The lasting impression of Chairman Mao: hyperfidelity of familiar-face memory

Liezhong Ge, Jing Luo, Mayu Nishimura§, Kang Lee#¶
Zhejiang University, Hangzhou 310027, People's Republic of China; § McMaster University, Hamilton, Ontario L8S 4L8, Canada; # Department of Psychology, University of California at San Diego, La Jolla, CA 92093, USA; e-mail: kang@psy.ucsd.edu

Abstract. We examined the accuracy of a highly-familiar-face representation in memory. In experiment 1, a famous portrait of Chairman Mao was digitally altered in terms of the distance between his two eyes, two pixels at a time. Mainland Chinese adults were shown the original or altered photos, one at a time, and asked to determine whether each was that of Chairman Mao or altered. Eastern Asian and Caucasian participants, who were unfamiliar with Mao's photo, were shown simultaneously the original face paired with the altered ones and asked to determine whether the photos were identical. The Mainland Chinese participants' memory threshold approximated the perceptual discrimination threshold of the Eastern Asian and Caucasian participants. Experiments 2 and 3 ruled out that the result of experiment 1 was due to artifacts of photographic alteration. The findings of the present study suggest that our memory of a very familiar face is highly accurate, at least in terms of the interocular configuration. The accuracy is perhaps only limited by the perceptual resolution capacity of our visual system.

1 Introduction

Recognising other members of one's biological or social group is of paramount importance for many animals and humans. This is because an individual's decision to fight, to flee, to mate, to cooperate, and to seek protection often depends on the outcome of such recognition. Unlike some lower animals who use auditory or chemical cues for conspecific recognition, humans recognise other members of their species primarily by relying on visual cues in general and faces in particular.

Face recognition is thought to involve comparing a presently seen face (or a part of it) with representations of familiar faces in memory (Bruce and Young 1998; Valentine 2001). One of the critical steps of face recognition is finding a match between the face and its memory representation. Successful face recognition therefore requires the representation of a familiar face in memory to be of sufficient quality. Poor quality face representation would result in failure to recognise a familiar face or mistaking an unfamiliar face as a familiar one. The existing evidence suggests that we are highly skilled at recognising familiar faces: many studies have shown that under normal viewing conditions adults perform rather well in tasks where they must differentiate between formerly seen faces and novel faces under normal viewing conditions (eg Chance and Goldstein 1979; Klatzky and Forrest 1984). Their memory of familiar faces is little affected by the passage of time (Bahrick et al 1975; Bruck et al 1991). Even children with developmental disorders appear to have near normal face recognition abilities (eg Klin et al 1999).

However, despite the extensive research on face recognition, no direct evidence exists regarding exactly how accurate our representation of familiar faces is in memory. It is unclear whether our representation of familiar faces (eg parents, friends, or public figures) is as accurate as a recently taken photograph, or is a mere approximation like a fuzzy, faded picture. A traditional and commonly used paradigm for testing individuals' accuracy of familiar-face memory is to familiarise them with a set of faces and then

¶ Author to whom all correspondence and requests for reprints should be addressed.

present either a previously seen face or a novel face, and ask them to judge whether the face is 'old' or 'new'. Because the familiar-face and unfamiliar-face stimuli used in such paradigms are often derived from photographs of real individuals, the familiar face tends to differ from the unfamiliar ones on a number of stimulus dimensions simultaneously. They may differ in the shapes and features of major face elements (eg eyes, nose, mouth), the spatial relationships of these elements, the characteristics of face contour, and even hairstyles. Thus, results from such paradigms at best offer information about how well one can functionally recognise a familiar face among unfamiliar faces during everyday encounters. They, however, provide a poor estimation of how accurate the individual's representation of a particular familiar face is in memory.

In the present study we used a psychophysical method to obtain a more accurate estimation of the accuracy of familiar-face representation in memory. In order to achieve this goal, we need to present individuals with familiar and unfamiliar faces that differ from each other only slightly. To obtain such highly similar faces, computer graphics programs must be used to alter a certain familiar face slightly on only a single stimulus dimension (eg the distance between the eyes). By increasing the alteration of the familiar face systematically on that dimension, we can derive a series of novel face stimuli that increasingly differ from the original familiar face stimulus. By presenting to the observers one face stimulus at a time and asking them to judge whether the presently seen face is the same as, or different from, the familiar face in their memory, we should obtain the minimal changes needed for an altered face to be judged as a novel one. Because individuals must make such judgments based on their memory of the original familiar face, this just noticeable difference (JND) provides a threshold level estimation of the accuracy of the individuals' representation of the familiar face in memory.

Our memories of familiar faces are thought to be based on at least three distinct, yet interrelated, types of information (Bruce and Young 1998; Tanaka and Farah 1993; Valentin et al 1997): (a) holistic information (abstract, undecomposed, global structure of a face), (b) featural information (the shape and size of such distinct facial elements as eyes, nose, and mouth), and (c) configural information (the spatial relationship between the facial elements). Although all three types of information contribute to our success in face recognition, the present study primarily focused on the representation accuracy of the configuration of a familiar face. The reason for focusing on this particular dimension of facial representation is both theoretical and methodological. Theoretically, existing evidence suggests that facial configuration plays a critical role in face recognition. For example, the recognition of a facial feature is enhanced when it is situated in a face configuration (Tanaka and Farah 1993). Configural processing has been primarily linked with activity in the right hemisphere, whereas featural processing tends to activate the left hemisphere (eg Hillger and Koenig 1991). Early visual deprivation due to congenital cataracts has permanent effects on processing of configural information, but does not affect featural processing (Le Grand et al 2001). In addition, there is also extensive evidence to suggest that schematic face stimuli with little or no accurate featural information are sufficient to trigger effectively face and emotion perception and recognition (eg Bentin et al 2002; Homa et al 1976; Oehman et al 2001). Thus, given the important role of configural information in face recognition, we speculated that we may have a highly accurate representation of the configuration of familiar faces.

The methodological reason for focusing on face configuration is that the configuration of a face can be manipulated and quantified with relative ease because of the advancement of computer graphics technology. For example, the configuration of a face can be changed by simply increasing or decreasing, one pixel at a time, the distance between the eyes. With easy-to-use photo retouching tools provided by computer graphics programs, well-established in many previous studies (eg Freire et al 2000; Rhodes et al 1993; Searcy and Bartlett 1996), naturally looking and artifact-free face

stimuli can be obtained (figure 1). Because the distance between the eyes is changed systematically in terms of the number of pixels (or visual angles), one can obtain a quantitative measure of the JND between the configuration of the original face and the altered versions.

We conducted three experiments to estimate the accuracy of adults' memory of very familiar faces. Chairman Mao's face was used. Our choice of Mao's face as the target

| Mao original | Mao − 4 | Mao − 12 | Mao − 18 |

| Mao original | Mao + 4 | Mao + 12 | Mao + 18 |

Figure 1. Sample stimuli used in experiments 1, 2, and 3.

face stems from the fact that Mao's images (photos and moving images on television and films) are omnipresent in Mainland China and all Chinese adults have been exposed to his images since early childhood. Thus, his face is highly familiar to most Mainland Chinese adults, which allows the recruitment of a sufficient number of participants to obtain estimations of the accuracy of a familiar-face representation. In the present study, we altered Mao's facial configuration by systematically increasing or decreasing the distance between his eyes, pixel by pixel. It should be noted that the configuration of a face can be systematically altered by either changing horizontally the interocular distance or changing vertically the distance between eyes, nose, and mouth, or both. We focused on the interocular change because the eye regions have been shown to be the focal point of face-to-face interactions (Argyle and Cook 1976) and the tendency to focus on the eyes emerges as early as 2 months of age (Maurer and Salapatek 1976). Thus, we hypothesised that individuals may be specifically sensitive to changes in the eye regions and their spatial relations to nose and mouth, which would in turn provide a threshold estimation of our familiar-face memory.

2 Experiment 1

In this experiment, participants took part in either of two conditions. In the recognition condition of experiment 1, we showed the original and altered face stimuli to Mainland Chinese participants, *one stimulus at a time*, and obtained the threshold of changes in the distance between Mao's eyes for the participants to judge the face to be different from their memory of Mao's face. In the discrimination condition, we used a perceptual discrimination method. Participants of Eastern Asian origin and Caucasian participants who were unfamiliar with Mao's face were shown the original photo of Mao's face and an altered one *simultaneously* and asked to judge whether both photos were identical. This procedure provided an estimation of the minimal amount of configural change needed for our perceptual system to resolve the differences between the original face and the altered ones. This estimation in turn serves as a benchmark to which the results from the recognition condition can be compared.

2.1 Methods

2.1.1 *Participants.* Eight Mainland Chinese undergraduates (four males and four females) participated in a recognition task. They were all born and raised in the People's Republic of China.

Two additional groups of participants were recruited as controls to participate in a discrimination task. One group consisted of eight Eastern Asian university undergraduates (three males and five females) who were raised outside Mainland China. The other group consisted of eight Caucasian undergraduates (three males and five females). Both groups overall reported that they were unfamiliar with Mao's photo. All participants had normal or corrected-to-normal vision.

2.1.2 *Materials.* A portrait of Chairman Mao was digitised and rendered gray (figure 1). The image has a width of 15.88 cm and height of 17.54 cm (450 by 497 pixels) with a resolution of 0.035 cm per pixel or 2.41 min of arc per pixel. We used Adobe Photoshop software to increase or decrease the distance between Mao's eyes (using the centre of his iris as the reference point), two pixels at a time (one pixel for each eye). The resultant faces were then photo retouched to create natural-looking shadings (see figure 1 for examples). Nine new faces in the eye-out condition had a greater interocular distance than that in the original photograph. These faces are referred to henceforth in the form of Mao + X, such as Mao + 2, Mao + 4, ..., to Mao + 18, where 'X' indicates the number of pixels by which the distance between the eyes of the new face differs from that of the original face. Nine faces in the eye-in condition had a smaller interocular distance between the eyes than that of the original. They are referred to as Mao − 2,

Mao − 4, ..., to Mao − 18. The original photo of Mao's face is henceforth referred to as Mao + 0.

2.1.3 *Procedure.* Participants were seen individually. They viewed face stimuli on a 15-inch monitor at a viewing distance of 50 cm. The stimulus presentation and data recording were controlled by a psychophysics software. The participants in the recognition task were shown randomly either Mao + 0 or an altered Mao. They were given the following instruction:

> "You are going to view a number of photos. Some of the photos show the face of Chairman Mao while others are not his face. The faces are very similar. You must look at each face as a whole, not just one part, and then decide whether the face is that of Mao or not. Please respond as accurately as possible without sacrificing speed."

Each photo was shown for a maximum of 10 s or until the participant responded, at which time the next photo was presented. No feedback was given. Participants saw 1152 presentations in total, and responded by pressing a response key on a computer keyboard. The experiment took about 1 h 20 min. There was a 2-min break every 192 trials. Half of the presentations were Mao + 0 and the other half were altered photos (32 times for each altered photo). The order in which these photos were presented was randomised.

In the discrimination task, the Eastern Asian and Caucasian undergraduates were shown Mao + 0 and one of the altered photos or two copies of Mao + 0 simultaneously. They were asked to judge whether the pair of photos was identical or different from each other *in any way*. One half of the stimulus pairs were identical photos of Mao + 0 and the other half contained altered photos paired with the original. For the non-identical pairs, participants saw 20 trials of each altered photo paired with Mao + 0, half of which had Mao+0 on the right side and the other half with Mao + 0 on the left side. The participants also saw the same number of identical pairs. Each pair was shown for a maximum of 10 s or until participants responded on the keyboard, at which time the next pair was presented.

2.2 *Results and discussion*

Figure 2 shows the mean percentage of trials in which the Mainland Chinese participants correctly identified the altered stimuli not to be Mao's face as a function of changes in distance (pixels) between Mao's eyes (the participants' correct identification rate of Mao + 0 was also included). A repeated-measures ANOVA, with the distances between Mao's eyes as the repeated measures, revealed that as the distance increased (eye-out condition), participants' correct identification rate increased ($F_{8,7} = 270.86$, $p < 0.001$). The same was true when the distance was decreased (eye-in condition) ($F_{8,7} = 128.88$, $p < 0.001$).

Figure 2 also shows the mean percentage of trials in which the Eastern Asian and Caucasian participants made a correct perceptual discrimination between the altered stimuli and the original stimulus as a function of changes in distance (pixels) between Mao's eyes. As the distance increased (eye-out) or decreased (eye-in), the Eastern Asian participants' correct discrimination rates increased ($F_{8,7} = 140.01$, $p < 0.001$; and $F_{8,7} = 114.95$, $p < 0.001$, respectively). The same was true for the Caucasian participants' correct discrimination rates in the eye-out and eye-in conditions ($F_{8,7} = 255.39$, $p < 0.001$; and $F_{8,7} = 991.82$, $p < 0.001$, respectively).

Each Mainland Chinese participant's JND in pixels was determined by using the 75% correct response point on the psychophysical function (Gescheider 1997), which was then multiplied by 2.41 (minutes of arc per pixel as viewed from 50 cm) to obtain threshold values in visual angles. Table 1 shows the Mainland Chinese participants' mean JNDs in both visual angles and pixels in the eye-out and eye-in conditions. Eastern Asian and Caucasian participants' JNDs in both the eye-out and eye-in conditions were
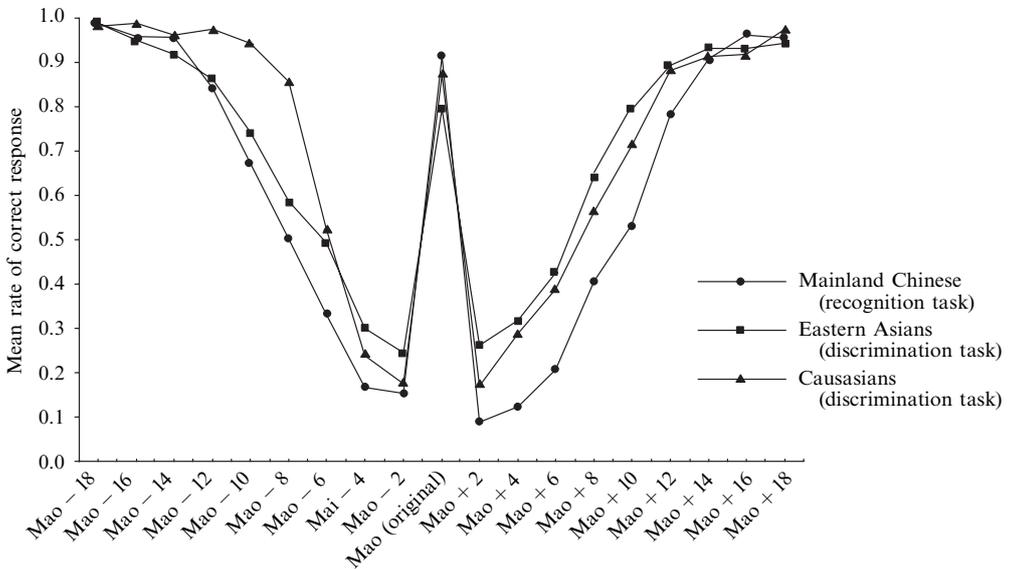
Figure 2. Mean correct response rates as a function of face stimuli, condition, and participant type in experiment 1.

Table 1. Means (standard deviations) of just noticeable differences (JNDs) in the eye-in and eye-out conditions in experiment 1.

Subjects	JND/min of arc		JND/pixels	
	eye-in	eye-out	eye-in	eye-out
Mainland Chinese	21.49 (7.25)	25.26 (2.96)	9.82 (3.31)	11.55 (1.35)
Eastern Asians	22.73 (8.34)	18.47 (4.00)	9.45 (3.46)	7.68 (1.66)
Caucasians	17.43 (3.72)	27.02 (7.15)	7.24 (1.39)	11.23 (2.97)

determined by the same method (table 1). Note that the Eastern Asian participants were similar to the Mainland Chinese participants in their experience in processing Eastern Asian faces but lacked familiarity with Mao's face. Thus, the Eastern Asian participants' performance in the discrimination task provides an estimate of how well the Mainland Chinese participants could have perceptually discriminated between Mao + 0 and the altered photos had they been unfamiliar with Mao's face. In contrast, the Caucasian participants were, in general, not as experienced as the Mainland Chinese in processing Eastern Asian faces. Nor were they familiar with Mao's face. Therefore, the Caucasian participants' JNDs provide an estimate of how well an individual without expertise in processing Eastern Asian faces could perceptually resolve the differences between two unfamiliar faces.

A 2 (conditions: eye-in versus eye-out) × 3 (subject type: Mainland Chinese, Eastern Asian, Caucasian) repeated-measures ANOVA with the first factor as repeated measures was conducted to compare the mean JNDs of the Mainland Chinese participants with those of the Eastern Asian and Caucasian participants. The main effects of subject type were not significant ($F_{2,21} = 0.79$, ns). Thus, the mean JNDs of the three types of participants were overall not significantly different from each other. The condition effect was also not significant ($F_{1,21} = 3.62$, ns). Only the condition by subject type interaction was significant ($F_{2,21} = 6.31$, $p < 0.01$). A posteriori analyses (Tukey) revealed that for the eye-in condition, the Chinese participants' JNDs in the recognition task were not significantly different from the Eastern Asians' and Caucasians' JNDs in the

discrimination task. For the eye-out condition, the Mainland Chinese participants' mean JND was significantly greater than that of the Eastern Asian participants but did not differ significantly from that of the Caucasian participants.

Thus, when the distance between Mao's eyes was increased, the Mainland Chinese participants' performance was significantly poorer than that of the Eastern Asian participants (by, on average, 6.79 min of arc). However, the Mainland Chinese participants' JNDs in the recognition task were comparable to those of the Caucasian participants in the discrimination task. This result suggests that the Mainland Chinese participants' memory accuracy of Mao, although poorer than their visual resolution capacity, approximates the perceptual discrimination accuracy of someone who is not experienced with Eastern Asian faces.

When the distance between Mao's eyes was reduced, the Mainland Chinese participants' performance in the recognition condition was comparable to that of the Eastern Asians and Caucasians. Note that, in the recognition condition, participants must compare the presently seen stimulus with their memory of Mao; whereas in the discrimination condition, participants only needed to compare two visually available stimuli. This result suggests that the Mainland Chinese adults' memory of Mao's face was highly accurate in the eye-in condition. Their accuracy was near the level at which their visual system could perceptually resolve the differences between two presently seen photographs.

However, one can argue that the present findings could be due to the experimental procedure used in this experiment: Mao + 0 was shown more frequently (576 times) than any of the altered ones (32 times per stimulus × 18 stimuli = 576). It is possible that the Mainland Chinese participants simply learned Mao + 0 during the course of the experiment and thus relied on their short-term memory of the most frequently appearing stimulus rather than their long-term memory of Mao to make discriminations between Mao + 0 and the altered ones.

This learning hypothesis is, however, unlikely to be true, at least for the following three reasons. First, the participants must be able to discriminate perceptually between Mao + 0 and the altered ones in order to know which photo is most frequently occurring and which is not. The results of the Eastern Asian and Caucasian participants suggest that such discrimination is difficult when one does not have a long-term memory of Mao + 0. Second, such discrimination must be done by comparing a presently seen face stimulus with the memory of the newly learned face. However, the results of the Eastern Asian and Caucasian participants suggest that discrimination is already very difficult when Mao + 0 is seen side by side with the altered ones. It is reasonable to assume that the discrimination task would be even harder when only one face stimulus is seen visually and the other has to be retrieved from memory. In other words, if the learning hypothesis is true, Mainland Chinese participants should perform substantially worse than the Eastern Asian and Caucasian participants in the discrimination task, which is in fact not the case.

Third, if this learning hypothesis were true, one would expect that the participants' memory threshold would decrease significantly as the experiment progresses. To address this possibility, we reanalysed the data by dividing the total number of trials into four blocks and calculated the memory threshold values for each participant for each block. The reason that we divided the trials into four blocks was that for each of the four blocks there were just 8 trials for each altered stimulus. Participants' correct or incorrect responses to these 8 trials were used for the calculation of a memory threshold. Dividing the trials into more blocks would require the calculation to be based on even fewer trials which would have made the threshold estimation highly variable and unreliable.

After dividing the trials into blocks, in the eye-in condition, the means (standard deviations) of the memory thresholds for block 1 through block 4 are as follows: 5.35 (1.64), 4.66 (2.08), 4.52 (1.60), and 4.34 (1.47). A repeated-measures ANOVA failed to reveal a significant block effect ($F_{3, 27} = 2.52$, $p > 0.05$). In the eye-out condition, the means (standard deviations) of the memory thresholds for block 1 through block 4 are as follows: 6.23 (1.46), 5.97 (1.21), 6.02 (1.63), and 5.48 (2.20). A repeated-measures ANOVA also failed to reveal a significant block effect ($F_{3, 27} = 0.66$, $p > 0.05$). In other words, the participants' memory thresholds of Mao did not decrease significantly as the experiment progressed. This finding is inconsistent with the explanation offered by the learning hypothesis. Thus, the excellent performance of the Mainland Chinese participants in the present experiment was likely due to their highly accurate memory of the face of Chairman Mao.

3 Experiment 2
In this experiment, the same stimuli as those used in experiment 1 were presented upside down. Evidence to date has shown that inverting faces tends to disrupt the processing of configural but not featural information of a face (Bartlett and Searcy 1993; Farah et al 1995; Tanaka and Sengco 1997). When faces that primarily differ in configuration are shown upside down, individuals' discrimination of the faces tends to fall near chance levels (Freire et al 2000). Thus, this procedure allowed us to assess whether altering Mao's photograph had led to noticeable artifacts and whether these artifacts, rather than face configuration, were the main information used by the Mainland Chinese participants to make their judgments in experiment 1.

3.1 Methods
3.1.1 *Participants.* Eight Mainland Chinese university undergraduate students (four males and four females) participated. They were all born and raised in the People's Republic of China and had normal or corrected-to-normal vision.

3.1.2 *Materials and procedure.* The same face stimuli as those used in experiment 1 were inverted and used as the stimuli for this experiment (see figure 1 for examples). The experimental procedure was identical to that of the recognition task of experiment 1.

3.2 Results and discussion
Figure 3 shows the mean percentage of trials in which the Mainland Chinese participants correctly identified the altered stimuli not to be Mao's face as a function of changes in distance (pixels) between Mao's eyes. As the distance increased, participants' correct identification rate increased ($F_{8, 9} = 11.02$, $p < 0.05$). The same was true when the distance was decreased ($F_{8, 9} = 14.95$, $p < 0.01$). However, no participant's correct identification rate reached the threshold level (75%). Further, when the mean correct identification rate of each altered stimulus was compared to chance (50%), the correct identification rates for the Mao + 2, Mao + 4, Mao + 6, Mao + 8, Mao − 2, and Mao − 4 stimuli were significantly below chance. That is, the participants tended to respond that these inverted altered faces were Mao's face. The mean correct identification rates for the rest of the stimuli were not significantly different from chance. These results suggest that the alterations made to Mao's face were mainly configural (Freire et al 2000). There appeared to be no noticeable featural artifacts in the altered stimuli. Otherwise, the participants' performance should be above, not below, the chance level.

However, one can argue that the alterations of Mao's face may result in artifacts that are configural in nature. For example, while increasing or decreasing the distance between Mao's eyes leads to changes in the configuration of Mao's face elements (which was the intended effect), it may also lead to changes in configuration that
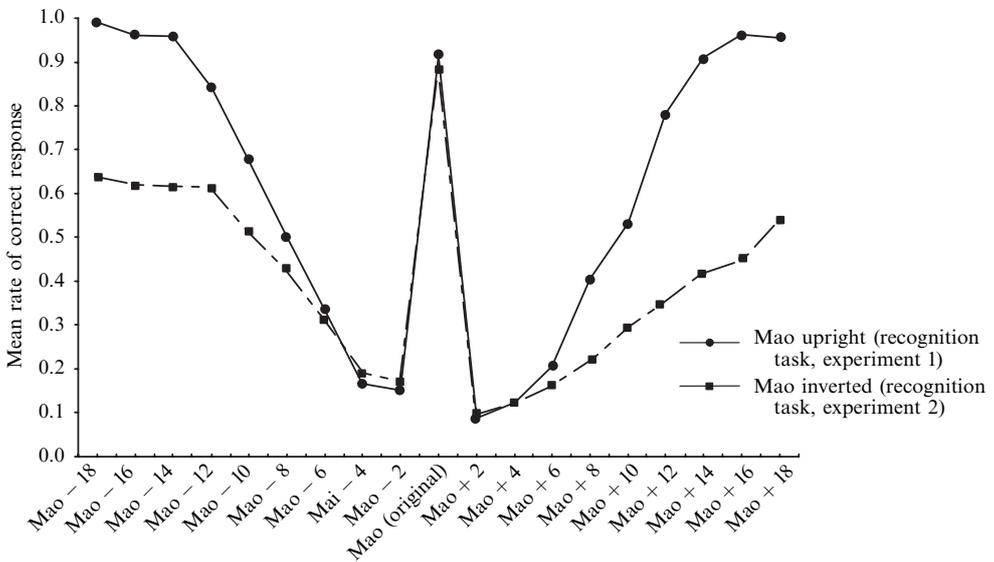
Figure 3. Mean correct response rates of Mainland Chinese participants in experiment 2 as compared to those of Mainland Chinese participants in experiment 1.

are not intended. For example, the shading of the altered faces may have appeared unnatural, the interocular distance of the altered faces may be unusual for a typical Chinese face, or the alteration had rendered the overall appearance of the altered face stimuli not to look like a typical Chinese face. The Mainland Chinese participants might have relied on such cues, rather than their memory representation of Mao, to judge whether or not a face stimulus was Mao's face. Although the inversion procedure can rule out the effect of featural artifacts, it is incapable of addressing the impact of configural artifacts on the participants' face recognition. Experiment 3 was conducted to address directly this configural artifacts hypothesis.

4 Experiment 3
In this experiment, Eastern Asian students who were unfamiliar with Mao's face were shown the original and altered face stimuli, one at a time. They were asked to rate on a Likert scale the face stimuli in terms of (i) whether the faces overall looked atypical of a Chinese face, (ii) whether the interocular distance looked atypical, and (iii) whether there were any visible artifacts in the stimuli. If the Mainland Chinese participants' performance in experiment 1 was due to these configural artifacts, there should be significant differences in rating between the original face and the altered faces that were just above the threshold levels. This prediction is based on the fact that in experiment 1 the estimation of the Mainland Chinese participants' memory threshold was derived from the correct response rate of an altered face that was just above the threshold (75%) and that of an altered face that was just below the threshold. Thus, if the configural artifacts hypothesis is correct, in comparison with the original face, the face stimuli that are just above the threshold level should be judged significantly more atypical in both overall appearance and interocular distance. Also, they should more likely be judged to have visible artifacts than the original face.

Based on the results of experiment 1 (table 1), the mean threshold for the eye-in condition was 9.82 pixels (range: 5.18 to 14.83 pixels) and that for the eye-out condition was 11.55 pixels (range: 9.59 to 13.01 pixels). Thus, the following face stimuli had an interocular distance just above the threshold level for at least one participant:

Mao − 6, Mao − 8, Mao − 10, Mao − 12, Mao − 14, and Mao − 16 in the eye-in condition, and Mao + 10, Mao + 12, and Mao + 14 in the eye-out condition. If the above configural artifacts indeed existed and could be used for making judgments about whether a stimulus was the original Mao or an altered one, the ratings for all these stimuli should be significantly different from that of the original face.

4.1 Methods

4.1.1 *Participants.* Twelve Eastern Asian undergraduates participated in the study (six males and six females). They were all born outside Mainland China and were unfamiliar with Mao's face. They had normal or corrected-to-normal vision.

4.1.2 *Materials and procedure.* The same face stimuli as those used in experiment 1 were again used for this experiment. The face stimuli were presented to participants one at a time in the same manner as that in the recognition condition of experiment 1, except that no viewing time limit was imposed. The face stimuli were randomly presented to participants. Upon the completion of rating one stimulus, the participant pressed a key to view and rate the next stimulus.

Participants were asked to rate the face stimuli on a 5-point Likert scale according to a statement. The meaning of each of the five points on the scale was labeled as follows: strongly agree, somewhat agree, not agree nor disagree, somewhat disagree, and strongly disagree. First, the participant was asked whether he or she agreed with the statement that "this face does not look like a typical Chinese face". Once the participants finished rating the original face and 18 altered ones, they were presented with another statement "the distance between the eyes on this face does not look like that of a typical Chinese individual" and asked to rate the face stimuli accordingly. Finally, they were told that some of the face stimuli were digitally altered and asked whether they agreed with the statement that "the eye regions of this face have visible artifacts (eg non-face related dots, blemishes, and wrong shading cues)".

4.2 Results and discussion

Table 2 shows the mean rating and standard deviation of the ratings of the original face and the altered ones. Paired samples t-tests compared participants' ratings of each of the altered stimuli with their ratings of the original face. For the first statement, "this face does not look like a typical Chinese face", only Mao − 16 was rated significantly different from the original Mao ($t_{11} = 2.41$, $p < 0.05$). The latter was rated as appearing more like a typical Chinese face than the former. For the second statement, "the distance between the eyes on this face does not look like that of a typical Chinese individual", only Mao + 16 and Mao + 18 were rated significantly different from the original face ($t_{11} = 2.53$, $p < 0.05$ and $t_{11} = 2.78$, $p < 0.05$), respectively. The interocular distance of the former was considered to look less like that of a typical Chinese individual. Again, the rest of the altered faces were not rated differently from the original one. For the third statement, "the eye regions of this face have visible artifacts (eg non-face related dots, blemishes, and wrong shading cues)", only the mean rating for Mao − 16 was significantly different from that of the original ($t_{11} = 2.32$, $p < 0.05$). Participants on average agreed somewhat with the statement that Mao − 16 appeared to have visible artifacts in the eye region.

These findings overall failed to confirm the configural artifacts hypothesis. In the eye-out condition, the significant difference in rating between the original face and the altered ones was only found with Mao + 16 and Mao + 18. In experiment 1, these two stimuli were far above the threshold level of any Mainland Chinese participants. The correct response rates for these two stimuli were never used in the calculation of any participant's memory threshold. The Mainland Chinese participants' memory thresholds were based on the correct response rates of Mao + 10 (1 participant),

Table 2. Means (standard deviations) of Eastern Asian participants' ratings of the original and altered face stimuli.

Stimulus	Atypical appearance	Atypical interocular distance	Visible artifacts
Mao + 0	4.33	3.67	3.50
	(1.15)	(1.37)	(1.09)
Mao − 2	4.25	3.75	3.58
	(1.36)	(1.22)	(1.31)
Mao − 4	4.58	3.67	3.17
	(0.90)	(1.37)	(1.47)
Mao − 6	4.67	3.92	3.50
	(0.49)	(1.44)	(1.17)
Mao − 8	3.83	3.83	3.00
	(1.27)	(1.27)	(1.41)
Mao − 10	4.08	3.92	3.50
	(1.00)	(1.08)	(1.09)
Mao − 12	3.83	3.50	3.17
	(1.47)	(1.31)	(1.19)
Mao − 14	4.00	3.67	3.08
	(1.35)	(1.30)	(1.44)
Mao − 16	2.83	3.33	2.42
	(1.64)	(1.30)	(0.90)
Mao − 18	3.08	2.83	2.50
	(1.51)	(1.03)	(1.24)
Mao + 2	4.33	3.67	3.67
	(1.15)	(1.56)	(1.30)
Mao + 4	4.33	3.83	3.17
	(0.98)	(1.27)	(1.40)
Mao + 6	4.33	3.67	3.83
	(0.89)	(1.23)	(0.94)
Mao + 8	4.33	3.00	3.50
	(0.98)	(1.28)	(1.09)
Mao + 10	3.67	2.83	3.17
	(1.37)	(1.53)	(1.11)
Mao + 12	4.00	3.17	3.33
	(1.28)	(1.40)	(1.30)
Mao + 14	3.00	2.5	3.08
	(1.60)	(1.24)	(1.31)
Mao + 16	2.92	2.42	3.00
	(1.62)	(1.08)	(1.28)
Mao + 18	3.08	2.33	2.58
	(1.73)	(1.15)	(1.24)

Note: 1 = strongly agree, 2 = somewhat agree, 3 = not agree nor disagree, 4 = disagree, 5 = strongly disagree.

Mao + 12 (3 participants), and Mao + 14 (four participants). However, in the present experiment, these stimuli were rated similarly to the original face in terms of the typicality of overall appearance and interocular distance as well as the visibility of artifacts. Thus, the configural artifacts hypothesis could not explain why the Mainland Chinese participants could recognise these altered stimuli not as the original Mao in the eye-out condition in experiment 1.

In the eye-in condition of this experiment, only the mean rating for Mao − 16 was significantly different from that of the original. However, in experiment 1, the correct response rate for Mao − 16 was used only once to calculate one participant's memory threshold. The rest of the participants' memory thresholds in this condition were computed on the basis of the correct response rates of Mao − 6 (two participants),

Mao – 10 (two participants), Mao – 12 (two participants), and Mao – 14 (one partici-
pant), which were rated in the same manner as the original in the present experiment.
In other words, these face stimuli were not considered by the participants in the
present experiment to have an atypical overall appearance and interocular distance,
nor were they believed to have visible artifacts. Thus, this finding also failed to confirm
that configural artifacts were mainly responsible for the high performance of the
Mainland Chinese participants in the eye-in condition of experiment 1 .

5 General discussion
The present study revealed that Mainland Chinese participants had a highly accurate
memory of Chairman Mao's face, to which they had extensive exposure since child-
hood. This conclusion is based on the evidence that the performance of the Mainland
Chinese participants in the recognition task of experiment 1 was highly similar to that
of the Eastern Asians and Caucasians in the discrimination task. Note that the recog-
nition task is much harder than the discrimination task, because the former requires
the participants to compare a presently seen face to a face representation in memory and
judge whether the presently seen face is "the same person" as that in their memory
(ie making an identity judgment); the latter only requires comparing two presently seen
faces and judging whether the presently seen stimuli are identical or different in any
way (ie making an absolute same – different judgment). Despite the differences in task
difficulty, the two tasks did not produce marked differences in performance. The
results of experiments 2 and 3 also suggest that the similarity in the Mainland Chinese
participants' performance between the tasks in experiment 1 was not due to the effects
of configural or featural artifacts in the face stimuli. Thus, the fact that the Mainland
Chinese participants in experiment 1 performed so well was likely due to the high
fidelity of their representation of Chairman Mao's face in memory.

To the best of our knowledge, the present study is the first to provide a direct
estimate of the accuracy of memory of a particular familiar face. As mentioned earlier,
in previous studies faces were used that differed from each other in terms of both
configuration and features. The accuracy of an individual's face memory was measured
by the rate of the number of correctly identified familiar and unfamiliar faces versus
the total number of faces presented (ie correct identification rate). Such a measure
provides only an estimate of an individual's memory accuracy of a group of familiar
faces, not of a particular familiar individual's face. In addition, this measure only
reveals the extent to which an individual can recognise familiar faces when contrasted
with markedly different unfamiliar faces. Note that the differences between those
familiar and unfamiliar faces can be easily resolved by our perceptual system. The
results of the present study show that our familiar-face memory can be as accurate
as the ability of our perceptual system to resolve the differences between faces. Clearly,
the traditional measure underestimated the accuracy of individuals' familiar-face memory.

Furthermore, in many of the existing face recognition studies, the so-called 'familiar'
faces are often unfamiliar faces that participants have seen shortly before being tested.
Hence, the correct identification rate in fact measures an individual's memory of
slightly familiar faces, not that of a highly familiar face. In fact, the paradigm used
in these studies is incapable of measuring memory accuracy of highly familiar faces
because all participants would perform at ceiling in these kinds of tasks. Our paradigm,
on the other hand, does not have such a limitation.

This last issue raises a number of theoretically important questions regarding the
formation of memory for familiar faces. For example, what is the relationship between
an individual's familiarity with a face and the individual's memory accuracy of it?
To what extent does the number of exposures or length of exposure to a face increase
one's memory accuracy of such a face? The Mainland Chinese participants in the

present study were of similar age and presumably had a similar duration and number of exposures to Chairman Mao's face. It is not clear whether different age groups (eg those of older or younger generation) of Mainland Chinese have a different level of accuracy as a result of the different amounts of exposure to Mao's face. It is also not clear whether the frequency of encountering Mao's photographic images plays any role in establishing one's accurate representation of Mao's face in memory. Because it was impossible to measure directly the frequency of the Mainland Chinese participants' encounters with Mao's photos, our data do not address this issue.

However, this issue can be addressed in future studies by exposing Eastern Asians or Caucasians to Mao's face, or Mainland Chinese to an unfamiliar face, in different frequencies or periods of time (ie using a training paradigm), and then testing their memory threshold of recently familiarised faces. Research in this manner can also answer the question of whether a highly accurate memory of a familiar face can be achieved by short-term, intensive, and constant exposure to the face, rather than the extended, yet irregularly timed exposure experienced by the Mainland Chinese participants. Results from such studies may contribute to the understanding of the process by which our representations of faces are formed, strengthened, consolidated, and become highly accurate.

Another question that requires investigation is the generalisability of our results to other familiar faces among Mainland Chinese participants as well as other populations. Although it is unique that the Mainland Chinese adults have been consistently and uniformly exposed to Mao's photos for an extended period of time, it is possible that similar experiments can be conducted in other locales where similar situations exist (eg highly publicised politicians, religious figures, and celebrities). It is possible that results similar to ours can be obtained with these individuals' faces in these locales (eg the memory of Che Guevara's face in South America, and that of Queen Elizabeth in Britain).

Another generalisability issue is also worth noting. In the present study, we tested the memory of the face of a public figure with whom none of our participants had direct personal contacts. They have become familiarised with the face through media images (eg photos, television programmes, and films). The image that the Mainland Chinese participants were most familiar with and being tested on in the present study is the standard portrait of Mao. This photo has a frontal viewpoint with a neutral expression. However, in our everyday life, we do not always encounter faces that have a frontal viewpoint or a neutral expression and learn about them via a medium. Rather, we most often directly observe others in person and their faces in a three-dimensional form. Faces are also seen from a variety of viewpoints in different lighting conditions with a variety of emotional expressions as well as different guises (eg wearing or not wearing a hat, a pair of glasses, etc). The memory of faces familiarised through such direct and personal encounters may be different from that of public figures familiarised through indirect, mediated encounters. It is possible that the former is even more accurate than the latter. This is because personal encounters provide the observer greater opportunity to encode appearance variations of a face such that an enriched, flexible representation of the face can be constructed. This possibility is yet to be confirmed by future studies.

Finally, although the present study focused on the accuracy of familiar face memory, it can also be construed as examining individuals' sensitivities to changes in the appearance of a familiar face. Thus, our findings show that individuals are highly sensitive to changes in the interocular distance of a highly familiar face. Such sensitivity appears to be only limited by how our visual system can resolve these changes. However, in the present study the changes were limited to configural changes along the horizontal dimension (ie the interocular distance). It is unclear how sensitive

individuals are to configural changes along the vertical dimension (eg the distance between the nose and mouth). Also, it is unknown whether individuals are also highly sensitive to changes in face features (eg replacing Mao's nose by another individual's nose). Answers to these questions should allow us to compare our sensitivity to changes in different aspects of face information, which in turn will lead to a more comprehensive understanding of the accuracy of our face memory.

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