Cultural Differences in the Effect of Mask Use on Face and Facial Expression Recognition

Yueyuan Zheng
mercuryzheng@connect.hku.hk
Department of Psychology,
University of Hong Kong

William G. Hayward
willhayward@ln.edu.hk
Department of Psychology,
Lingnan University

Sarah de la Harpe
sarahhilary.delaharpe@research.uwa.edu.au
School of Psychological Science,
University of Western Australia

Romina Palermo
romina.palermo@uwa.edu.au
School of Psychological Science,
University of Western Australia

Angeline Y. Yang
angelineyang@berkeley.edu
UC Berkeley

Janet H. Hsiao
jhsiao@hku.hk
Department of Psychology,
The State Key Laboratory of Brain and Cognitive Sciences, and
Institute of Data Science,
University of Hong Kong

Abstract

We examined whether mask use had differential impacts on face and facial expression recognition across cultures, as cultures associated with more eyes-focused face scanning strategies may be less affected. Asian and White participants performed face and facial expression recognition with unmasked and masked Asian and White faces. White participants attended more to the eye region in both tasks; however, their performance was less impaired by mask use only in facial expression recognition. In both tasks, individuals adopting more eyes-focused strategies for unmasked faces were less impaired by mask use. Also, participants had larger performance impairment for judging expressions of Asian than White faces, consistent with the finding that they adopted more nose-focused strategies for Asian than White faces. Thus, although individuals from different cultures or expression recognition of different races may be affected differentially by mask use, these effects may be better explained by individual differences in preferred attention strategies.

Keywords: eye movements; EMHMM; face recognition; mask; emotion recognition

Introduction

With the persistence of the COVID-19 pandemic, protective measures including mask-wearing have become a common practice in many countries, especially in Asia. Since adults process faces holistically with automatized attention (Richler et al., 2012; Richler et al., 2011), the occlusion of the lower half of a face due to mask use may significantly disrupt face perception and categorization in various dimensions, including identity, emotion, gender, and age (Fitousi et al., 2021; Tso et al., 2022; Ramdani et al., 2022). Previous studies have reported that people from different cultures may view faces differently and also process own- vs other-race faces differently (e.g., Wong et al., 2023; Hsiao & Chan, 2023). Thus, mask use may have differential impacts on face processing across cultural groups and for faces of different races. Here we aim to examine this issue in face recognition and facial expression recognition, two critical tasks during daily social interactions, through eye tracking.

In face recognition, Asian participants were found to look more often at the face center whereas White participants looked more at facial features, particularly the eyes (Blais et al., 2008; Kelly et al., 2011; Cheng et al., 2018). Previous research has reported that adults develop consistent eye movement strategies for faces over time (Hsiao, An, et al., 2022) and deviation from their preferred strategy impairs face recognition performance (Peterson & Eckstein, 2013). Since recognizing faces with a mask may require more attention to the eye region, individuals who typically attend to the eyes may have less demand to adjust their attention strategies, leading to less performance impairment due to the mask. Accordingly, White participants may be less affected by mask use when identifying faces.

However, this cultural difference in attention strategy has not been consistently reported. Some studies have reported no difference in eye movement pattern between Asians and Whites (Or et al., 2015). Instead, individuals differ in their preference of using more eyes- or nose-focused attention strategies across cultures (Chuk, Crookes et al., 2017). Thus, individual differences in preferred attention strategy may better account for face recognition performance impairment due to mask use than culture. Performance impairment due to mask use may also depend on one's cognitive abilities. For example, individuals with better abilities to adjust attention strategies according to mask conditions during face learning were shown to have less impairment in recognition performance (Hsiao, Liao et al., 2022).

Differences in attention strategy have also been observed in viewing own- vs. other-race faces. For example, Chinese adults had increased attention to the eyes of White faces as compared with Chinese faces (Fu et al., 2012). This strategy difference may be related to the other-race effect (ORE) observed in the literature: individuals recognize faces of their own race better than those of other races (Meissner & Brigham, 2001; Stelter & Schweinberger, 2022). Note however that while the ORE has been well observed in White participants, it has not been consistently reported in Asian (Wong et al., 2021; Burgund, 2021) and Black participants (Stelter et al., 2023), or with effect stronger in Whites than in Asian and Black observers (Chuk, Crookes et al., 2017; Stelter et al., 2023). An association between the ORE and eye movement behavior has been reported: directing participants'

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eye gaze to diagnostic features such as the eyes for White faces and the nose and mouth for Asian and Black faces is shown to facilitate recognition performance (Hills & Pake, 2013; Hills, Cooper, et al., 2013). This finding suggested that cultural difference in attention strategy may also be related to physiognomic characteristics of faces. It also suggested that mask use may impair the recognition of Asian faces more than White faces due to the covering of diagnostic features in the nose and mouth regions.

Accordingly, we hypothesized that in face recognition, White participants may have less change in attention strategy and less performance impairment than Asian participants. In addition, individual differences in preferred attention strategy for face processing may be associated with differences in performance impairment due to mask use. Also, the recognition of Asian faces may be affected more by mask use than White faces.

Cultural differences in attention strategies have also been reported in facial expression recognition: Asians fixated more on the eyes than the mouth whereas White participants attended to all facial features equally (Jack et al., 2009; Caldara, 2017). This attention strategy difference may be related to performance differences across cultures. For example, Shioiri et al. (1999) reported that White observers performed better in identifying emotions of both own- and other-race faces than Asians (e.g., Shioiri et al., 1999). Jack et al. (2009) showed that Asian participants had poorer performance in identifying anger/disgust and surprise/fear expressions due to decreased attention to the diagnostic mouth region as compared with White participants (Yitzhak et al., 2020). Since White individuals may use more features from the lower half of the faces than Asians, they may be more affected by mask use. Indeed, a recent study reported that White Americans recognized emotions better but had larger performance impairment due to mask use than Asian (Korean) participants (Kang et al., 2021). However, people adjust their attention strategies with more experience with masked faces (Barrick et al., 2021).

Differences in attention strategies have also been observed in recognizing expressions of faces of different races. For example, Chinese participants looked at the eyes of Asian (own-race) faces longer than White (other-race) faces (Ma et al., 2022). These attention strategy differences may also be related to differences in how emotions are expressed across cultures. For example, expressions of White faces were argued to be generally more expressive than those of Asian faces and thus were better recognized (e.g., Ma et al., 2022). Jack et al. (2012) showed that expressions of White faces featured more in the eyebrows and mouth, whereas expressions of Asians featured more in the eye region. Given these differences, mask use may impact the recognition of expressions of faces of different races differentially.

Accordingly, we hypothesized that in contrast to face recognition, Asian participants may have less change in attention strategy and less performance impairment in facial expression recognition due to mask use. Also, the recognition of expressions of White faces may be affected more than those of Asian faces. However, similar to face recognition, individual differences in preferred attention strategy for facial expression recognition may be associated with differences in performance impairment due to mask.

Method

Participants

We recruited 48 Asian adults (28 females, 19-40 years old, M = 22.45, SD = 4.27) in Hong Kong SAR and 32 White adults (26 females, 17-47 years old, M = 23.72, SD = 8.98) in Perth, Australia[1]. Asian participants had significantly more contact with Asians than White participants, $t(78) = 8.24$, $p < .001$, $d = 1.88$, and vice versa for White participants, $t(78) = 11.29$, $p < .001$, $d = 2.58$, based on self-reported Racial Contact Questionnaire (McKone et al., 2019). Participants had normal or corrected-to-normal vision with no diagnosed neurodevelopmental disorder or brain injury.

Design

Face Recognition Task The design consisted of a between-participant variable participant group (Asian vs. White) and three within-participant variables face race (Asian vs. White), mask condition during learning (masked vs. unmasked), and mask condition during recognition (masked vs. unmasked). The dependent variables were recognition performance in discrimination sensitivity d’ and eye movement pattern during recognition as quantified using Eye Movement analysis with Hidden Markov Models (EMHMM; Chuk et al., 2014). ANOVA was used for the analysis. In addition, we focused our examinations on the mask effect under three scenarios defined using the 4 conditions in Table 1: (1) Effect of mask use during learning (Condition 4 - Condition 2) where the mask condition was manipulated only during face learning; (2) Effect of mask use during recognition (Condition 4 - Condition 3) where mask condition was manipulated only during face recognition; (3) Effect of mask use in the whole face recognition task (Condition 4 - Condition 1) where mask conditions during learning and recognition were manipulated at the same time. For each scenario, the mask effect was calculated as (baseline condition - mask condition) / (baseline condition + mask condition), which normalized for individual differences in overall performance level/behavior. In these planned examinations on the normalized mask effect, ANOVA was used with a between-participant variable participant group (Asian vs. White) and a within-participant variable face race (Asian vs. White). Pearson’s correlation was used to examine whether a person’s preferred attention strategy for faces (i.e.,

[1] According to a power analysis, to test the expected 2 (participant group: Asian vs. White) x 2 (face race: Asian vs. White) mixed design for face recognition and facial expression recognition tasks, the sample size required is 90, assuming a small to medium effect size f = 0.15, a = 0.05, power = 0.8. Here we presented our preliminary findings based on 80 participants.

the baseline condition) predicted the impact of mask use on face recognition performance.

Table 1: The four combinations of mask conditions in the face recognition task

	Learning	Recognition
Condition 1	Masked	Masked
Condition 2	Masked	Unmasked
Condition 3	Unmasked	Masked
Condition 4 (baseline)	Unmasked	Unmasked

Facial Expression Recognition Task The design consisted of a between-participant variable participant group (Asian vs. White) and two within-participant variables face race (Asian vs. White) and mask condition (masked vs. unmasked). The dependent variables were recognition accuracy and eye movement pattern as measured using EMHMM. ANOVA was used. In addition, similar to the face recognition task, we calculated the normalized mask effect as a dependent variable and conducted ANOVA with a between-participant variable participant group (Asian vs. White) and a within-participant variable face race (Asian vs. White). Pearson's correlation was used to examine whether a person's preferred attention strategy for unmasked faces predicted the impact of mask use on facial expression recognition performance.

Apparatus and Materials

Participants' eye movements were recorded by an EyeLink 1000 eye tracker (desk mount model; SR Research) with a 1000 Hz sampling rate. Resolution of the monitor (19 inches) was 1440 x 900 pixels. A chinrest was placed in front of the monitor at a distance of 75 cm to minimize head movements. A keyboard was used to collect behavioral responses.

The stimuli of the face recognition task consisted of 256 colored frontal-view young-adult face images, with half Asians and half Whites. The faces of each race contained an equal number of males and females. All faces were in a neutral expression and were unfamiliar to the participants. The face images were edited to exclude external features. All face images were converted to grayscale and normalized in luminance distribution (histMatch) using the SHINE Toolbox (Willenbockel et al., 2010) to reduce the influence of face color on face processing. Faces were randomly divided into two groups as target and foil images. Each image was edited by adding a white mask to create a masked version. For each face identity, mask conditions during learning and recognition were counterbalanced across participants. The width of the faces was 6° of visual angle, equivalent to the size of a real face at a functional distance for face identification (~2m; McKone, 2009).

The stimuli of the facial expression recognition task consisted of 960 young adult face images with 6 emotion categories (happy, sad, angry, fearful, disgusted, and surprised; Ekman, 1992), 2 mask conditions (masked and unmasked) and 40 different face models for each race. Participants viewed each face model in either masked or unmasked condition only (480 images for each participant). For each face model, the mask condition was counterbalanced across participants. Face width was 6° of visual angle to be consistent with the face recognition task.

Procedure

Participants performed a face recognition and a facial expression recognition task with eye-tracking. The standard 9-point calibration and validation procedures were used before each block and whenever the drift check error was more than 1° of visual angle. Each trial started with a solid circle at the screen center for drift check. Participants looked at the dot when it appeared, and the experimenter pressed a key to present the stimulus. Each stimulus was randomly presented at one of the four quadrants to counterbalance the initial fixation direction to the face. All stimuli were presented away from the horizontal and vertical central lines of the screen with the same distance. They completed a racial contact questionnaire (McKone et al., 2019) and a demographic questionnaire at the end.

In face recognition, participants completed 8 blocks of the task, with each block consisting of a learning phase and a recognition phase. In the learning phase, participants viewed 16 face images one at a time, each for 5 s, and were asked to remember them for later recall. In the recognition phase, they were presented with old faces together with 16 new faces one at a time in a different lighting condition (to create variance in stimuli between the two phases) and judged whether they had seen the faces earlier. In each block, there were 4 stimuli in each of the four mask condition combinations (Table 1), and both Asian and White faces were presented.

In facial expression recognition, participants judged the facial expression of the presented face as accurately and quickly as possible by pressing corresponding buttons. 480 trials were presented in a random order in 10 blocks with 48 trials each. Each face was presented for maximum 5 s and disappeared once a response was detected.

Eye Movement Data Analysis

EMHMM was used to analyze eye movement data. A participant's eye movements in each of the mask and face race condition combinations were summarized using a hidden Markov model (HMM, a type of time-series statistical model in machine learning) in terms of personalized regions of interest (ROIs) and transition probability among the ROIs. The number of hidden states (i.e., ROIs) was automatically determined using variational Bayesian approach (McGrory & Titterington, 2009). The individual models were then clustered to discover two representative patterns, pattern A and B, using variational hierarchical expectation maximization (VHEM) algorithm (Coviello et al., 2014). Following previous studies (Hsiao, Lan, et al., 2021; Zheng & Hsiao, 2022), we quantified each participant's eye movement pattern in a condition using A-B scale, calculated as $(L_A - L_B) / (|L_A| + |L_B|)$, where L_A and L_B represent log-likelihoods of the participant's eye movement data being generated by pattern A and pattern B HMM respectively. The log-likelihood measure reflects similarity of a participant's eye movement to the representative patterns. More positive A-B scale indicates higher similarity to pattern A.

Results

Face Recognition Task

Effect of Mask on Recognition Performance

For recognition performance, a main effect of participant group was observed, $F(1, 78) = 16.27$, $p < .001$, $\eta^2_p = .17$: White participants performed better than Asian participants, $t(78) = 4.03$, $p < .001$. A main effect of face race was found, $F(1, 78) = 16.39$, $p < .001$, $\eta^2_p = .17$: Participants performed better for White than Asian faces, $t(78) = 4.05$, $p < .001$. There was also a main effect of mask condition during learning, $F(1, 78) = 96.17$, $p < .001$, $\eta^2_p = .55$, and a main effect of mask condition during recognition, $F(1, 78) = 7.29$, $p = .008$, $\eta^2_p = .09$, indicating poorer performance for faces with masks in either phase. An interaction between participant group and face race was observed, $F(1, 78) = 16.53$, $p < .001$, $\eta^2_p = .17$. The post-hoc analyses showed White participants performed better in recognizing White than Asian faces, $t(78) = 5.24$, $p < .001$, but no difference was observed in Asian participants, $p = 1.00$. There was also a 3-way interaction among participant group, mask condition during learning and mask condition during recognition (Figure 1), $F(1, 78) = 4.71$, $p = .033$, $\eta^2_p = .06$, and a 4-way interaction among participant group, face race, mask conditions during learning and mask condition during recognition, $F(1, 78) = 5.82$, $p = .018$, $\eta^2_p = .07$.

To better understand the interactions with mask condition, we examined how Asian and White participants differed in the (normalized) mask effect in the 3 different mask scenarios. No main effect of participant group or face race, or interaction between participant group and face race was observed in any of the 3 scenarios (ps > .05). This suggested that after normalizing the individual difference in overall performance level (in particular, there was a main effect of participant group in performance), the two participant groups did not differ in the mask effects and face race did not modulate the mask effects.

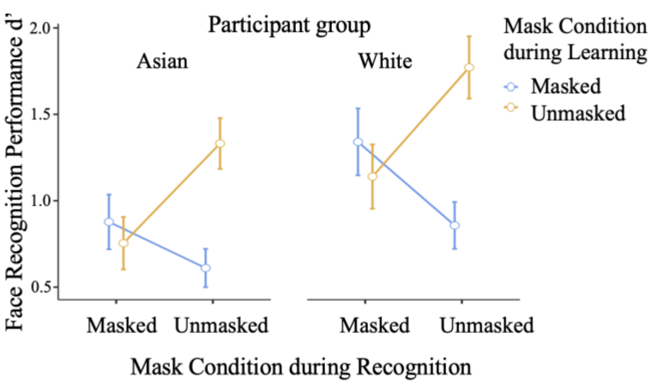

Figure 1: Face recognition performance across different mask conditions in Asian and White participants.

Effect of Mask on Eye Movement Pattern

Two representative eye movement patterns were discovered: eyes-focused and nose-focused patterns (Figure 2). This finding was consistent with previous EMHMM studies on face recognition (Chuk, Chan et al., 2017; Chan et al., 2018; An & Hsiao, 2021). After the first fixation at the face center to locate the face (red ROI: 95% probability), individuals adopting the eyes-focused pattern typically looked at the eye region at the second fixation (green and blue ROIs) and most likely stayed looking at the eye region afterward. In contrast, individuals adopting the nose-focused pattern started by looking at the face center (red ROI: 82%) and mainly continued looking at the face center. The two representative HMMs differed significantly according to KL divergence estimation, $F(1, 638) = 1196.70$, $p < .001$, $\eta^2_p = 0.65$.

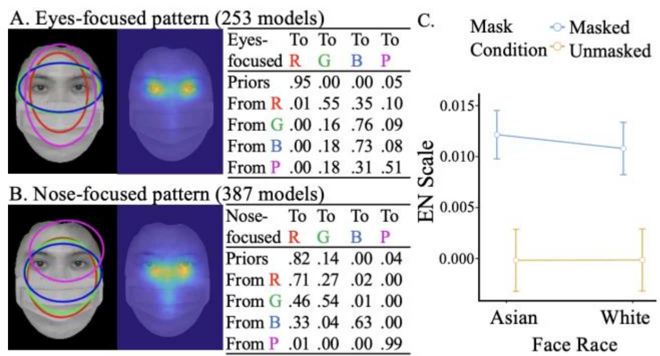

Figure 2: (A) Eyes-focused and (B) nose-focused patterns of the face recognition task. Ellipses show ROIs as 2-D Gaussian emissions. The table shows transition probabilities among the ROIs. Priors show the probabilities that a fixation sequence starts from the ellipse. The image in the middle shows the corresponding heatmap. (C) Eye movement pattern as measured in EN scale in different face race and mask conditions in face recognition.

We quantified participants' eye movement pattern using A-B scale, which we refer to as EN scale (Eyes-Nose scale) to be consistent with previous studies. In EN scale, there was a main effect of participant group, $F(1, 78) = 27.44$, $p < .001$, $\eta^2_p = .26$: White participants were more eyes-focused than Asian participants, $t(78) = 5.24$, $p < .001$. A significant main effect of face race was observed, $F(1, 78) = 4.96$, $p = .029$, $\eta^2_p = .06$: Participants were more eyes-focused for Asian than White faces, $t(78) = 2.23$, $p = .029$. There was also a main effect of mask condition during learning, $F(1, 78) = 14.64$, $p < .001$, $\eta^2_p = .16$, a main effect of mask condition during recognition, $F(1, 78) = 119.58$, $p < .001$, $\eta^2_p = .61$, and an interaction between face race and mask condition during recognition, $F(1, 78) = 4.56$, $p = .036$, $\eta^2_p = .06$ (Figure 2C): people were more eyes-focused for masked Asian faces than White faces, $t(78) = 2.86$, $p = .027$, but no face race effect was observed when they viewed unmasked faces, $p = 1.000$.

For the (normalized) mask effect on eye movement pattern, there was no main effect of participant group or face race, or interaction between participant group and face race in any of the 3 scenarios (ps > .05). This suggested that culture difference or face race did not modulate the mask effect on attention strategy.

Baseline Eye Movement Behavior and the Mask Effects

Correlation analysis showed that a more eyes-focused pattern at the baseline condition was associated with better recognition performance, r(78) = .31, p = .006, consistent with previous studies (e.g., Hsiao, An, et al., 2021). Consistent with our hypothesis, participants with a more nose-focused pattern at the baseline condition had larger impairment due to mask use (mask effect) during learning, r(78) = .36, p < .001, during recognition, r(78) = .33, p = .003, and during the whole task, r(78) = .41, p < .001.

Facial Expression Recognition Task

Effect of Mask on Recognition Performance

For recognition accuracy, a main effect of participant group was observed, F(1, 78) = 21.76, p < .001, η^2_p = .22: White participants performed better than Asian participants, t(78) = 4.66, p < .001. A significant main effect of face race was also observed, F(1, 78) = 156.47, p < .001, η^2_p = .67: Participants performed better for White than Asian faces, t(78) = 12.51, p < .001. Also, there was a main effect of mask condition, F(1, 78) = 850.18, p < .001, η^2_p = .92, an interaction between participant group and face race, F(1, 78) = 25.03, p < .001, η^2_p = .24, an interaction between face race and mask condition, F(1, 78) = 33.10, p < .001, η^2_p = .30, and a 3-way interaction among participant group, face race, and mask condition (Figure 3), F(1, 78) = 7.31, p = .008, η^2_p = .09.

For the (normalized) mask effect, there was a main effect of participant group, F(1, 78) = 4.08, p = .047, η^2_p = 0.05: Asian participants had larger impairment due to mask use than Whites, t(78) = 2.02, p = .047. A significant main effect of face race was observed, F(1, 78) = 798.31, p < .001, η^2_p = 0.91: Participants had larger impairment due to mask use for Asian than White faces, t(78) = 28.25, p < .001. No interaction effect was found. This suggested that masks induced larger impairment in Asian participants and for the recognition of Asian faces.

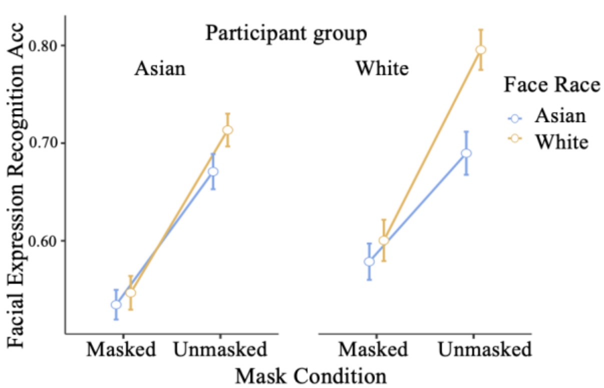

Figure 3: The interaction effect among participant group, mask condition and face race in expression recognition.

Effect of Mask on Eye Movement Pattern

Similar to the face recognition task, we discovered eyes-focused and nose-focused patterns (Figure 4) for facial expression recognition. The two representative HMMs differed significantly based on KL divergence estimation, F(1, 1918) = 4631.9, p < .001, η^2_p = 0.71. In EN scale, we observed a main effect of participant group, F(1, 78) = 7.64, p = .007, η^2_p = 0.09: White participants were more eyes-focused than Asians, t(78) = 2.76, p = .007. A significant main effect of face race was observed, F(1, 78) = 99.42, p < .001, η^2_p = 0.56: participants were more eyes-focused for White than Asian faces, t(78) = 9.97, p < .001. There were a main effect of mask condition, F(1, 78) = 277.88, p < .001, η^2_p = 0.78, t(78) = 16.67, p < .001, and an interaction between face race and mask condition, F(1, 78) = 61.47, p < .001, η^2_p = 0.44 (Figure 4C): people were more eyes-focused for White faces than Asian faces when viewing unmasked faces, t(78) = 10.34, p < .001, but no effect was observed when viewing masked faces, p = .907. This indicated that mask use reduced the effect of face race on eye movement pattern.

For the (normalized) mask effect on eye movement pattern, no main effect of participant group or face race, or interaction between them was observed in any of the 3 scenarios (ps > .05). This suggested that culture difference or face race did not modulate the mask effect on attention strategy.

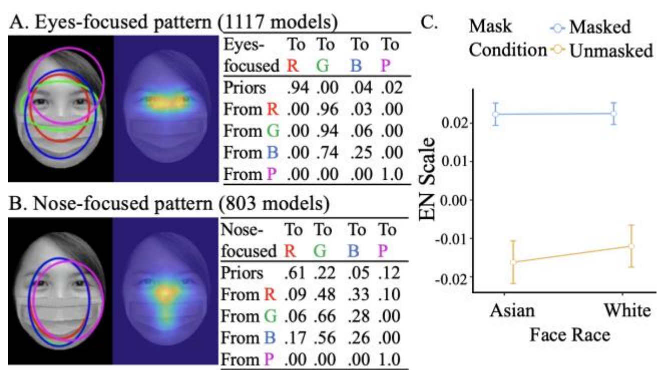

Figure 4: (A) Eyes-focused and (B) nose-focused patterns of the facial expression recognition task. (C) Eye movement pattern as measured in EN scale in different face race and mask conditions in facial expression recognition.

Baseline Eye Movement Behavior and the Mask Effects

In contrast to face recognition, a more eyes-focused pattern at the baseline condition was not significantly correlated with better recognition performance, r(78) = .15, p = .191. Consistent with our hypothesis, participants with a more nose-focused pattern at the baseline unmasked condition had larger impairment due to mask use in facial expression recognition, r(78) = .22, p = .048.

Discussion

Here we examined cultural differences between Asian and White participants in the impact of mask use on performance and attention strategy during face and facial expression recognition of Asian and White faces, and whether having a preferred attention strategy focusing more on the eye region was associated with reduced impairment due to mask use. Through a data-driven machine-learning-based approach, EMHMM, we discovered two representative eye movement patterns, eyes-focused and nose-focused patterns, in both face and facial expression recognition. In both tasks, White participants had more eyes-focused patterns and better recognition performance than Asian participants. However, White participants were less affected by mask use than Asian participants only in facial expression recognition, but not in face recognition. More specifically, after we normalized participants' mask effects by dividing them by their overall performance levels, there was no cultural group or face race difference in the mask effect in face recognition. This suggested that cultural difference or race of the faces did not modulate the impact of mask use on face recognition. In contrast, consistent with our hypothesis, participants who adopted more eyes-focused eye movement patterns in the baseline, unmasked condition had less performance impairment due to mask use in both face and facial expression recognition tasks. This finding suggested that individual differences in preferred attention strategy, rather than culture, play a more important role in accounting for variations in performance impairment due to mask use in both face and facial expression recognition.

Our finding that White participants adopted more eyes-focused strategies than Asian participants in face recognition was consistent with some previous studies (Blais et al. 2008; Kelly et al., 2011; Cheng et al., 2018). Since individuals adopting eyes-focused strategies were found to perform better in face recognition in the literature (e.g., Chuk, Chan et al., 2017; Hsiao, An, et al., 2021), the observed cultural difference in attention strategy may account for the finding that White participants outperformed Asian participants in face recognition performance. Indeed, eyes-focused strategy was positively associated with recognition performance in the current study, consistent with the literature. Note however that this cultural difference in attention strategy or recognition performance has not been consistently observed in the literature (e.g., Blais et al., 2008; Caldara et al., 2010). Chuk, Crookes et al. (2017) showed substantial individual differences in adopting eyes- or nose-focused strategies within either Asian or White participants, suggesting that individual differences in preferred attention strategy also play a more important role than culture in accounting for variations in recognition performance.

In contrast to face recognition, Asian participants had larger performance impairment due to mask use than White participants in facial expression recognition. This result was in contrast to Kang et al. (2021), where a larger performance impairment due to mask use was found in White than Asian participants. This inconsistency may be related to the higher performance level in White than Asian participants, which was consistently observed in both studies. After we normalized the mask effect in performance by dividing by overall performance level, Asian participants were shown to have larger performance impairment due mask use, consistent with the finding that they also generally used a more nose-focused strategy than White participants in facial expression recognition.

We also found that participants attended more to the eyes of White faces than Asian faces in facial expression recognition. In addition, participants had better recognition performance for White than Asian faces. Nevertheless, the correlation between eye movement pattern and recognition performance at the baseline condition was not significant, in contrast to that in face recognition. Indeed, Yitzhak et al. (2020) have recently suggested a weak association between face scanning behavior and facial expression recognition performance, consistent with our finding. The better performance for recognizing White faces than Asian faces may result from higher intensity in the expressions of White than Asian faces (Ma et al., 2022), instead of the match between attention strategies and locations of diagnostic information.

In addition, participants had larger performance impairment due to mask use for Asian faces than White faces. This result was consistent with the finding that participants also adopted a more nose-focused pattern for Asian than White faces, potentially missing the more expressive facial features for recognizing Asian faces (Jack et al., 2012). Interestingly, mask use reduced the effect of face race on both facial expression recognition performance and eye movement pattern, consistent with a previous study using a passive viewing task (Zheng et al., 2022).

In conclusion, here we showed that although White participants attended more to the eye region than Asian participants in both face and facial recognition tasks, their recognition performance impairment due to mask use differed only in facial expression recognition but not in face recognition. Specifically, White participants were less impaired by mask use in facial expression recognition. Nevertheless, in both tasks, individuals whose preferred attention strategies were more eyes-focused when viewing faces without masks were less impaired by mask use, suggesting that individual differences in preferred attention strategy may play a more important role than culture in accounting for variances in the performance impairment. We also found that participants had larger performance impairment due to mask use for judging expressions of Asian than White faces, consistent with the observation that participants adopted a more nose-focused strategy for viewing Asian than White faces. Together these findings suggested that although individuals from different cultures (such as Asians vs. Whites) or the recognition of expressions of different races (such as Asian vs. White faces) may be affected differentially by mask use, the mechanism underlying these effects may be more relevant to individual differences in preferred attention strategies. Future work may examine whether person-specific attention strategies can be learned to reduce performance impairment due to mask use.

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References

An, J., & Hsiao, J. H. (2021). Modulation of Mood on Eye Movement and Face Recognition Performance. *Emotion, 21*(3), 617–630.

Barrick, E., Thornton, M., & Tamir, D. (2021). Mask exposure during COVID-19 changes emotional face processing. *PloS One, 16*(10), E0258470.

Blais, C., Jack, R., Scheepers, C., Fiset, D., & Caldara, R. (2008). Culture Shapes How We Look at Faces. *PloS One, 3*(8), E3022.

Burgund, E. (2021). Looking at the own-race bias: Eye-tracking investigations of memory for different race faces. *Visual Cognition, 29*(1), 51-62.

Caldara, R. (2017). Culture reveals a flexible system for face processing. *Current Directions in Psychological Science, 26*(3), 249-255.

Caldara, R., Zhou, X., & Miellet, S. (2010). Putting Culture Under the "Spotlight" Reveals Universal Information Use for Face Recognition. *PLoS ONE, 5*(3), e9708–e9708.

Chan, C. Y. H., Chan, A. B., Lee, T. M. C., & Hsiao, J. H. (2018). Eye-movement patterns in face recognition are associated with cognitive decline in older adults. *Psychonomic Bulletin & Review, 25*(6), 2200–2207. https://doi.org/10.3758/s13423-017-1419-0

Cheng, Z., Hayward, W. G., Chan, A. B., & Hsiao, J. H. (2018). Optimal face recognition performance involves a balance between global and local information processing: Evidence from cultural difference. In T.T. Rogers, M. Rau, X. Zhu, & C. W. Kalish (Eds.), *Proceeding of the 40th Annual Conference of the Cognitive Science Society* (pp. 1476-1481). Austin, TX: Cognitive Science Society.

Chuk, T., Chan, A. B., & Hsiao, J. H. (2014). Understanding eye movements in face recognition using hidden Markov models. *Journal of Vision*, *14*(11), 8–8.

Chuk, T., Chan, A. B., & Hsiao, J. H. (2017). Is having similar eye movement patterns during face learning and recognition beneficial for recognition performance? Evidence from hidden Markov modeling. *Vision Research*, *141*, 204–216.

Chuk, T., Crookes, K., Hayward, W. G., Chan, A. B., & Hsiao, J. H. (2017). Hidden Markov model analysis reveals the advantage of analytic eye movement patterns in face recognition across cultures. *Cognition*, *169*, 102-117.

Coviello, E., Chan, A. B., & Lanckriet, G. R. G. (2014). Clustering Hidden Markov Models with Variational HEM. *Journal of Machine Learning Research, 15*, 697–747.

Fitousi, D., Rotschild, N., Pnini, C., & Azizi, O. (2021). Understanding the Impact of Face Masks on the Processing of Facial Identity, Emotion, Age, and Gender. *Frontiers in Psychology, 12,* 743793.

Fu, G., Hu, C. S., Wang, Q., Quinn, P. C., & Lee, K. (2012). Adults Scan Own- and Other-Race Faces Differently. *PLoS ONE*, *7*(6), e37688–e37688.

Hills, P. J., Cooper, R. E., & Pake, J. M. (2013). Removing the own-race bias in face recognition by attentional shift using fixation crosses to diagnostic features: An eye-tracking study. *Visual Cognition*, *21*(7), 876–898.

Hills, P. J., & Pake, J. M. (2013). Eye-tracking the own-race bias in face recognition: Revealing the perceptual and socio-cognitive mechanisms. *Cognition, 129*(3), 586-597.

Hsiao, J. H., An, J., Hui, V. K. S., Zheng, Y., & Chan, A. B. (2022). Understanding the role of eye movement consistency in face recognition and autism through integrating deep neural networks and hidden Markov models. *npj Science of Learning, 7*(1), 28–28.

Hsiao, J. H., An, J., Zheng, Y., & Chan, A. B. (2021). Do portrait artists have enhanced face processing abilities? Evidence from hidden Markov modeling of eye movements. *Cognition, 211*, 104616.

Hsiao, J. H., & Chan, A. B. (2023). Visual attention to own- vs. other-race faces: Perspectives from learning mechanisms and task demands. *British Journal of Psychology*.

Hsiao, J. H., Lan, H., Zheng, Y., & Chan, A. B. (2021). Eye movement analysis with hidden Markov models (EMHMM) with co-clustering. *Behavior Research Methods*, *53*(6), 2473–2486.

Hsiao, Liao, W., & Tso, R. V. Y. (2022). Impact of mask use on face recognition: an eye-tracking study. *Cognitive Research: Principles and Implications*, *7*(1), 32–32.

Jack, R., Blais, C., Scheepers, C., Schyns, P., & Caldara, R. (2009). Cultural Confusions Show that Facial Expressions Are Not Universal. *Current Biology, 19(*18), 1543-1548.

Jack, R. E., Caldara, R., & Schyns, P. G. (2012). Internal representations reveal cultural diversity in expectations of facial expressions of emotion. *Journal of Experimental Psychology: General, 141*(1), 19.

Kang, J., Kang, S., Jeong, E., & Kim, E. (2021). Age and Cultural Differences in Recognitions of Emotions from Masked Faces among Koreans and Americans. *International Journal of Environmental Research and Public Health, 18*(19), 10555.

Kelly, D. J., Liu, S., Rodger, H., Miellet, S., Ge, L., & Caldara, R. (2011a). Developing cultural differences in face processing. *Developmental Science, 14*(5), 1176–1184.

Ma, X., Fu, M., Zhang, X., Song, X., Becker, B., Wu, R., Xu, X., Gao, Z., Kendrick, K., & Zhao, W. (2022). Own race eye-gaze bias for all emotional faces but accuracy bias only for sad expressions. *Frontiers in Neuroscience, 16*, 852484–852484.

McGrory, C. A., & Titterington, D. M. (2009). Variational Bayesian analysis for hidden Markov models. *Australian & New Zealand Journal of Statistics*, *51*(2), 227–244.

Mckone, E., Crookes, K., & Kanwisher, N. (2009). The cognitive and neural development of face recognition in humans. *The cognitive neurosciences*, 467–482.

McKone, E., Wan, L., Pidcock, M., Crookes, K., Reynolds, K., Dawel, A., ... & Fiorentini, C. (2019). A critical period for faces: Other-race face recognition is improved by childhood but not adult social contact. *Scientific reports*, *9*(1), 1-13.

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law, 7*(1), 3–35.

Or, C. C. F., Peterson, M. F., & Eckstein, M. P. (2015). Initial eye movements during face identification are optimal and similar across cultures. *Journal of Vision, 15*(13), 12.

Ramdani, C., Ogier, M., & Coutrot, A. (2022). Communicating and reading emotion with masked faces in the Covid era: A short review of the literature. *Psychiatry Research*, 114755.

Peterson, M., & Eckstein, M. (2013). Individual differences in eye movements during face identification reflect observer-specific optimal points of fixation. *Psychological Science, 24*(7), 1216-1225.

Richler, J. J., Cheung, O. S., & Gauthier, I. (2011). Holistic processing predicts face recognition. *Psychological Science, 22*(4), 464–471.

Richler, J. J., Palmeri, T. J., & Gauthier, I. (2012). Meanings, mechanisms, and measures of holistic processing. *Frontiers in Psychology, 3,* 553–553.

Shioiri, T., Someya, T., Helmeste, D., & Tang, S.W. (1999), Misinterpretation of facial expression: A cross-cultural study. *Psychiatry and Clinical Neurosciences, 53*, 45-50.

Stelter, M., & Schweinberger, S. R. (2022). Understanding the mechanisms underlying the other-‘race’ effect: An attempt at integrating different perspectives. *British Journal of Psychology*.

Stelter, M., Simon, D., Calanchini, J., Christ, O., & Degner, J. (2023). Real-life outgroup exposure, self-reported outgroup contact and the other-race effect. *British Journal of Psychology*.

Tso, R. V. Y., Chui, C. O., & Hsiao, J. H. (2022). How does face mask in COVID-19 pandemic disrupt face learning and recognition in adults with autism spectrum disorder? *Cognitive Research: Principles & Implications*, *7*, 64.

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behav. Res. Methods*, *42*, 671-684.

Wong, H. K., Estudillo, A. J., Stephen, I. D., & Keeble, D. R. T. (2021). The other-race effect and holistic processing across racial groups. *Scientific Reports, 11*(1), 8507–8507.

Wong, H. K., Keeble, D. R. T., & Stephen, I. D. (2023). Do they “look” different(ly)? Dynamic face recognition in Malaysians: Chinese, Malays and Indians compared. *British Journal of Psychology*.

Yitzhak, N., Pertzov, Y., Guy, N., & Aviezer, H. (2020). Many ways to see your feelings: Successful facial expression recognition occurs with diverse patterns of fixation distributions. *Emotion*.

Zheng, Y., Chen, D., Hu, X., & Hsiao, J. (2022). The impact of mask use on social categorization. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (pp. 2024-2630). Cognitive Science Society..

Zheng, Y., & Hsiao, J. H. (2022). Differential audiovisual information processing in emotion recognition: An eye-tracking study. *Emotion.* Advance online publication.