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# The eye-size illusion: Psychophysical characteristics, generality, and relation to holistic face processing

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**Abstract.** Rakover [(2011). In Y. H. Zhang (Ed.), *Advances in face image analysis: Techniques and technologies* (pp. 316–333). Hershey, PA: IGI Global] observed a novel eye-size illusion: when increasing the size of a face but keeping the size of its eyes unchanged, the eyes are perceived to be smaller than in the original face. Here, we systematically manipulated the face size and found that the magnitude of this illusion linearly changed as a function of the face frame size (experiment 1). Additionally, the same magnitude of an illusion was observed for the perception of the size of the mouth when we changed the face frame but kept the mouth size constant (experiment 2). Further, when the faces and eyes were presented upside down, the magnitude of the illusion was significantly reduced in both Chinese participants (experiment 3) and Caucasian participants (experiment 4). The results suggest that the perception of eye or mouth size occurs in the relational context of the whole face; and when the face is inverted, thereby disrupting holistic processing, the magnitude of the illusion is reduced. We therefore suggest that holistic processing is involved in producing the illusion.

**Keywords:** eye-size illusion, holistic face processing, inversion effect

## 1 Introduction

Rakover (2011) reported a novel 'eye-size illusion'. The illusion is generated by size transformations made on a picture of a face: with increases or decreases in the size of the face frame except for the eye area (including eyes and eyebrows: figure 1a), the perception of the size of the eyes is affected. In particular, the eyes embedded in a smaller face frame are perceived as larger than the eyes embedded in a larger face, even though the size of the eyes in the two faces is equal. The eye-size illusion was developed from the famous geometrical illusion of Ebbinghaus/Titchener, in which a central circle surrounded by large circles is perceived as being smaller than the same central circle surrounded by small circles (eg Coren & Girgus, 1978). The difference in size perception is due to the surrounding visual cues, and the way the brain processes these visual cues. The existence of the Ebbinghaus/Titchener illusion demonstrates that our brain cannot ignore the background information when perceiving the target embedded in different contexts.

Rakover (2011) conducted a series of experiments and found that the eye-size illusion with human faces was greater than the headlight illusion with cars. Moreover, the geometrical form illusion was weaker than the eye-size illusion and headlight illusion. These results suggest that the illusion is affected by the level of learning and experience with the visual information in which the illusion is embedded. Because individuals are presumably exposed to faces more frequently than to cars and geometrical forms, they become expert at processing facial information and develop a prototype or norm for faces which facilitates their fine-tuned

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**Figure 1.** [In color online, see http://dx.doi.org/10.1068/p7647] (a) and (c) Examples of a test trial. The face on the right was the original face, and the face on the left was 14% smaller in the face frame but with the same size of eyes (a) or mouth (c). (b) and (d) Examples of a filler trial. The face on the right was 14% smaller in the eyes (b) or mouth (d) but with the same size of face frame as in the original face, and the face on the left was 4% larger than the original face in the face frame.

discrimination among individual faces. Given that higher levels of learning were associated with greater magnitude of the illusion, the results support an expertise-based account, according to which learning and experience play an important role in processing visual information (eg Gauthier & Tarr, 1997; Rakover & Cahlon, 2001; Rossion & Gauthier, 2002).

What causes the eye-size illusion is a question yet to be answered. One tentative hypothesis is based on the idea that a general visual mechanism is involved in processing visual illusions with all kinds of information (eg faces, cars, geometrical forms). The eye-size illusion is governed by the same size-contrast effect that is similarly applied to other kinds of objects. Another hypothesis is that a face-specific mechanism might specifically account for the eye-size illusion. More so than other objects in our visual world, faces are processed holistically (Tanaka & Farah, 1993). Face parts are typically integrated into a gestalt, thereby reducing accessibility in retrieving information about individual features (Boutet, Gentes-Hawn, & Chaudhuri, 2002; Bruce & Young, 2012; Farah, Wilson, Drain, & Tanaka, 1998; Gauthier, Curran, Curby, & Collins, 2003; for a review, see Maurer, Le Grand, & Mondloch, 2002). For example, recognition of an individual facial feature (eg the eyes) is impaired when the test face differs from the studied face in terms of the spatial relations between features. However, this impairment is not observed when faces are inverted (Farah et al., 1998). These results suggest that face features in the relational context of the whole face are processed holistically rather than independently.

To further explore the parameters affecting the illusion, we systematically increased or decreased face size in four experiments. Participants were presented with pairs of faces and asked to choose which face contained larger eyes (or mouths). The pairs of faces consisted of combinations of one original face and a variant in face frame size. The variants ranged from 86% (smaller) to 114% (larger). The magnitude of the illusion was indicated by the proportional response of selecting the relatively smaller faces as having larger eyes, given that the actual size of the eyes remained equal throughout.

## 2 Experiment 1

Experiment 1 aimed to establish the eye-size illusion and measure the threshold of the eye-size illusion. Following Rakover (2011), we generated the eye-size illusion by increasing or decreasing the original face except for the eye area. We expected that the perceived size of the eyes in the new faces would depend systematically on the degree of transformation in the face area: an increase in face area should reduce the perceived size of the eyes, and a decrease in face area should enlarge the perceived size of the eyes.

To determine the threshold of the illusion, we manipulated the degree of variation in the face frame (except for the eye area) and paired each variant with the original face. When presented with the face pairs, participants were asked to select which of two faces had larger eyes. A tuning function of participants' response across different levels of size transformation was thus obtained.

### 2.1 *Method*

2.1.1 *Participants.* The participants were Chinese undergraduate students ($n$ = 23, six males, mean age = 19.74 years) who reported to have normal or corrected-to-normal vision.

2.1.2 *Materials and procedure.* Stimuli were color photographs of ten Chinese adults (five males) in frontal pose and with neutral facial expression. The mean size of the original faces was 325 × 441 pixels, and the mean size of the eye area across the 10 faces was 235 × 85 pixels. The faces were presented superimposed on to a gray background. For each individual face we produced 10 altered versions by increasing or decreasing the size of the original face frame (except for the eye area) to a different extent (2%, 4%, 6%, 10%, and 14%). On each trial one original face and one altered version of the face were displayed on the left and right of a 17 inch computer screen and aligned horizontally at the bottom edge of the faces. The left and right placement of the faces was counterbalanced between trials. The combination of variables produced a total of 200 illusory pairs of faces where the size of the eye area was constant [(10 different origin faces: five males and five females) × (5 levels of transformation: 2%, 4%, 6%, 10%, and 14%) × (2 directions of transformation: increase and decrease) × (2 positions per pair: left and right)]. Another 100 pairs of faces in which the size of the eyes were actually different were used as fillers (see figure 1b for an example). The fillers were generated by either face frame change or face feature change [(10 different origin faces) × (5 types of combination: 114% frame vs 86% eyes, 116% frame vs 88% eyes, 86% frame vs 114% eyes, 88% frame vs 116% eyes, and 116% eyes vs 86% eyes) × (2 positions per pair)]. The purpose of the fillers was to disrupt the possibility that participants might use the convenient strategy of picking the smaller faces as having larger eyes. All of the 300 pairs of faces were mixed and presented in a random order. Participants were instructed to respond via key press which face had larger eyes as accurately and rapidly as possible. The approximate viewing distance of the participants was 60 cm.

### 2.2 *Results and discussion*

The 'proportion of selecting the smaller face as being the one with bigger eyes' was used as the dependent measure. Only the responses for the illusory pairs of faces were used for analyses. Figure 2 shows the mean proportion of the smaller face has 'bigger eyes' responses for each degree of variation, collapsed across left–right position of presentation (because the left vs right positioning of the stimuli produced no significant differences). To examine the effect of face size change on the perception of eye size, we conducted a 5 (degree of variation: 2%, 4%, 6%, 10%, and 14%) × 2 (direction: increase vs decrease) repeated measures ANOVA.

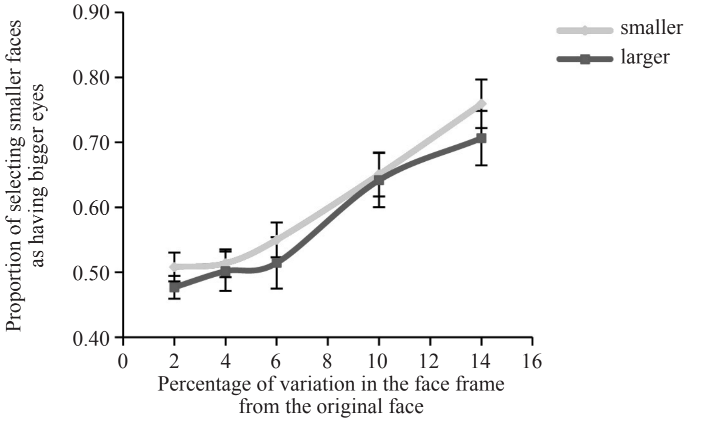


**Figure 2.** Experiment 1 ($n = 23$): mean proportion of smaller face responses as a function of degree of variation in the face frame, for smaller and larger directions of change. Error bars show ±1 SEM.

The main effect for the degree of variation was significant ($F_{4,88} = 24.75, p < 0.001, \eta^2 = 0.53$). With increase or decrease in the face size, the smaller face responses increased significantly and systematically, suggesting that the eye size illusion changes as a function of the face frame size (figure 2).

Neither the main effect of direction nor its interaction with variation were significant. Therefore, data for face size increase and decrease were collapsed in the following analyses. An a posteriori test with Bonferroni correction was used to determine the differences in the smaller face responses between the degrees of variation. We found that proportions of the smaller face responses were significantly higher for 10% and 14% variations relative to 2%, 4%, and 6% variations (figure 2). We then conducted one-sample *t*-tests comparing proportional responses for each degree of variation with chance (50%), and they revealed that significantly more smaller face responses occurred at variations of 10% and 14% ($p$s $< 0.05$), but not when the changes of the face frame were smaller than 10%. This latter result indicates that, when the variation in the face frame was greater than or equal to 10% of the original face size, participants perceived that smaller faces had bigger eyes, although the size of the eyes in the pair of original and altered faces was exactly the same. This finding suggests the presence of the eye-size illusion.

For each participant, data points of smaller face response for each relative size of larger face to smaller face [10 in total: $x$ = (102/100, 100/98, 104/100, 100/96, 106/100, 100/94, 110/100, 100/90, 114/100, 100/86)] were fitted with a logistic function to calculate the point of subjective equality (PSE) where the eyes in the two faces looked equally in size ($y = 0.50$). The average PSE across all the subjects was 109% (SD = 28%).

## 3 Experiment 2

Experiment 2 investigated whether the eye-size illusion could be observed for another major internal face feature—namely, the mouth. Previous studies have suggested that the eyes are perceptually more discriminable than the nose or mouth (eg Sergent, 1984; Tanaka & Farah, 1993). Also, recent work suggests that the upper region of the face is processed differentially compared with the lower region—for example, observers are more sensitive to configural change in the upper region of faces than the lower region of faces (O'Donnell & Bruce, 2001; Quinn & Tanaka, 2009; Tanaka, Kaiser, Bub, & Pierce, 2009). The manipulation of contrast negation on the eye region is more important for holistic representations of facial identity than the manipulations on the forehead, nose, or mouth regions (Sormaz, Andrews, & Young, 2013). On the basis of these prior findings, it may be that the magnitude of the size illusion observed with the eyes in the upper region of the face will differ from the magnitude of the size illusion observed with the mouth in the lower region of the face.

3.1 *Method*
3.1.1 *Participants.* Twenty-one Chinese undergraduate students (eight males, mean age = 20.90 years) participated in the mouth condition, and another eighteen Chinese students (four males, mean age = 20.39 years) participated in the eye condition. All reported normal or corrected-to-normal vision.

3.1.2 *Materials and procedure.* Stimuli in the eye condition were exactly the same as in experiment 1, while stimuli in the mouth condition were the same individual faces with the same degrees of size transformation in the face frame, except for the mouth (figures 1c and 1d). Procedure was the same as in experiment 1. Participants were randomly assigned to complete either the mouth or the eye condition.

3.2 *Results and discussion*
Figure 3 shows the mean proportion of the smaller face responses for each degree of variation, collapsing across left–right position of presentation and larger–smaller direction of transformation. To examine the effect of feature on the magnitude of the illusion, we conducted a 5 (degree of variation: 2%, 4%, 6%, 10%, and 14%) × 2 (feature: mouth vs eyes) mixed-model ANOVA with degree of variation as a within-subject variable and feature as a between-subject variable. The main effect for the degree of variation was significant ($F_{4,148} = 36.77$, $p < 0.001$, $\eta^2 = 0.50$), but neither the main effect of face feature nor its interaction with the degree of variation were reliable (figure 3). These results suggest that changing the face frame size produces the same systematic changes in the perception of the size of the mouth that were observed for the size of the eyes. In other words, the eye-size illusion observed in experiment 1 is robust, not limited to the upper half of the face, and can be generalized to at least one other major face feature.

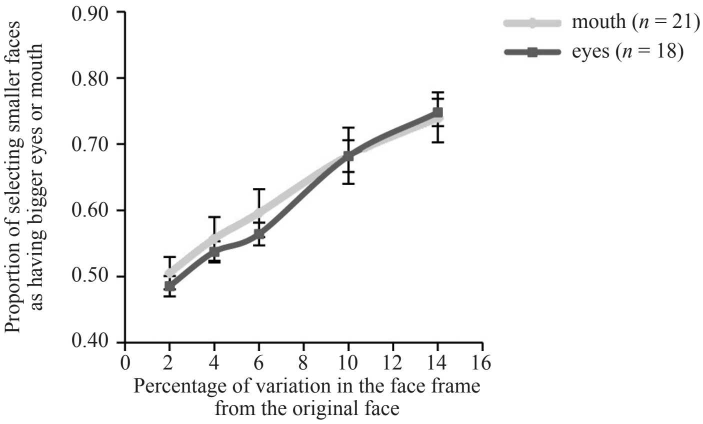


**Figure 3.** Experiment 2: mean proportion of smaller face responses as a function of degree of variation in the face frame, for mouth and eye transformations. Error bars shown ±1 SEM.

## 4 Experiment 3
Experiment 3 investigated whether face orientation would affect the magnitude of the eye-size illusion. Face inversion has been shown to affect face recognition (eg Yin, 1969) and disrupt the processing of configural information (eg Bartlett & Searcy, 1993; Freire, Lee, & Symons, 2000; Lee & Freire, 1999) and holistic information (eg Tanaka & Gordon, 2011). According to the holistic face processing hypothesis, facial features are encoded as an integrated whole and inversion disrupts the perception of the whole face more than perception of facial parts presented in isolation (Rhodes, Brake, & Atkinson, 1993; Tanaka & Gordon, 2011). We hypothesized that a major reason for the eye/mouth-size illusion is that such face features are processed in the relational context of the face, not in isolation, and the perception of their

size is thus processed holistically along with other parts of the face. To ascertain whether the eye-size illusion paradigm reflects holistic face processing, we investigated differences in the magnitude of eye-size illusion for upright and inverted faces.

4.1 *Method*

4.1.1 *Participants.* Twenty-six Chinese undergraduate students (seven males, mean age = 20.77) participated in the inverted condition, and another twenty-six Chinese students (four males, mean age = 19.69 years) participated in the upright condition. All reported normal or corrected-to-normal vision.

4.1.2 *Materials and procedure.* Stimuli in the upright condition were exactly the same as in experiment 1, while stimuli in the inverted condition were the same stimuli in the upright condition but were presented upside down. Procedure was the same as in experiment 1. Participants were randomly assigned to complete either the upright or the inverted condition.

4.2 *Results and discussion*

Figure 4 (left panel) shows the mean proportion of the smaller face responses for each degree of variation, collapsing across left–right position of presentation and larger–smaller direction of transformation. To examine the effect of orientation on the magnitude of the illusion, we conducted a 5 (degree of variation: 2%, 4%, 6%, 10%, and 14%) × 2 (orientation: upright vs inverted) mixed-model ANOVA with degree of variation as a within-subject variable and orientation as a between-subject variable. The main effect for the degree of variation was significant ($F_{4,200} = 57.84$, $p < 0.001$, $\eta^2 = 0.54$). The interaction between the degree of variation and face orientation was also significant ($F_{4,200} = 4.02$, $p = 0.004$, $\eta^2 = 0.07$). To explain the interaction, independent sample $t$-tests revealed that the smaller face responses were significantly greater in the upright condition than in the inverted one, when the degree of variation was 10% and 14% ($t_{50} = 2.07$, $p = 0.043$ and $t_{50} = 1.98$, $p = 0.053$, respectively). The inversion effect was not present when the degree of variation was smaller than 10%.

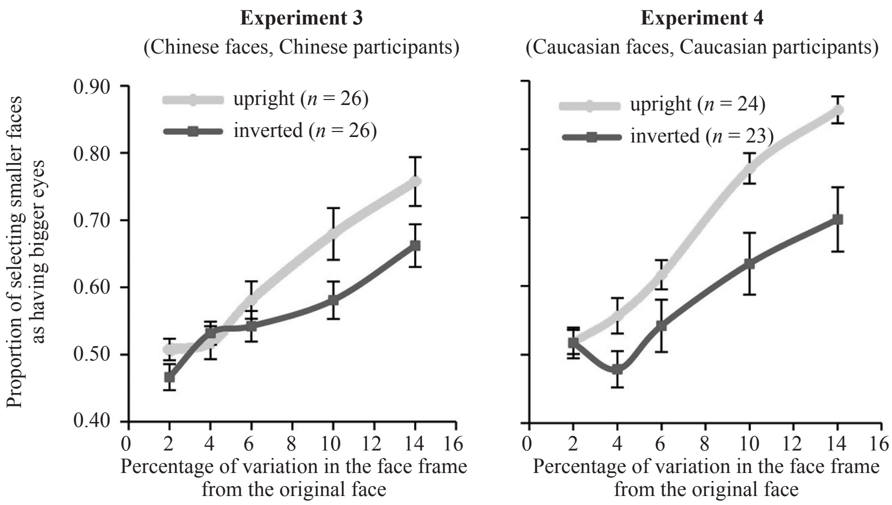


**Figure 4.** Mean proportion of smaller face responses as a function of degree of variation in the face frame. Error bars show ±1 SEM.

Our findings are not consistent with those found by Rakover (2011, 2013), who also measured the eye illusion in upright and inverted face orientations. By increasing or decreasing the size of the entire face except for the eye area to be 10%, 15%, and 20%, Rakover found that the magnitude of the illusion, as indicated by the percentage of choices of one face having bigger eyes, did not differ between the upright and inverted face positions. By contrast, we found that face orientation affected the magnitude of the eye-size illusion.

Our results showed that the illusion was greater for upright versus inverted faces when the variation in the face frame was 10% and above.

To explain the different findings between Rakover (2011, 2013) and the current study, one might consider the different experimental designs used to present the upright and inverted face orientations in the two studies (within subject in the Rakover studies vs between subject in the present study). However, the inversion effect has been robustly demonstrated using either within-subject or between-subject design (Valentine, 1988). Hence, the experimental design difference should not be the major reason leading to the different results. Another reason could be due to different combinations of illusory stimuli used in the two studies. In the Rakover studies, participants were asked to judge the stimulus pairs with only one size of configural change during each test (eg a 10% change only). By contrast, we presented stimulus pairs with a broader range of size transformations in each test so that a tuning function of the inversion effect across different degrees of variation could be measured. By presenting different degrees of size change to each participant, we observed that the smaller face responses linearly changed with the increasing degree of size change. Furthermore, the differential tuning functions between upright and inverted positions revealed that participants were more sensitive to the size changes in upright versus inverted faces (figure 4, left panel).

## 5 Experiment 4

To ascertain that the eye-size illusion and related inversion effect are not limited to Chinese participants judging Chinese faces, we conducted experiment 4 by asking Caucasian participants to judge pairs of Caucasian faces.

### 5.1 *Method*

5.1.1 *Participants.* Twenty-three Caucasian undergraduate students (four males, mean age = 20.48 years) participated in the inverted condition and another twenty-four Caucasian students (six males, mean age = 20.92 years) participated in the upright condition. All reported normal or corrected-to-normal vision.

5.1.2 *Materials and procedure.* The face stimuli were generated from 10 original adult Caucasian faces (5 male) using the same method as in experiment 1. The mean size of the original faces was 334 × 452 pixels, and the mean size of the eye area across the 10 faces was 242 × 91 pixels. Procedure was the same as in experiment 1. Participants were randomly assigned to complete either the upright or the inverted condition.

### 5.2 *Results and discussion*

Figure 4 (right panel) shows the mean proportion of the smaller face responses for each degree of variation, collapsing across left–right position of presentation and larger–smaller direction of transformation. A 5 (degree of variation: 2%, 4%, 6%, 10%, and 14%) × 2 (orientation: upright vs inverted) mixed-model ANOVA with degree of variation as a within-subject variable and orientation as a between-subject variable showed significant main effects for the degree of variation ($F_{4,180} = 80.34$, $p < 0.001$, $\eta^2 = 0.64$) and orientation ($F_{1,45} = 6.49$, $p = 0.014$, $\eta^2 = 0.13$). The interaction between the degree of variation and face race was also significant ($F_{4,180} = 5.77$, $p < 0.001$, $\eta^2 = 0.11$). To explain the interaction, independent sample $t$-tests revealed that the smaller face responses were significantly greater in the upright condition than in the inverted condition when the degree of variation was 10% and 14% ($t_{45} = 2.81$, $p = 0.007$ and $t_{45} = 3.19$, $p = 0.003$). The inversion effect was not in evidence when the degree of variation was smaller than 10% (figure 4, right panel). The results indicate that the eye-size illusion is not limited to Chinese participants judging Chinese faces. Moreover, the findings from both Chinese and Caucasian participants taken together reinforce the conclusion that the magnitude of the eye-size illusion is sensitive to face orientation, suggesting that its occurrence may indeed involve holistic processing.

## 6 General discussion

The present study measured the magnitude of a novel face feature size illusion. In addition to replicating the original observation by Rakover (2011), we found that systematically increasing the size of a face frame but keeping the size of the eyes unchanged linearly decreases the perception of the size of the eyes. Decreasing the face size results in an illusion in the opposite direction. PSE measurements suggest that the size of the illusion is approximately 9%. Rakover (2011) used 20%, 15%, and 10% of changes in the face frame and found that the proportion choices of one face over the other were all significantly different from chance. On the basis of this previous finding, we further manipulated the degree of change in the face frame in order to decide the minimum variation that can robustly elicit the illusion. We found that the eye-size illusion can be consistently observed with variation in the face frame being 10% or more (larger or smaller).

The eye-size illusion is consistent with the Ebbinghaus illusion in which the perceived size of a central target is altered by the surrounding visual cues. Both illusions illustrate a simple size-contrast effect, in which a large contextual size makes the target appear smaller, whereas a small contextual size makes the target appear larger. Similar to the Ebbinghaus illusion, we found that the magnitude of the eye-size illusion is governed by the relative size between facial context and the target feature: the more contrast in the size, the stronger the illusion that is produced.

However, different from the Ebbinghaus/Titchener geometrical illusion (ie this illusion is unaffected by inversion), the eye-size illusion is sensitive to face orientation: the illusion is greater when faces are presented upright than when they are inverted. The impact of inversion on the magnitude of the eye-size illusion supports the hypothesis that the perception of feature size in the facial context involves holistic face processing. A compelling demonstration of holistic face processing is the face composite task, where the recognition of the top part of a face is impaired when it is aligned with the bottom part from another identity (Young, Hellawell, & Hay, 1987). In parallel to the face composite paradigm, the eye-size illusion might reveal the same mechanism when the perception of facial features is altered by the transformation of facial context. In the composite face task, although participants were explicitly instructed to focus on a part of the face stimulus, the interference of the other part arose automatically. Similar to the composite face task, the occurrence of the eye-size illusion also relies on the automatic integration of the face context and the perception of the face part. Furthermore, when faces were inverted, the interference of facial context in the perception of facial features was ameliorated in both the face composite and eye-size illusion tasks. Taken together, these data suggest that the occurrence of the eye-size illusion might involve holistic face processing.

As suggested by Rakover (2013), there are two major factors leading to the illusion: general visual processing (eg the size-contrast effect, which may cause the Ebbinghaus illusion) and configural/holistic face processing. The inversion effect observed in experiments 3 and 4 of the current study suggests that holistic face processing may play a more important role than general visual processing in producing the eye-size illusion. However, the specific aspect (eg configural vs featural) that is impaired as a consequence of face inversion is controversial (Freire et al., 2000; McKone & Yovel, 2009; Tanaka & Gordon, 2011). Therefore, additional and more direct tests are needed to understand more clearly and deeply the role of holistic face processing in general and configural processing specifically in producing the eye-size illusion.

To further test whether the eye-size illusion reflects holistic processing, future studies should measure and compare the magnitudes of the illusion for faces at different levels of familiarity. Previous studies have shown that holistic processing is commonly found in expert- level face processing. For example, holistic processing has been demonstrated to have a more significant impact on own-race versus other-race face processing (eg Tanaka, Kiefer, & Bukach, 2004) and own-age versus other-age face processing (eg Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008). If the eye-size illusion is attributable to holistic face processing, the magnitude of the illusion should be larger with more experienced and familiar face classes versus less experienced and unfamiliar face classes. To support this speculation, Rakover (2011) found that the eye-size illusion with human faces was greater than the headlight illusion with cars and the geometrical form illusion. As individuals are more familiar with faces relative to cars and geometrical forms, the differential findings with human faces versus cars and geometrical shapes suggest that experience may play an important role in the extent to which the visual context affects the perception of target size (Rakover, 2011, 2013).

To summarize, we examined the psychophysical characteristics of the eye-size illusion and found that increasing or decreasing the size of a face frame to be 10% or above but keeping the size of the eyes unchanged significantly changes the perception of the size of the eyes. We also observed that the illusion generalizes to another facial feature (ie mouth) and to another race of participants judging faces of their own race. Most importantly, we found that the magnitude of the illusion decreased when the faces were inverted, compared with their upright position. The inversion effect suggests that holistic processing plays an important role in producing the illusion.

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