High familiar faces have both eye recognition and holistic processing advantages

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Significance:

People recognize familiar faces better than unfamiliar faces, known as the familiarity effect. Here, we examined whether familiarity effects exist in both part-based and holistic processing. Experiment 1 showed that participants recognized the eyes of high-familiar faces better than low-familiar and unfamiliar ones, while the performance for mouths was similar across familiarity. Experiment 2 demonstrated a stronger inversion effect for high-familiar faces, a weaker inversion effect for low-familiar faces, but a non-significant inversion effect for unfamiliar faces. Taken together, we argue that increased face experience has a cumulative effect on both eyes processing and holistic processing.

Abstract:

People recognize familiar faces better than unfamiliar faces (Burton & Jenkins, 2012). However, it remains elusive whether familiarity affects part-based and/or holistic processing. Wang and colleagues (2015, 2019) found both enhanced part-based and holistic processing in eye relative to mouth regions (i.e., in a region-selective manner) for own-race and own-species faces, i.e., faces with more experience. Here, we examined the role of face familiarity in eyes (part-based, region-selective) and holistic processing. Face familiarity was tested at three levels: high-familiar (faces of students from the same department and the same class who attended almost all courses together), low-familiar (faces of students from the same department but different classes who attended some courses together), and unfamiliar (faces of schoolmates from different departments who seldom attended the same courses). Using the old/new task in Experiment 1, we found that participants recognized eyes of high-familiar faces better than low-familiar and unfamiliar ones, while similar performance was observed for mouths, indicating a region-selective, eyes familiarity effect. Using the “Perceptual field” Paradigm (Van Belle et al., 2015) in Experiment 2, we observed a stronger inversion effect for high-familiar faces, a weaker inversion effect for low-familiar faces, but a non-significant inversion effect for unfamiliar faces, indicating that face familiarity plays a role in holistic processing. Taken together, our results suggest that familiarity, like other experience-based variables (e.g., race and species), can improve both eyes processing and holistic processing.

Keyword familiarity, face recognition, holistic processing, part-based processing, eyes processing

1 Introduction

People are better at recognizing familiar than unfamiliar faces. Familiar faces have been demonstrated to enhance and speed up face recognition (Burton & Jenkins, 2012: Jenkins, White, Van Montford & Burton, 2011). Even in challenging circumstances (such as low-quality videos, Bruce et al, 2001), people can maintain high performance on familiar face recognition. By contrast, people's performance on unfamiliar face recognition is worse. For example, their ability to recognize unfamiliar faces can be affected by both the quality of the materials (video quality: Bacci et al., 2021; Bruce et al, 2001; Davis & Valentine, 2009) and the experimental settings (such as lighting, viewpoint and pose, Hill & Bruce,1996; O'Toole et al., 1998; Patterson & Baddeley, 1977). In addition, compared with unfamiliar face recognition, familiar face recognition has more automated processing (Yan et al, 2017). The advantage of a familiar face in early facial processing is also supported by ERP studies (Caharel & Rossion, 2021; Gosling and Eimer, 2011; Herzmann et al., 2004; Miyakoshi et al., 2008). Familiarity has an impact on the N250 component: the higher the familiarity, the larger the amplitude of the N250 (Gosling and Eimer, 2011; Herzmann et al., 2004; Huang et al., 2017; Miyakoshi et al., 2008). According to a recent review, familiarity also affects the N170 component, with higher face familiarity corresponding to the smaller N170 amplitudes (Caharel & Rossion, 2021; Huang et al., 2017). In summary, these studies suggest that familiar faces are recognized better than unfamiliar faces and the processing of faces with varied degrees of familiarity likely differ from each other.

However, the mechanisms underlying the processing of familiar and unfamiliar faces are still unclear (e.g., evidence of featural processing: Ellis, Sheperd, & Davis, 1979; Kramer, Manesi, Towler, Reynolds, & Burton, 2018; evidence of configural processing: Burton et al, 2015). It is widely accepted that holistic processing is essential in face processing (McKone et al., 2007; Michel, Rosson et al., 2006; Tanaka et al 2004; Yarmey, 1971). And recent studies have shown the importance of part-based processing (Ge et al., 2008; Jenkins & Burton, 2011; Visconti di Oleggio Castello et al., 2017). In the current study, we focus on how familiarity affects part-based processing and holistic processing.

Familiar faces have advantages in part-based processing, i.e., the processing of distinctive facial features like the eyes, nose, and mouth (Ge et al., 2008; Jenkins & Burton, 2011; Visconti di Oleggio Castello et al., 2017). The eye region of familiar faces is easier to be recognized than that of unfamiliar faces in both adults and children (Ge et al., 2008). With increased familiarity, people's fixation durations and sensitivity to the eye area increased (Heisz & Shore, 2008; O'Donnell & Bruce, 2001; Quinn & Wiese, 2022). Using the Bubbles method, Royer and collaborators found that a greater dependence on the eye region is associated with better face recognition ability (Royer et al., 2018). By contrast, it is less clear whether familiarity influences mouth recognition. Some studies have shown that familiarity does not affect people's sensitivity to mouth positions and shapes (Brooks & Kemp, 2007; O'Donnell & Bruce, 2001). However, Osborne and Stevenage (2013) found that recognizing the mouths of familiar faces was more accurate than those of unfamiliar faces (Osborne & Stevenage, 2013). The nose seems to play a less significant role in face processing (Osborne & Stevenage, 2013; Roberts & Bruce, 1988). When features are presented individually, the eyes provide the most reliable information for sex judgment, whereas the nose provides the least (Roberts & Bruce, 1988). Additionally, in the identity-matching task, familiarity has little effect on the accuracy of the nose matching (Osborne & Stevenage, 2013). According to the findings of the research above, the current study only investigated whether the familiar face advantage exists in the recognition of the eyes and/or the mouth.

Another potential aspect that differs between familiar and unfamiliar faces is holistic processing, which is robustly linked to face recognition ability (Wang et al., 2012; DeGutis et al., 2013). The Experience-Based Holistic Processing hypothesis proposes that holistic face processing improves as contact experience increases, and that enhanced holistic processing results in improved face recognition. It is supported by the findings of studies on the "Other Race Effect" and the "Other Age Effect" (Kuefner et al., 2008; Michel, Rosson et al., 2006; Tanaka et al 2004; Michel, Rosson et al., 2006; Wang et. al. 2019). Compared with other-race faces and other-age faces, people show stronger holistic processing when recognizing their own-race faces (Part-whole task: Michel, Rosson et al., 2006; Tanaka et al 2004; Composite face task: Michel, Rosson et al., 2006; Wang et. al. 2019) and own-age faces (Inversion task: Kuefner et al., 2008) and are more sensitive to the change of the holistic information of their own-race faces (Rhodes et al., 2006). Similarly, research shows that familiar faces have stronger holistic processing than unfamiliar faces (Caharel et al., 2006; Huang et al., 2017; Marzi & Viggiano, 2007). In a familiarity decision task, the face inversion effect was more pronounced for famous than for unknown faces (Huang et al., 2017; Marzi & Viggiano, 2007). In a face recognition task, familiar faces were identified more quickly than unfamiliar ones, and familiar face inversions increased response time, but unknown face inversions did not (Caharel et al., 2006). In addition, ERP component impacted by familiarity and face orientation, such as N170, which is believed to reflect holistic representation (Caharel et al., 2006; Caharel & Rossion, 2021; Huang et al., 2017; Marzi & Viggiano, 2007) and N250 (Huang et al., 2017). However, inconsistent results were observed in some other studies. Participants showed comparable holistic processing for familiar and unfamiliar faces, in the composite face task and the part-whole task (Fitousi, 2020; Osborne & Stevenage, 2013). Therefore, it remains unclear whether familiarity influences holistic processing.

In this study, we conducted two experiments to measure part-based processing and holistic processing of faces at three familiarity levels (high-familiar, low-familiar, or unfamiliar). Experiment 1 used an old/new task: after participants learned the whole faces, they were presented with facial parts (eyes or mouths) to judge whether the face parts were from the OLD faces which they learned before or NEW faces which they did not learn. In Experiment 2, the perceptual field paradigm (Van Belle et al.,2015) was used. Participants were first presented with an upright (or inverted) composed face (which consists of two faces, a central face and a peripheral face, with one eye of the central face embedded in the peripheral face), and then two original faces (the central face and the peripheral face). Participants were asked to choose the face which was more similar in identity to the composed face. It is noteworthy that for decades researchers have been using famous faces to gain insights into the effects of familiarity （for a review see: Ramon & Gobbini, 2018), but few of them controlled participants' experience with the faces. One exception was Ge and colleagues (2008), who used the classmates' faces as stimuli to ensure that participants had known each other for the same length of time. Here, we adopted a similar approach as Ge and colleagues (2008) to manipulate familiar faces at three levels. Specifically, high-familiar faces were the faces of undergraduates who were from the same department and the same class as the participants; they had more contact experience with each other, as they took courses together and took part in the same activities. Low-familiar faces were the faces of undergraduates who were from the same department but different classes; they had less contact experience with each other, as they only attended some of the courses and extracurricular activities together. Unfamiliar faces were the faces of undergraduates from departments other than the participants'; they had little contact experience, as their daily life hardly overlapped.

Based on the aforementioned assumptions, the experiments' results are predicted as following. (1) If the familiarity affects the part-based processing, in Experiment 1, we should find that with the increase of face familiarity, the participants' recognition performance of face parts would be better. Also, if this performance improvement is region-selective, as familiarity increases, the recognition performance of the eyes should be better, whereas the recognition performance of the mouth will not improve or only slightly. (2) If the familiarity affects the holistic processing, with the increase of face familiarity, the proportion of choosing peripheral faces will be higher in the upright condition, while the effect of familiarity would be negligible in the inverted condition. In other words, with the increase of familiarity, the differences in the proportion of choosing peripheral faces between the upright and inverted conditions will gradually increase; that is, the inversion effect will become stronger.

2 Experiment 1

2.1 Method

2.1.1 Participants

Forty-six undergraduates [15 males, mean age=20.1, standard deviation = 1.6] from two classes (from 1st grade and 3rd grade separately) in the same department took part in Experiment 1. The participants from the same class had known each other for more than nine months and were intimately acquainted due to their participation in the same courses and activities. The participants from different classes were also slightly familiar with each other, since they came from a small department (no more than 200 students) and only a portion of their courses and extracurricular activities overlapped. All participants reported normal or correct-to-normal vision, were right-handed and gave informed consent before the experiment. The experiment was approved by the Human Research Ethics Committee of Zhejiang Sci-Tech University.

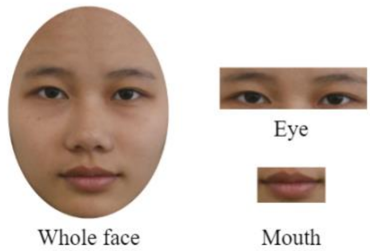
2.1.2 Materials

Three sets of faces were prepared. There were a set of 20 participants' faces from one class, a set of 20 participants' faces from a different class, and another set of 20 faces of unfamiliar undergraduates. High-familiar faces are those of the participants' classmates. Low-familiar faces are those of the undergraduates from the other class in the same department. Unfamiliar faces are the faces of unfamiliar undergraduates in the university. There was no jewelry, glasses, or makeup on these faces. All faces were in a frontal pose with a neutral expression.

Using Adobe Photoshop, we cut these 60 photos into ellipses of the same size (314 × 443 pixels), removed external clues (hairstyle, ears, accessories, head shape), and finally got 60 standardized faces. Then, we crop out a rectangle 10 pixels from the edge of the eyes and mouth to get 120 face part images. Finally, we had 6 groups (20 images in each group) of images: 3 (face familiarity: unfamiliar, low-familiar, high-familiar) x 2 (face part: eyes or mouth). (See example stimuli in Fig. 1).

Figure 1

Examples of the whole face, eyes, and mouth in Experiment 1



2.1.3 Procedure and Design

Experiment 1 was programmed with E-Prime 2.0. The participants were seated in front of the screen (resolution 1024×768 pixels) at a viewing distance of 60cm.

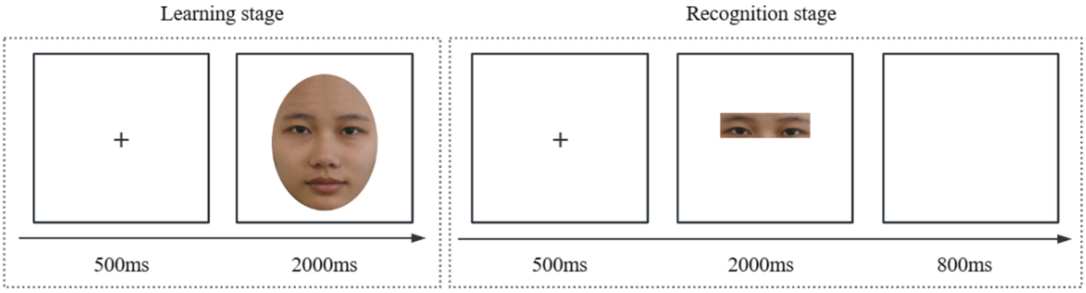
We used a 3 (face familiarity: unfamiliar, low-familiar, or high-familiar) x 2 (face part: eyes or mouth) within-subjects design. The different levels of face familiarity were showed in different blocks and its order was randomized. Each participant performed a total of 3 block (unfamiliar, low-familiar, or high-familiar) x 2 (eyes or mouth) x 20 identities =120 trials.

We used a recognition task in Experiment 1. The task was divided into two stages: learning and recognition. The specific process is as follows (see Fig. 2): In the learning stage, participants were asked to passively view and remember 10 faces presented in a random order; each repeated for three times to enhance memorization. In the recognition stage, 10 eyes or 10 mouths of those learned faces were randomly mixed with another 10 eyes or 10 mouths of unlearned faces for recognition. Participants were asked to judge whether the presented face parts belonged to a previous face seen in the learning stage or not. Half of the participants were told to press “1” for “yes” or “2” for “no” on the number pad; for the other half, the key-pressing requirement was reversed. Participants were asked to judge as accurately as possible. The image would disappear once a response was made, or the stimulus had been shown for

2000ms. All images were presented only once.

Figure 2

Timeline of an example trial from the old/new task in Experiment 1



2.2 Results

We excluded the data of two participants. For one participant, the data of one block was missing (for unknown reason), and the other participant had an accuracy of 0 in two blocks.

We performed repeated-measures ANOVAs to examine the effect of familiarity (3: unfamiliar, low-familiar, high-familiar) and face parts (2: eyes, mouth) on discriminability measure (*d'*), response bias (criterion c) and response time (RT), separately.

Parts from learned faces and those from unlearned faces were treated as "signal" and "noise" separately in Signal Detection Theory. The discriminability measure (*d'*) and the response bias (criterion c) were calculated accordingly. And the reaction time (RT) results were derived from the RT of all trials. (See Tab. 1).

The *d'* results are shown in Tab. 1 and Fig. 3. The main effect of face familiarity was significant, F (2,86) =9.251, p<.001, η_p^2 =.177. Bonferroni showed that the d' of high-familiar faces was higher than that of low-familiar faces (p<.001) and unfamiliar faces (p=.038). The main effect of face part was significant, F (1,43) =7.873, p=.008, η_p^2 =.155, and the d' of eyes was higher than that of mouths (p=.008). More importantly, the interaction between face familiarity and face part was significant, F (2,86) =7.871, p<.001, η_p^2 =.155.

To explore the interaction between face familiarity and face part, we performed simple effect analyses. The results showed that when the face parts were eyes, the d' of high-familiar faces was higher than that of low-familiar faces (p=.003) and unfamiliar faces (p=.001), but there was no significant difference between low-familiar and unfamiliar faces (p=.863). When the face parts were mouths, the d' of low-familiar faces was lower than that of unfamiliar faces (p=.011), others were not significant (p=1.000, p=.084). In the unfamiliar condition, there was no significant difference between the eyes and mouth (p=.113). In the low-familiar condition, the d' of eyes was higher than that of the mouth (p=.016). In the high-familiarity condition, the d' of eyes was also higher than that of the mouth (p=.002). In addition, further analysis found that with the increase in familiarity, the difference between eyes and mouths became larger, and the differences between eyes and mouths of high-familiar faces and low-familiar faces were larger than those of unfamiliar faces (p<.001, p=.040).

The results of c and RT were shown in Tab. 1. For c, the main effect of face familiarity was not significant, F (2,86) =0.249, p=.780. The main effect of face part was significant, F (1,43) =11.233, p=.002, η_p^2 =.207. Participants judged the mouths more strictly than the eyes (p=.002). The interaction between face familiarity and face part was not significant, F (2,86) =0.884, p=.417. For RT, the effects of face familiarity, face part and their interaction were all not significant (F (2,86) =1.084, p=.343, F (1,43) =4.033, p=.051, F (2,86) =2.092, p=.130).

Table 1

Means of accuracy, reaction time, d' and c in Experiment 1

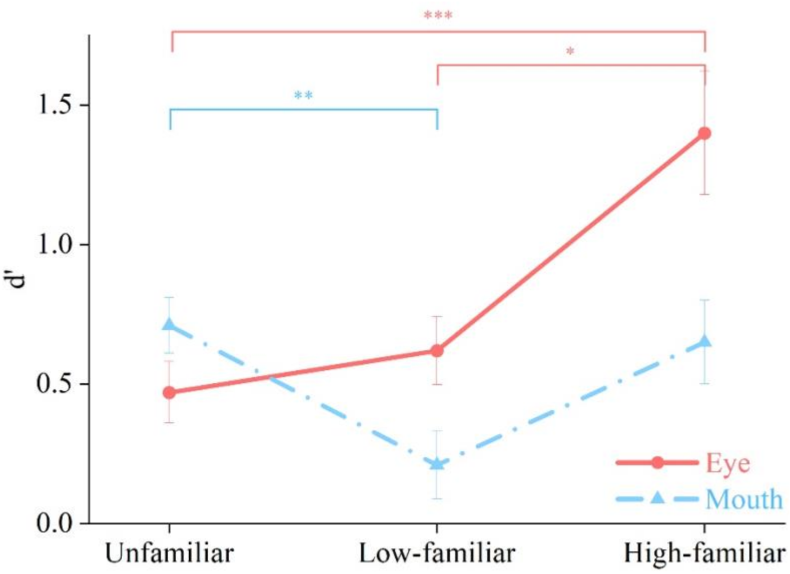
Familiarity	*Part*	*Accuracy (%)*	*Response time(ms)*	*d'*	*c*
Unfamiliar	Eye	57.95 (54.54, 61.37)	1121 (1080, 1162)	0.470 (0.253, 0.686)	-0.264 (-0.382, -0.146)
	Mouth	60.91 (57.69, 64.13)	1092 (1056, 1128)	0.706 (0.499, 0.913)	0.117 (-0.061, 0.296)
Low-familiar	Eye	60.23 (56.38, 64.08)	1099 (1064, 1133)	0.620 (0,370, 0.870)	-0.224 (-0.329, -0.120)
	Mouth	52.50 (48.89, 56.11)	1045 (996, 1095)	0.206 (-0.043 0.455)	-0.001 (-0.216, 0.215)

High-familiar	Eye	68.86 (63.46, 74.27)	1094 (1038, 1150)	1.399 (0.954, 1.844)	-0.233 (-0.401, -0.066)
	Mouth	60.00 (55.35, 64.65)	1098 (1051, 1145)	0.648 (0.356, 0.940)	0.025 (-0.149, 0.199)

Note. 95% confidence interval in parentheses.

Figure 3

Sensitivity d' for Unfamiliar faces, Low-familiar faces and High-familiar faces in Experiment 1



Note. * p<.05, ** p <.01, *** p <.001. Error bars represent the standard error of the mean.

3 Experiment 2

3.1 Method

3.1.1 Participants

Forty undergraduates [15 males, mean age=20.1, standard deviation = 1.3] from two classes (from 1st grade and 3rd grade separately) in the same department took part in Experiment 2. The participants from the same class had known each other for more than nine months and were intimately acquainted due to their participation in the same courses and activities. The participants from different classes were also slightly familiar with each other, since they came from a small department (no more than 200 students) and only a portion of their courses and extracurricular activities overlapped. All participants reported normal or correct-to-normal vision, were right-handed and gave informed consent before the experiment.

The experiment was approved by the Human Research Ethics Committee of Zhejiang Sci-Tech University.

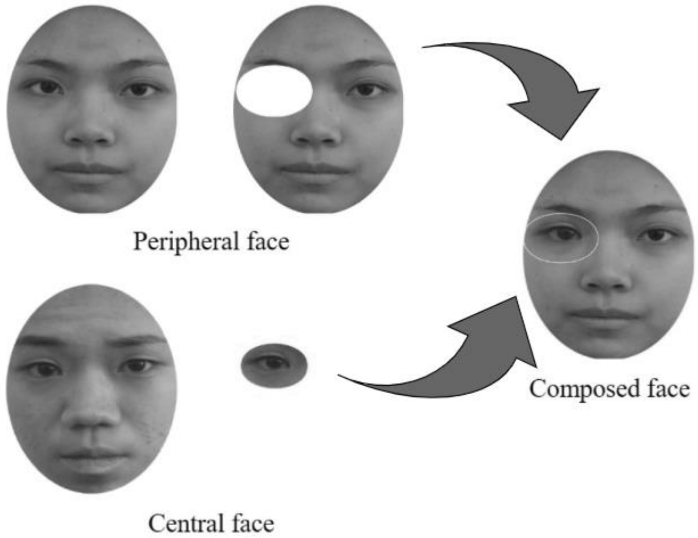
3.1.2 Materials

Three sets of faces were prepared. There were 16 participants' faces from one class, 16 participants' faces from the other class, and 16 faces of unfamiliar undergraduates. Same as Experiment 1, for participants, high-familiar faces were the faces of their classmates. Low-familiar faces were the faces of undergraduates from the other class in the same department. Unfamiliar faces were the faces of strange undergraduates in the university. There was no jewelry, glasses, or makeup on these faces. All faces were in a frontal pose with a neutral expression.

Using Adobe Photoshop, we cut these 48 pictures into ellipses of the same size (314 × 443 pixels) and removed external clues (hairstyle, ears, accessories, head shape). We paired face images of the same group and gender according to skin color, interpupillary distance, and attractiveness, resulting in 24 pairs of paired faces. Then, in each pair of faces, we got a composed face by fusing the left/right eye area of one face (the central face) with the non-eye area of the other face (the peripheral face), and the coverage area was feathered to make the transition at the fusion natural. The central face and the peripheral face were also exchanged so that a pair of faces will get 4 composed faces, and a total of 96 composed faces were obtained after processing. Finally, to make the composed faces look more natural and to minimize the effects of chromatic aberration, we processed the original and composed faces in black and white. (See example stimuli in Fig. 4).

Figure 4

Examples of peripheral face, central face, and composed face in Experiment 2



Note. Take the left eye as an example. The composed face by fusing the left eye area of the central face with the non-eye area of the peripheral face. The white ellipse in the composed face is a highlight that is not present in the actual images in Experiment 2.

3.1.3 Procedure and Design

Experiment 2 was programmed with E-Prime 2.0. The participants were seated in front of the screen (resolution 1024×768 pixels) at a viewing distance of 60cm.

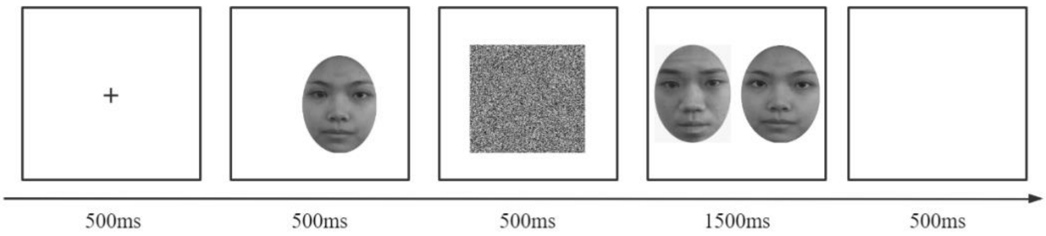
We used a two-alternative-force-choice task in Experiment 2. Before the formal experiment, participants completed 2 practice trials and feedbacks were provided for each trial to ensure that participants understood the experimental task.

The trial procedure was as follows (see Fig. 5): Participants saw a "+" (500ms), and then a composed face (500ms). The participants were instructed to maintain their gaze on the fixation point, and when a composed face was shown, its central region (i.e., the left or right eye) located where the fixation point was. Subsequently, a mask (500ms) was presented. Finally, two original faces (the central face and the peripheral face, 1500ms) were presented. Participants were asked to choose the face that was more similar to the composed face. Participants were told to press "1" for "left" or "2" for "right" on the number pad. The face would not disappear until a response was collected or the presentation's allowed time had passed. Participants were asked to try to make judgments within the time limit.

We used a 2 (face familiarity: unfamiliar, low-familiar, or high-familiar) x 2 (face orientation: upright or inverted) within-subjects design, where upright and inverted faces were shown in different blocks, and the order was randomized. Each participant completed 192 trials in total.

Figure 5

Timeline of an example trial from the matching task in Experiment 2



3.2 Results

A 3(face familiarity: unfamiliar, low-familiar, high-familiar) x 2 (face orientation: upright or inverted) repeated measures ANOVA was performed on the proportion of choosing the peripheral faces, with both independent variables as within-subjects factors.

The main effect of face familiarity was significant, F (2,78) =25.860, p<.001, η_p^2 = .399. Bonferroni showed that the percentage of choosing peripheral faces was higher when the stimuli were the high-familiar faces, compared with low-familiar and unfamiliar faces (p<.001; p<.001). The main effect of face orientation was significant, F (1,39) =26.512, p<.001, η_p^2 = .405. The percentage of choosing peripheral faces was higher when the faces were presented upright than inverted. The interaction between face familiarity and face orientation was significant, F (2,78) =24.878, p<.001, η_p^2 = .389.

Further analysis found that when the stimuli were presented upright, the percentage of choosing peripheral faces was higher for the high-familiar faces, compared with the low-familiar and unfamiliar faces (p<.001; p<.001). It indicated that, for the upright faces, participants processed the high-familiar faces more holistically than low-familiar and unfamiliar faces. When the stimuli were inverted, there was no significant difference between the high-familiar faces, the low-familiar, and the unfamiliar faces (p=.303; p=1.000; p=1.000). For the unfamiliar faces, there was no significant difference between the upright faces and the inverted faces (p=.358). For the low-familiar faces, the percentage of choosing peripheral faces was higher when the faces were presented upright than inverted(p=.032), indicating a significant holistic face processing. For the high-familiar faces, the percentage of choosing peripheral faces was higher when the faces were presented upright than inverted(p=.001), indicating a significant holistic face processing. (See Tab. 5 and Fig. 6).

Table 2

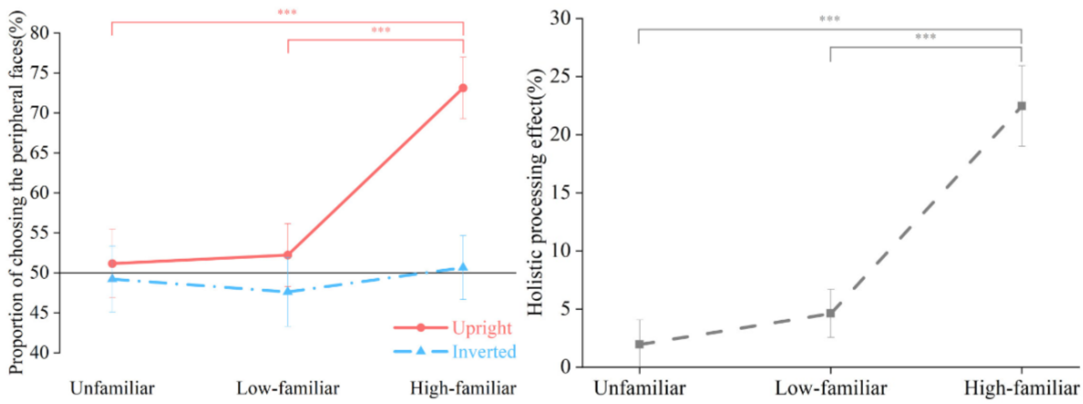
Means of proportion of choosing the peripheral faces in Experiment 2

Familiarity	*Orientation*	*The proportion of choosing the peripheral faces (%)*
Unfamiliar	Upright	51.17 (42.51,59.83)
	Inverted	49.22 (40.86,57.58)
Low-familiar	Upright	52.23 (44.27,60.18)
	Inverted	47.62 (38.90,56.34)
High-familiar	Upright	73.13 (65.36,80.89)
	Inverted	50.66 (42.61,58.72)

Note. 95% confidence interval in parentheses.

Figure 6

Proportion of choosing the peripheral face(left) and holistic processing effect (right) for Unfamiliar faces, Low-familiar faces, and High-familiar faces in Experiment 2



Note. ***p <.001. Error bars represent the standard error of the mean.

4 Discussion

This study examined whether familiarity affects part-based processing and holistic processing. First, using a recognition task, we found that high-familiar faces were recognized better by their eyes than low-familiar and unfamiliar ones, while the performance of the mouth area did not show a similar familiarity effect. This finding suggests a region-selective familiarity effect for part recognition. Second, using the "Perceptual field" Paradigm (Van Belle et al., 2015), we found that high-familiar faces had a larger inversion effect (*ps*<.001, <.05, >.35, in high-familiar, low-familiar, and unfamiliar faces conditions, respectively). This finding suggests a familiarity effect for holistic processing. Overall, our results demonstrate that familiarity, like other experience-based variables (e.g., race and species), can improve both eyes processing and holistic processing.

The results of Experiment 1 showed that participants' discriminability of the eyes was better than that of the mouth for high-familiar relative to low-familiar and unfamiliar faces, and the performance difference between eyes and mouth became larger as the familiarity increased. This result is consistent with previous studies. Ge et al. (2008) investigated whether children aged 4, 8, and 14 could recognize their classmates through facial parts after having known them for one school year. Children were more likely to identify their peers through the eyes than through the mouths (Ge et al.,2008). But the mechanisms of the eye advantage of familiarity are not well understood. It might result from the eyes containing more diagnostic information (Vinette et al., 2004) or familiarity (Ge et al.,2008, Heisz & Shore, 2008; O'Donnell & Bruce, 2001; Quinn & Wiese, 2022). The result of experiment 1 suggests that it may be the latter. Firstly, when it comes to recognizing unfamiliar faces, there is no difference in the participants' performance in recognizing the eyes and mouth. Therefore, the benefit of information in the eyes does not necessarily result in the advantage of recognition. Secondly, the results of Experiment 1 showed high-familiar faces were recognized better by their eyes than low-familiar and unfamiliar ones, while the mouth area did not show a similar effect. With higher familiarity, participants' discriminability of the eyes gradually improved, but their discriminability of the mouth did not. The results of Experiment 1 thus demonstrate that increased familiarity enhances face part recognition, but only for eyes, suggesting a regional specificity. These findings provide strong evidence that experience can enhance the ability to recognize face parts.

In Experiment 2, we found that the proportion of choosing the peripheral faces was significantly higher in the upright condition than in the inverted condition. It is in line with Van Belle and colleagues

(2015), who used the same perceptual field paradigm and observed that inversion reduced the proportion of choosing peripheral faces of typical participants but an acquired prosopagnosia patient with preserved peripheral vision almost never chose the peripheral faces in the upright condition. These findings indicate that the inverted face would cause the participants' perceptual fields to become smaller like acquired prosopagnosia, hence decreasing holistic processing. More crucially, we found that in the upright condition, the proportion of choosing peripheral faces gradually increased with the enhancement of face familiarity, whereas in the inverted condition, the promoting effect of familiarity disappeared. The results are in line with previous research using the inverted paradigm. Face inversion effect of familiar faces is stronger than that of unfamiliar faces (Huang et al., 2017), and even there is no face inversion effect of unfamiliar faces (Loftus et al., 2004), suggesting that familiarity can enhance holistic face processing. Contrary to our results, using the part-whole task and the composite face task, Osborne & Stevenage (2013) found that familiarity has little effect on holistic processing. The index of holistic processing in the part-whole task and the composite task is the difference between the participants' accuracy in the two conditions (such as alignment and misalignment, whole and part), which is easily influenced by the participants' accuracy in each condition. The perceptual field paradigm uses the straightforward ratio of participants' preferences for the central face to the peripheral face as an indicator (Van Belle et al., 2015; Wang, 2023). It allows for more precise comparison of the holistic processing quantity in various conditions.

It is noteworthy that, to assess the holistic processing in different conditions, we compared the proportion of choosing the peripheral faces between conditions (face familiarity or face orientation), rather than comparing the proportion to a specific (absolute) value (e.g., 50%). This is because the peripheral face is visually more similar to the study face in most cases; thus, even when no holistic processing is involved, participants might still more choose the peripheral faces (e.g., the proportion of choosing the peripheral faces being higher than 50%). This potential issue can be avoided by comparing the proportions between conditions, which does not depend on the absolute value of the proportion and is a valid approach to inspect the strength of the holistic processing when the participants recognize faces with different familiarity. Because the peripheral faces of the original faces with different levels of familiarity were produced in the same manner. Therefore, for different familiarity conditions, the proportion of original faces in the peripheral faces was the same. In Experiment 2, the proportion of participants choosing peripheral faces increased with increasing familiarity in the upright condition and the proportions of choosing peripheral faces were comparable for the three kinds of faces in the inverted condition, indicating that familiarity affected the perceptual field of upright faces and, consequently, the holistic processing. More importantly, the percentage of choosing peripheral faces was higher when the faces were presented upright than inverted (the inversion effect) for high-familiar faces(p=.001) and low-familiar faces (p=.032), but not for unfamiliar faces (p=.358), which indicates that the percentage of choosing peripheral faces like the composite face effect and the part-whole effect can be reduced by inversion (Crookes et al., 2013; Goffaux and Rossion, 2006) and the inversion effect of the percentage of choosing peripheral faces can be affected by familiarity. Therefore, we conclude that familiarity affects the holistic face processing based on not only a single but several results.

The results of this study demonstrate that familiarity has an accumulative influence on both part-based processing and holistic processing. As familiarity increases from unfamiliar to low-familiar to high-familiar faces, participants' recognition of features (eyes) and holistic processing of faces improve. Previous studies have shown that people recognize different types of familiar faces differently, such as the performance for one’s own face being better than that of friends (Bortolon et al.,2018), and that of friends being better than that of celebrities (Herzmann et al.,2004; Keyes & Zalicks, 2016; Bortolon et al.,2018). According to our study, significant performance enhancements may result from the integration of both part-based processing and holistic processing. Specifically, in Experiment 1, with the increase of familiarity, participants’ performance to recognize the eyes improved gradually rather than immediately, indicating that their part-based processing had improved. In Experiment 2, the holistic processing effect also improves gradually with increasing familiarity. Our findings are consistent with the studies on races (Michel, Caldara, et al., 2006; Michel, Rossion et al., 2006; Mondloch et al.,2010; Tanaka et al.,2004; Wang et al., 2015). Due to the dual improvement of part-based processing and holistic processing, participants were more adept at discriminating their own-race faces but not those of other races as they gained more own-race face experience (Michel, Caldara, et al., 2006; Michel, Rossion et al., 2006; Mondloch et al.,2010; Tanaka et al.,2004; Wang et al., 2015). Additionally, the familiar faces used in the current study were from their classmates, and the variations in familiarity were more connected with the frequency of contact than with the intensity of the emotional bond. As a result, we propose that increased face experience has a cumulative effect on both part-based processing and holistic processing.

Previous studies showed that upper and lower facial halves might be involved in the human holistic face processing differently, with the upper facial half having a larger holistic processing than the lower facial half (Nemrodov et al., 2014; Parkington & Itier, 2019; Wang et al., 2019, 2023). In our recent study using the same "perceptual field" paradigm, we found that when participants fixated on the eyes, their perception field was larger for upright faces than the inverted faces, which was in line with the current study (Wang et al., 2023). Also, the perception field was larger when participants fixated on the eyes than the mouth, and only when participants fixated on the eyes, did inversion significantly reduce the range of perception field (Wang et al., 2023). Based on these findings, eyes may play a key role in holistic face processing. Furthermore, experience may regulate the holistic processing of the eye areas. In a study on the "Other Species Effect", when asked to judge whether the upper halves of faces were the same or different in a composite face task, participants showed a strong composite-face effect for own-race faces, a relatively weaker but still significant composite-face effect for other-race faces, but no composite-face effect for monkey (other-species) faces (Wang et al., 2019). In Experiment 2, however, we only used the eye areas as the central region of the composed faces and found inversion has a bigger influence on the holistic processing of the eye region of familiar faces than that of unfamiliar faces. Thus, it is unclear whether the effect of familiarity on holistic processing would be regulated by region, just like experience (such as race and species, Wang et al., 2019). Further research should include more facial features such eyes, mouth, and nose.

The current findings suggest that familiarity affects both eyes processing and holistic processing, which is similar to what is shown in face other-race effect (ORE) and species-specific effect (SSE) (Wang et al., 2015, 2019), thereby suggesting a broader experience-based holistic processing hypothesis for face recognition. To test the potential key roles of eyes in holistic face processing, we can use the part-whole task in future research to examine the relationship between the familiarity effect of eye processing and holistic processing.

Declarations

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Conflicts of interest:

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics approval:

The study involving human participants were reviewed and approved by Institutional Review Board at Zhejiang Sci-Tech University.

Consent to participate:

The participants provided their written informed consent to participate in this study.

Consent for publication:

The authors affirm that the participants provided informed consent for publication.

Availability of data and materials:

The data and materials for all experiments are available at https://www.scidb.cn/s/rYZb6b. None of the experiments was preregistered.

Code availability:

Experimental code is available upon request to the corresponding author.

Authors' contributions:

ZW, TW, YS and HJ conceptualized, designed the study and wrote the manuscript. ZW, WZ and WD collected the data. ZW, TW, YL and LZ performed the statistics, and wrote the first draft. All authors read and approved the final manuscript.

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References

Bacci, N., Houlton, T. M. R., Briers, N., & Steyn, M. (2021). Validation of forensic facial comparison by morphological analysis in photographic and CCTV samples. *International Journal of Legal Medicine*, 135(5), 1965–1981. https://doi.org/10.1007/s00414-021-02512-3

Brooks, K. R., & Kemp, R. I. (2007). Sensitivity to feature displacement in familiar and unfamiliar faces: Beyond the internal/external feature distinction. *Perception*, 36(11), 1646–1659. https://doi.org/10.1068/p5675

Bruce, V., Henderson, Z., Newman, C., & Burton, A. M. (2001). Matching identities of familiar and unfamiliar faces caught on CCTV images. *Journal of Experimental Psychology: Applied*, 7(3), 207–218. https://doi.org/10.1037/1076-898X.7.3.207

Bortolon, C., Lorieux, S., & Raffard, S. (2018). Self- or familiar-face recognition advantage? New insight using ambient images. *Quarterly Journal of Experimental Psychology*, 71(6), 1396–1404. https://doi.org/10.1080/17470218.2017.1327982

Burton, A. M., & Jenkins, R. (2012). Unfamiliar Face Perception. In: G. Rhodes, A. Calder, M. Johnson, & J. V. Haxby (Eds.), *Oxford Handbook of Face Perception*. Oxford, UK: Oxford University Press.

Burton, A. M., Schweinberger, S. R., Jenkins, R., & Kaufmann, J. M. (2015). Arguments Against a Configural Processing Account of Familiar Face Recognition. *Perspectives on Psychological Science*, 10(4), 482–496. https://doi.org/10.1177/1745691615583129

Caharel, S., Fiori, N., Bernard, C., Lalonde, R., & Rebaï, M. (2006). The effects of inversion and eye displacements of familiar and unknown faces on early and late-stage ERPs. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, 62(1), 141–151. https://doi.org/10.1016/j.ijpsycho.2006.03.002

Caharel, S., & Rossion, B. (2021). The N170 is Sensitive to Long-term (Personal) Familiarity of a Face Identity. *Neuroscience*, 458, 244–255. https://doi.org/10.1016/j.neuroscience.2020.12.036

Crookes, K., Favelle, S., & Hayward, W. G. (2013). Holistic Processing for Other-Race Faces in Chinese Participants Occurs for Upright but Not Inverted Faces. *Frontiers in Psychology*, 4. https://doi.org/10.3389/fpsyg.2013.00029

Davis, J. P., & Valentine, T. (2009). CCTV on trial: Matching video images with the defendant in the dock. *Applied Cognitive Psychology*, 23(4), 482–505. https://doi.org/10.1002/acp.1490

DeGutis, J., Wilmer, J., Mercado, R. J., & Cohan, S. (2013). Using regression to measure holistic face processing reveals a strong link with face recognition ability. *Cognition*, 126(1), 87–100. https://doi.org/10.1016/j.cognition.2012.09.004

Ellis, H. D., Shepherd, J. W., & Davies, G. M. (1979). Identification of familiar and unfamiliar faces from internal and external features: Some implications for theories of face recognition. *Perception*, 8(4), 431–439. https://doi.org/10.1068/p080431

Fitousi, D. (2020). Decomposing the composite face effect: Evidence for non-holistic processing based on the ex-Gaussian distribution. *Quarterly Journal of Experimental Psychology*, 73(6), 819–840. https://doi.org/10.1177/1747021820904222

Ge, L., Anzures, G., Wang, Z., Kelly, D. J., Pascalis, O., Quinn, P. C., Slater, A. M., Yang, Z., & Lee, K. (2008). An inner face advantage in children's recognition of familiar peers. *Journal of Experimental Child Psychology*, 101(2), 124–136. https://doi.org/10.1016/j.jecp.2008.05.006

Goffaux, V., & Rossion, B. (2006). Faces are 'spatial'—Holistic face perception is supported by low spatial frequencies. *Journal of Experimental Psychology: Human Perception and Performance*, 32(4), 1023–1039. https://doi.org/10.1037/0096-1523.32.4.1023

Gosling, A., & Eimer, M. (2011). An event-related brain potential study of explicit face recognition. *Neuropsychologia*, 49(9), 2736–2745. https://doi.org/10.1016/j.neuropsychologia.2011.05.025

Heisz, J. J., & Shore, D. I. (2008). More efficient scanning for familiar faces. *Journal of Vision*, 8(1), 9. https://doi.org/10.1167/8.1.9

Herzmann, G., Schweinberger, S. R., Sommer, W., & Jentzsch, I. (2004). What's special about personally familiar faces? A multimodal approach. *Psychophysiology*, 41(5), 688–701. https://doi.org/10.1111/j.1469-8986.2004.00196.x

Hill, H., & Bruce, V. (1996). The effects of lighting on the perception of facial surfaces. *Journal of Experimental Psychology: Human Perception and Performance,* 22(4), 986–1004. https://doi.org/10.1037/0096-1523.22.4.986

Huang, W., Wu, X., Hu, L., Wang, L., Ding, Y., & Qu, Z. (2017). Revisiting the earliest electrophysiological correlate of familiar face recognition. *International Journal of Psychophysiology*, 120, 42–53. https://doi.org/10.1016/j.ijpsycho.2017.07.001

Jenkins, R., & Burton, A. M. (2011). Stable face representations. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1571), 1671–1683. https://doi.org/10.1098/rstb.2010.0379

Jenkins, R., White, D., Van Montfort, X., & Mike Burton, A. (2011). Variability in photos of the same face. *Cognition,* 121(3), 313–323. https://doi.org/10.1016/j.cognition.2011.08.001

Keyes, H., & Zalicks, C. (2016). Socially Important Faces Are Processed Preferentially to Other Familiar and Unfamiliar Faces in a Priming Task across a Range of Viewpoints. *PLOS ONE*, 11(5), e0156350. https://doi.org/10.1371/journal.pone.0156350

Kramer, R. S. S., Manesi, Z., Towler, A., Reynolds, M. G., & Burton, A. M. (2018). Familiarity and Within-Person Facial Variability: The Importance of the Internal and External Features. *Perception*, 47(1), 3–15. https://doi.org/10.1177/0301006617725242

Kuefner, D., Macchi Cassia, V., Picozzi, M., & Bricolo, E. (2008). Do all kids look alike? Evidence for an other-age effect in adults. *Journal of Experimental Psychology: Human Perception and Performance*, 34(4), 811–817. https://doi.org/10.1037/0096-1523.34.4.811

Loftus, G. R., Oberg, M. A., & Dillon, A. M. (2004). Linear theory, dimensional theory, and the face-inversion effect. *Psychological Review*, 111(4), 835–863.

Marzi, T., & Viggiano, M. P. (2007). Interplay between familiarity and orientation in face processing: An ERP study. *International Journal of Psychophysiology*, 65(3), 182–192. https://doi.org/10.1016/j.ijpsycho.2007.04.003

McKone, E., Brewer, J. L., MacPherson, S., Rhodes, G., & Hayward, W. G. (2007). Familiar Other-Race Faces Show Normal Holistic Processing and are Robust to Perceptual Stress. *Perception*, 36(2), 224–248. https://doi.org/10.1068/p5499

Mondloch, C. J., Elms, N., Maurer, D., Rhodes, G., Hayward, W. G., Tanaka, J. W., & Zhou, G. (2010). Processes underlying the cross-race effect: An investigation of holistic, featural, and relational processing of own-race versus other-race faces. *Perception*, 39(8), 1065–1085. https://doi.org/10.1068/p6608

Michel, C., Caldara, R., & Rossion, B. (2006). Same-race faces are perceived more holistically than other-race faces. *Visual Cognition*, 14(1), 55–73. https://doi.org/10.1080/13506280500158761

Michel, C., Rossion, B., Han, J., Chung, C.-S., & Caldara, R. (2006). Holistic Processing Is Finely Tuned for Faces of One's Own Race. *Psychological Science*, 17(7), 608–615. https://doi.org/10.1111/j.1467-9280.2006.01752.x

Miyakoshi, M., Kanayama, N., Nomura, M., Iidaka, T., & Ohira, H. (2008). ERP study of viewpoint-independence in familiar-face recognition. *International Journal of Psychophysiology*, 69(2), 119–126. https://doi.org/10.1016/j.ijpsycho.2008.03.009

Nemrodov, D., Anderson, T., Preston, F. F., & Itier, R. J. (2014). Early sensitivity for eyes within faces: A new neuronal account of holistic and featural processing. *NeuroImage*, 97, 81–94. https://doi.org/10.1016/j.neuroimage.2014.04.042

O'Donnell, C., & Bruce, V. (2001). Familiarisation with Faces Selectively Enhances Sensitivity to Changes Made to the Eyes. *Perception*, 30(6), 755–764. https://doi.org/10.1068/p3027

Osborne, C. D., & Stevenage, S. V. (2013). Familiarity and face processing. *Quarterly Journal of Experimental Psychology*, 66(1), 108–120. https://doi.org/10.1080/17470218.2012.699077

O'toole, A. J., Edelman, S., & Bülthoff, H. H. (1998). Stimulus-specific effects in face recognition over changes in viewpoint. *Vision research*, 38(15-16), 2351-2363. https://doi.org/10.1016/S0042-6989(98)00042-X

Patterson, K. E., & Baddeley, A. D. (1977). When face recognition fails. *Journal of Experimental Psychology: Human Learning and Memory*, 3(4), 406–417. https://doi.org/10.1037/0278-7393.3.4.406

Parkington, K. B., & Itier, R. J. (2019). From eye to face: The impact of face outline, feature number, and feature saliency on the early neural response to faces. *Brain Research*, 1722, 146343. https://doi.org/10.1016/j.brainres.2019.146343

Quinn, B. P., & Wiese, H. (2022). The role of the eye region for familiar face recognition: Evidence from spatial low-pass filtering and contrast negation. *Quarterly Journal of Experimental Psychology*, 174702182210859. https://doi.org/10.1177/17470218221085990

Ramon, M., & Gobbini, M. I. (2018). Familiarity matters: A review on prioritized processing of personally familiar faces. *Visual Cognition*, 26(3), 179–195. https://doi.org/10.1080/13506285.2017.1405134

Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: Configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review*, 13(3), 499–505. https://doi.org/10.3758/BF03193876

Roberts, T., & Bruce, V. (1988). Feature Saliency in Judging the Sex and Familiarity of Faces. *Perception*, 17(4), 475–481. https://doi.org/10.1068/p170475

Royer, J., Blais, C., Charbonneau, I., Déry, K., Tardif, J., Duchaine, B., Gosselin, F., & Fiset, D. (2018). Greater reliance on the eye region predicts better face recognition ability. *Cognition*, 181, 12–20. https://doi.org/10.1016/j.cognition.2018.08.004

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: Evidence from a cross-cultural study. *Cognition*, 93(1), B1–B9. https://doi.org/10.1016/j.cognition.2003.09.011

Van Belle, G., Lefèvre, P., & Rossion, B. (2015). Face inversion and acquired prosopagnosia reduce the size of the perceptual field of view. *Cognition*, 136, 403–408. https://doi.org/10.1016/j.cognition.2014.11.037

Vinette, C., Gosselin, F., & Schyns, P. G. (2004). Spatio-temporal dynamics of face recognition in a flash: It’s in the eyes. *Cognitive Science*, 28(2), 289–301. https://doi.org/10.1207/s15516709cog2802_8

Visconti di Oleggio Castello, M., Wheeler, K. G., Cipolli, C., & Gobbini, M. I. (2017). Familiarity facilitates feature-based face processing. *PLOS ONE*, 12(6), e0178895. https://doi.org/10.1371/journal.pone.0178895

Wang, R., Li, J., Fang, H., Tian, M., & Liu, J. (2012). Individual Differences in Holistic Processing Predict Face Recognition Ability. *Psychological Science*, 23(2), 169–177. https://doi.org/10.1177/0956797611420575

Wang, Z., Quinn, P. C., Jin, H., Sun, Y.-H. P., Tanaka, J. W., Pascalis, O., & Lee, K. (2019). A regional composite-face effect for species-specific recognition: Upper and lower halves play different roles in holistic processing of monkey faces. *Vision Research*, 157, 89–96. https://doi.org/10.1016/j.visres.2018.03.004

Wang, Z., Quinn, P. C., Tanaka, J. W., Yu, X., Sun, Y.-H. P., Liu, J., Pascalis, O., Ge, L., & Lee, K. (2015). An other-race effect for configural and featural processing of faces: Upper and lower face regions play different roles. *Frontiers in Psychology*, 06. https://doi.org/10.3389/fpsyg.2015.00559

Wang, Z., Ni, H., Zhou, X., Yang, X., Zheng, Z., Sun, Y.-H. P., Zhang, X., & Jin, H. (2023). Looking at the upper facial half enlarges the range of holistic face processing. *Scientific Reports*, 13(1), 2419. https://doi.org/10.1038/s41598-023-29583-z

Yan, X., Young, A. W., & Andrews, T. J. (2017). The automaticity of face perception is influenced by familiarity. *Attention, Perception, & Psychophysics*, 79(7), 2202–2211. https://doi.org/10.3758/s13414-017-1362-1

Yarmey, A. D. (1971). Recognition memory for familiar “public” faces: Effects of orientation and delay. *Psychonomic Science*, 24(6), 286–288. https://doi.org/10.3758/BF03329007