more than one way to extract the required diagnostic facial information without detrimentally impacting upon accuracy. Numerous authors have reported that unlike objects, faces are processed holistically (e.g., Hole, 1994; Le Grand, Mondloch, Maurer, & Brent, 2004; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987). In other words, rather than processing facial features independently, the face is perceived and processed as a whole unit or Gestalt. However, it has also been argued that other-race faces may be processed more analytically (i.e. by attending to individual features; Tanaka & Farah, 1993). It is critical to note that the eye movements we report are consistent with the general differences in processing strategies as defined in the cultural literature, but they do not inform us about with *holistic* or *featural* face processing. However, a related study has shown that the divergent cultural eye movement strategies seen for human faces also extend to sheep faces and *greebles*, suggesting that there is no straightforward relationship between eye movements and the underlying cognitive processes involved in human face processing (Kelly, Miellet, & Caldara, 2010).

## 6.1 Conclusions

Thought, behavior, eye movement and cognitive processes can be shaped by cultural forces. Future work will need to focus on how culture exerts its influence across ontogeny, but evidence from developmental studies and populations such as adoptees will bring us close to understanding this intriguing interaction.

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**Figure and Table Captions**

Figure 1. BBC participant's Recognition Accuracy and Reaction Time for Asian and Caucasian faces

Figure 2. Group Fixation Maps. Significantly fixated areas delimited by white lines.

Figure 3. Classifier Templates. 'Eastern' templates marked by green box. 'Western' template marked by red box.

Figure 4. Experiment 1: Individual participant's fixation maps and results from classification procedure. 'Eastern' strategies marked by green boxes. 'Western' strategies marked by red boxes.

Figure 5. Expression classification accuracy results from BBC, EA and WC populations (Data for EA and WC populations taken from Jack et al. 2009).

Figure 6. Experiment 2: Individual participant's expression fixation maps and results from the classification procedure. 'Eastern' strategies marked by green boxes. 'Western' strategies marked by red boxes.

Table 1. Average number of fixations (Standard deviations in parentheses) made during learning and recognition phases for Western Caucasian and East Asian faces.

Table 2. Experiment 1: Correlation results from the classification procedure.

Table 3. Experiment 2: Correlation results from the classification procedure.