Title

Culture shapes 7-month-olds' perceptual strategies in discriminating facial expressions of emotion.

Authors

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Main text

Emotional facial expressions are considered adaptive universal signals that emerged through phylogenetic evolution because of their crucial role for the survival of social species. From infancy, humans develop dedicated neural circuits [1] to exhibit and recognize a variety of facial expressions [2]. However, increasing evidence has shown instead that culture not only specifies when and how certain emotions can be expressed – i.e., social norms – but the mature perceptual mechanisms used to transmit and decode the visual information from emotional signals also differ between Western and Eastern adults [3-5]. Specifically, the mouth is more informative for transmitting emotional signals in Westerners and the eye region for Easterners [4], engendering culture-specific fixation biases towards these features [5]. During development, it is recognized that cultural differences can be observed at the level of emotional reactivity and regulation [6], and to the culturally dominant modes of attention [7]. Nonetheless, no study has ever explored whether culture shapes the processing of facial emotional signals early in development. Our data show that by 7 months infants from both cultures visually discriminate facial expressions of emotion by relying on culturally distinct fixation strategies, resembling those used by the adults from the environment in which they develop [5].

We used we used a visual discrimination paradigm, based on the principles of familiarization and novelty preference, on 7 month-old Western Caucasian (WC - born and raised in the UK; N = 77) and East Asian (EA) infants (born and raised in Japan; N = 76), while tracking their

eye movements. Infants were familiarized with one emotional expression (i.e., fear or happiness) across different facial identities (*familiarization* phase), followed by the presentation of pairs of faces displaying the familiarized emotion alongside the novel one (*test* phase) (Figure S1A-B, Supplemental Information - SI). Half of the infants were familiarized to fear, the other half to happiness. The race of the faces (own- *vs.* other-) was kept constant across *familiarization* and *test* phases and manipulated between participants. The visual preference during the *test* phase indicates infants' ability to discriminate between facial expressions of emotion. To determine the perceptual strategies infants used to accomplish the discrimination task, we tracked infants' eye movements during both the *familiarization* and *test* phases.

A data driven analysis method based on robust non-parametric statistics [8] revealed that during the *familiarization* phase (Figure S1D) WC infants fixated significantly more on the mouth compared to EAs. EA infants showed a significant bias towards the eye region and displayed longer fixations on the eyes than WCs (Figure 1A). Crucially, the facial expression and the race of the faces did not alter infants' fixation strategies. These cultural differences in eye movements are in line with those previously reported in adults for emotional recognition [5], and distinct from those typically found when infants [9], children [10] and older adults extract face identity information. To then assess whether infants discriminate between emotional facial expressions during the *test* phase, we applied a multivariate generalized linear model and novel 2D-surface visualization (Figure 1B-D). All infants looked longer towards fearful compared to happy faces (Figure 1B). Also, as a result of familiarization, they fixated longer the novel compared to the familiarized emotional expression (Figure 1C), which indicates an effective expression discrimination. The viewing bias towards the fearful expression (i.e., longer fixation duration) was reduced when the infants were familiarized with own-race fearful faces (Figure 1D), while, importantly, the culturally specific perceptual strategies remained unchanged. In addition, we applied unsupervised clustering using a Gaussian mixture model to quantify the fixation strategy between *familiarization* and *test* phases (see SI). Importantly, the analysis of the relation between the fixation patterns during the *familiarization* and *test* phase showed that the cultural fixation bias is consistently present at the individual level in infant observers (Figure S2B). The strength of this fixation bias was weaker in WC infants after familiarization to fearful faces, compared to the EA infants whom *persistently* fixated the eye region regardless of task demands such as exploration and discrimination of emotional facial expressions (Figure S2C).

The acquisition of effective representations in infants for discriminating facial expressions is based on an optimal combination of neural systems dedicated to the processing of emotion and their refinement through experience [1]. Our results show that culture-specific early experience can determine the information intake for the biological neural circuitry. Eastern and Western 7-month-old infants effectively discriminate happy and fearful faces, but the pattern of eye movements used to reach this developmental milestone differ. These culturally-specific information sampling biases resemble the previously reported eye movement fixation mappings in adults [5], with the Easterners focusing more toward the eye region while processing facial expressions and Westerns focusing more on the mouth [4]. These differences in the informative value of face areas during emotion communication are also reflected in the use of emoticons, with Eastern adults reporting predominantly changes in expressions through the eyes ^_^ T_T (i.e., happy and sad) and for the Westerners through the mouth respectively :-) :-(. The cultural environment, such as parental practices, may also contribute in several ways to the development of these scanpath differences. Asian mothers use less emotional expressivity and more non-direct body contact stimulation than the Western ones [6], which could lead to Asian infants' increased attention to the culturally-specific facial emotional signals in the eye region. This attentional strategy may be further reinforced by other culturally driven parental practices for promoting learning throughout childhood, consolidating into the diverse modes of attention observed in older children and adults [7]. Overall, our findings show that culture heavily shapes the development of perceptual strategies used to process biologically-relevant social signals from an early stage in life.

Supplemental Information

Supplemental Information includes experimental procedures and two figures and can be found with this article online at *bxs.

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References

1. Leppänen, J.M., and Nelson, C.A. (2009). Tuning the developing brain to social signals of emotions. Nat. Rev. Neurosci. *10*, 37-47.

2. Hoehl, S. (2014). Emotion processing in infancy. In Children and Emotion: New Insights into Developmental Affective Science, K.H. Lagattuta, ed. (Basel: Karger), pp. 1-12.

3. Jack, R.E., and Schyns, P.G. (2015). The human face as a dynamic tool for social communication. Curr. Biol. *25*, 621-634.

4. Jack, R.E., Garrod, O.G.B., Yu, H., Caldara, R., and Schyns, P.G. (2012). Facial expressions of emotion are not culturally universal. Proc. Natl. Acad. Sci. USA *109*, 7241–7244.

5. Jack, R.E., Blais, C., Scheepers, C., Schyns, P.G., and Caldara, R. (2009). Cultural confusions show that facial expressions are not universal. Curr. Biol. *19*,1543-1548.

6. Kisilevsky, B.S., Hains, S.M., Lee, K., Muir, D.W., Xu, F., Fu, G., Zhao, Z.Y., and Yang, R.L. (1998). The still-face effect in Chinese and Canadian 3-to 6-month-old infants. Dev. Psychol. *34*, 629–639.

7. Senzaki, S., Masuda, T., Takada, A., and Okada, H. (2016). The communication of culturally dominant modes of attention from parents to children: a comparison of Canadian and Japanese parent-child conversations during a joint scene description task. PloS One, *11*, e0147199.

8. Lao, J., Miellet, S., Pernet, C., Sokhn, N., and Caldara, R. (2016). *i*Map4: An Open Source Toolbox for the Statistical Fixation Mapping of Eye Movement data with Linear Mixed Modeling. Behav. Res. Methods. 10.3758/s13428-016-0737-x (online publication date: 03 May 2016)

9. Wheeler, A., Anzures, G., Quinn, P.C., Pascalis, O., Omrin, D.S., and Lee, K. (2011).

Caucasian infants scan own-and other-race faces differently. PLoS One, *6*, e18621.

10. Kelly, D.J., Liu, S., Rodger, H., Miellet, S., Ge, L. and Caldara, R. (2011). Developing cultural differences in face processing. Dev. Sci. *14*, 1176-1184.

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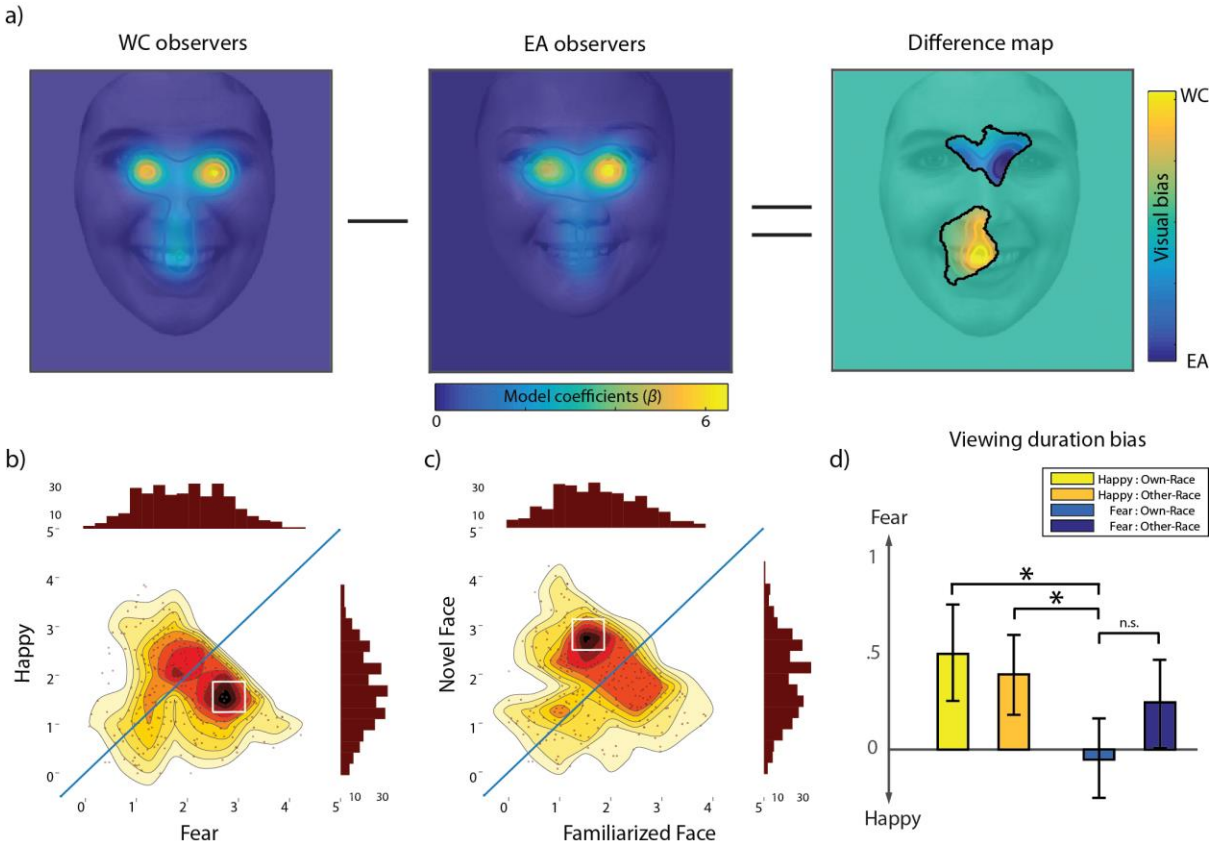
Figure legend

Figure 1. Testing cultural differences in emotional face exploration and discrimination.

(A) The spatial modelling of the fixation patterns was conducted using *i*Map4, a data-driven framework for statistical fixation mapping ([8] - see SI for more details). Pixel-wise ANOVA on the model coefficients of the linear mixed model (Eq. s1) revealed a significant main effect of *Culture* on the mouth and the nose area and a significant main effect of *Culture* around the eye region. By performing a linear contrast between WC and EA infants, our data show that WC infants fixated more on the mouth compared to EAs, whereas EA infants showed a bias towards the eye region and displayed longer fixation duration on the eye than WCs (detail statistical values are reported in SI).

(B, C, D) To disentangle the effect of viewing duration of the *test phase*, we applied a multivariate generalized linear model and a novel visualization of the effect on a 2D surface. Linear contrast on the multivariate generalized linear model coefficients (Eq. s2 in SI) revealed the effect of facial expression during the *test phase* (B). Infants showed a strong fixation bias towards fearful compared to happy faces, looking longer at the fearful ($M_{viewing\ duration}$ = 1.95s [1.853, 2.051]) than at the happy faces ($M_{viewing\ duration}$ = 1.68s [1.589, 1.772]; F (1, 596) = 16.00, p = 7.119e-05; brackets show bootstrapped 95% confidence interval). This bias for facial expressions is presented as a 2D surface with the estimated density peak showed in white square (more details in SI). Moreover, we found a main effect of familiarity (C), as infants fixated longer on the novel expression ($M_{viewing\ duration}$ = 1.90 [1.807, 2.000]) compared to the familiarized expression ($M_{viewing\ duration}$ = 1.73 [1.633, 1.831]; F (1, 596) = 6.61, p = .0104). We also found a significant *Culture* difference in the fearful face bias (F (1, 596) = 3.95, p = .0473), whereas the *Culture* difference in the novel face bias is not significant (F (1, 596) = 1.12, p = .2691). Importantly, as shown in (D), the viewing bias towards fearful expressions is reduced when the infants were familiarized with fearful faces, thus explaining the main effect of *familiarity*. Infants familiarized with own-race fearful faces showed the least viewing bias towards fear compared to the other three conditions (F (3, 596) = 3.09, p = .0266). Error bars report 95% bootstrapped CI.


a)
WC observers
EA observers
Difference map
WC
Visual bias
EA
Model coefficients (β)
0
6
b)
Happy
Fear
c)
Novel Face
Familiarized Face
d)
Viewing duration bias
Happy : Own-Race
Happy : Other-Race
Fear : Own-Race
Fear : Other-Race
Fear
Happy
n.s.

Supplemental Information

Document S1. Experimental Procedures and Two Figures