Perception, 2013, volume 42, pages 488–494

doi:10.1068/p7439

Face contour is crucial to the fat face illusion

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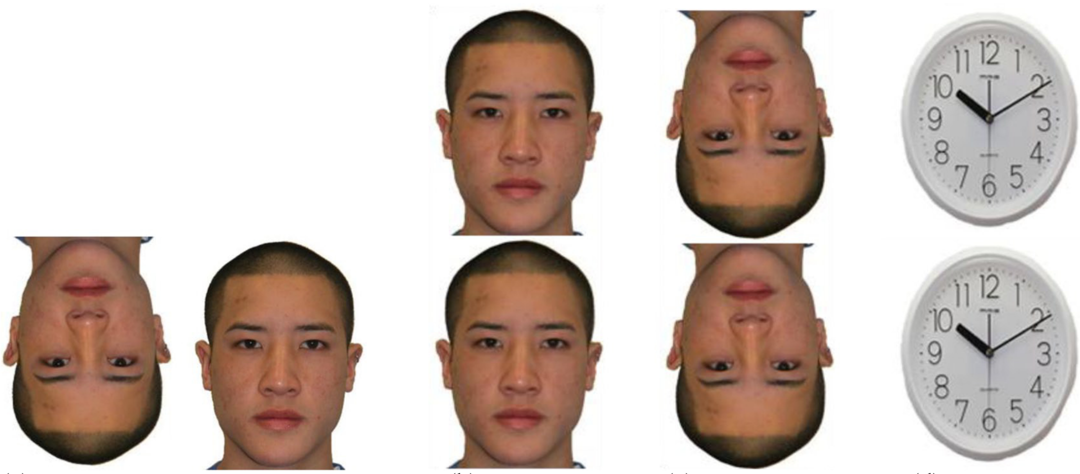
Received 27 December 2012, in revised form 11 April 2013

Abstract. In 2010 Thompson reported a "fat face thin" illusion that, when next to an inverted face, an upright face looks "fatter". Sun et al (2012 *Perception* **41** 117–120) observed that one of the faces need not be inverted for the illusion to emerge: when two identical faces are presented one above the other, the face at the bottom appears "fatter" than the top one. Neither inverted faces nor clocks induced the illusion. Here we conducted three experiments probing the role that face contour plays in producing the fat face illusion. In experiment 1 line drawing faces were found to induce the illusion, suggesting that face contour is important for producing the illusion. In experiment 2 line drawing faces with scrambled internal features and empty line drawing faces devoid of internal features were found to induce the illusion. In experiment 3 internal face features arranged in their canonical face layout, but not in a scrambled layout, were found to induce the illusion. However, the magnitude of the effect was significantly weaker than the effect obtained for empty face contour in experiment 2. Collectively, these results suggest that a fat face illusion is obtained when there is sufficient information in the stimulus to activate an internal face schema.

Keywords: fat face, illusion, photograph, texture, line drawing, contour, top–down processing

1 Introduction

Thompson (2010) reported a "fat face thin" illusion that, when next to an inverted face, an upright face looks "fatter" (see figure 1a). Sun et al (2012) followed with an observation that one of the faces did not need to be inverted for the illusion to emerge. Specifically, Sun et al reported that, when two identical faces are presented one above the other, the bottom face looks "fatter" (figure 1b), but neither inverted faces (figure 1c) nor clocks (figure 1d) induced a similar effect.



(a) (b) (c) (d)

Figure 1. [In color online, see http://dx.doi.org/10.1068/p7439] (a) Thompson's (2010) "fat face thin" illusion where the upright face appears fatter. (b) The fat face illusion where the bottom image appears fatter (Sun et al 2012). (c) No illusion when faces were inverted. (d) No illusion when clocks were used.

In the present study we aimed to specify the necessary and sufficient information for the fat face illusion to emerge. Specifically, we examined two issues: (a) is a line drawing face that is without skin texture sufficient for inducing the illusory fatness judgment? (b) If a line drawing face is sufficient to produce the effect, which part (ie the internal features or the external contour) of a line drawing face is necessary?

2 Experiment 1

In experiment 1 to examine whether skin texture is necessary for the fat face illusion, we used photographs of faces (with skin texture) and line drawings of faces (without skin texture). If face contour and the internal features are sufficient to cause the fat face illusion, the illusion should still occur when skin texture is removed from a face photograph. However, if skin texture is necessary, the illusion should disappear when skin texture is removed from a face photograph.

2.1 *Method*

2.1.1 *Participants.* Forty-six Chinese undergraduates (mean age = 20.2 years, SD = 2.25 years) served as participants, with normal or corrected-to-normal vision.

2.1.2 *Stimuli.* Two sets of stimuli were used. Stimulus set 1 included color photographs of twenty Chinese adults (ten males) in frontal pose, with white background (see figure 2 for an example). Expanding or compressing the width of each original face by 3% produced two altered versions to be used for the experiment, which were 103% and 97% of the original. On each trial two images of the same individual were displayed at the top and bottom of a computer screen, one above the other. Each altered version of the same face was paired with the other or itself, producing four combinations for the top and bottom images, as shown in figure 2.

Thus, in stimulus set 1 40 pairs were identical in size (top = bottom), and 40 pairs were different (20 for top < bottom and 20 for top > bottom). Stimulus set 2 included line drawing faces transformed from set 1 (see figure 3 for an example). Nothing else was different between the two sets.

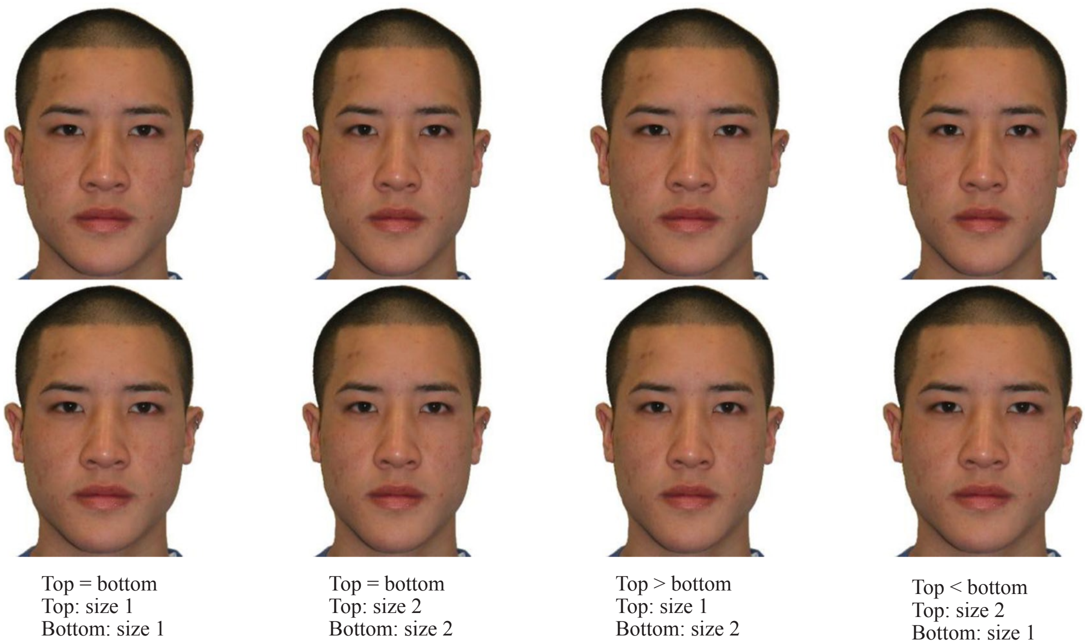


Figure 2. [In color online.] Face pairs of one individual face, one above the other (sizes 1 and 2 were 103% and 97% of the original face, respectively).

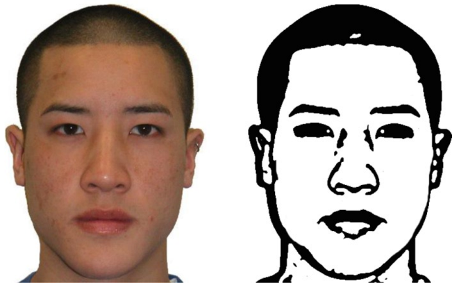


Figure 3. [In color online.] (a) A photograph face. (b) A line drawing face transferred from the photograph face.

2.1.3 *Design.* Participants were randomly assigned to one of two groups, with one group for the photographs of faces and the other group for the line drawings of faces ($N = 25$ and 21, respectively).

2.1.4 *Procedure and task.* On each trial, after a 500 ms fixation cross, two images were displayed at the top and bottom of a computer screen, one above the other. The two images were of the same individual. Each pair was presented once to each participant. All the trials were presented in random order. Participants were instructed to respond via key press which face was "fatter" as accurately and rapidly as possible. After each response the two images disappeared and a blank screen was presented for 500 ms.

2.2 *Results and discussion*

Table 1 shows the means and standard errors of the rates of the "bottom face is fatter" responses (henceforth referred to as bottom responses) for the three trial types in the photograph and line drawing conditions. For photographs the fat face illusion was replicated. In the top = bottom condition, response rate was significantly higher than the expected rate (81.5% versus 50%; $t_{24} = 13.54$, $p < 0.001$), indicating that participants perceived the bottom face to be fatter than the top face even though they were identical (ie participants showed the fat face illusion). For the top < bottom and the top > bottom conditions the combined response rate was significantly higher than the expected rate (57.2% versus 50%; $t_{24} = 4.59$, $p < 0.001$), indicating that in trials with unequal top and bottom faces participants still perceived the bottom one to be fatter.

Table 1. Means (and standard errors in parentheses) of the "bottom is fatter" response rates in photograph and line drawing conditions.

	Actual image size	"Bottom is fatter" response rate/%	Expected rate/%
Photograph faces	top < bottom	99.4 (0.3)	100
	top = bottom	81.5 (2.3)	50
	top > bottom	14.8 (3.2)	0
Line drawing faces	top < bottom	99.5 (0.3)	100
	top = bottom	87.0 (1.9)	50
	top > bottom	9.7 (1.8)	0

For line drawings participants showed the same fat face illusion. Comparing response rates with the expected rates, we found (i) in the top = bottom condition response rate was significantly higher than the expected rate (87.0% versus 50%; $t_{20} = 18.99$, $p < 0.001$), indicating that participants perceived the bottom face to be fatter than the top face even though they were identical; (ii) for the top < bottom and the top > bottom conditions the combined response rate was significantly higher than the expected rate (54.6% versus 50%; $t_{20} = 4.73$, $p < 0.001$), indicating that with unequal top and bottom faces participants still perceived the bottom one to be fatter.

Comparing the response rates in the top = bottom condition, for the photographs and line drawings, we found that the difference was marginally significant (81.5% versus 87.0%; $t_{44} = -1.76$, $p = 0.085$), suggesting that line drawings of faces without skin texture induced a fat face illusion of even larger magnitude than that produced with photographs of faces.

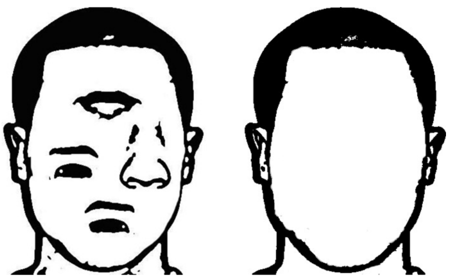
3 Experiment 2

In experiment 2 to examine whether face contour is sufficient for the fat face illusion, we used scrambled faces and empty faces with the same task as in experiment 1. Scrambled faces reduce internal part information and disrupt configural processing, and empty faces eliminate all internal part information. The "fat face thin" illusion was disrupted when internal features were eliminated (Thompson and Wilson 2012, experiment 3). If internal features are also necessary for the fat face illusion, empty faces should not induce it. Alternatively, if face contour is sufficient for producing the illusion, then the illusion should still occur when the internal parts of a face are scrambled or even eliminated.

3.1 *Method*

3.1.1 *Participants.* A new group of forty Chinese undergraduates (mean age = 19.5 years, SD = 2.15 years) served as participants, with normal or corrected-to-normal vision.

3.1.2 *Stimuli.* A set of scrambled faces and a set of empty faces were transformed from the line drawing face set used in experiment 1 (see figure 4 for examples of the scrambled faces and empty faces). There were, again, 80 pairs in each stimulus set (40 top = bottom pairs, 20 top < bottom pairs, and 20 top > bottom pairs).



(a) (b)

Figure 4. (a) A scrambled face. (b) An empty face.

3.1.3 *Design.* Participants were randomly assigned to one of two groups, with one group for the scrambled faces and the other group for the empty faces ($N = 20$ in each group).

3.1.4 *Procedure and task.* The procedure and task were the same as those used in experiment 1.

3.2 *Results and discussion*

Table 2 shows the means and standard errors of the rates of the "bottom face is fatter" responses associated with the three trial types for the scrambled and empty face conditions. Both types of stimuli induced the fat face illusion. Comparing response rates with the expected rates, we found that in the top = bottom condition response rates were significantly higher than the expected rate for both the scrambled faces (87.9% versus 50%, $t_{19} = 16.69$, $p < 0.001$) and the empty faces (83.6% versus 50%; $t_{19} = 10.13$, $p < 0.001$), indicating that the fat face illusion was induced for both scrambled and empty faces. For the top < bottom and the top > bottom conditions, the combined response rates for scrambled face and empty

Table 2. Means (and standard errors in parentheses) of the "bottom is fatter" response rates in scrambled and empty face conditions.

	Actual image size	"Bottom is fatter" response rate/%	Expected rate/%
Scrambled faces	top < bottom	99.7 (0.3)	100
	top = bottom	87.9 (2.3)	50
	top > bottom	15.9 (4.0)	0
Empty faces	top < bottom	100.0 (0.0)	100
	top = bottom	83.6 (3.3)	50
	top > bottom	16.4 (4.5)	0

face were both significantly higher than the expected rate (57.8% and 58.2% versus 50%, respectively; $t_{19} = 4.11$, $p = 0.001$ and $t_{19} = 3.77$, $p = 0.001$, respectively), indicating that with unequal top and bottom faces participants still perceived the bottom one to be fatter.

Comparing the response rates for scrambled faces and empty faces, in the top = bottom condition, to the line drawings of faces, we found that the difference was not significant ($t_{38} = 1.07$, $p > 0.29$), indicating that rearranging versus eliminating internal part information had no effect on the size of the fat face illusion. These results suggest that face contour is sufficient to induce the fat face illusion by itself.

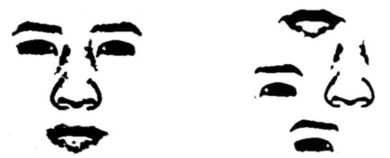
4 Experiment 3

To examine whether face contour is necessary for inducing the fat face illusion, we investigated the effect of internal features of the line drawing faces by comparing the internal face parts in a normal layout with the parts in a scrambled layout. If face contour is necessary, the internal features should induce no illusion. However, if face contour is not necessary, the internal features should also induce the fat face illusion.

4.1 *Method*

4.1.1 *Participants.* A new group of thirty-eight Chinese undergraduates (mean age = 19.9 years, SD = 2.29 years) served as participants, with normal or corrected-to-normal vision.

4.1.2 *Stimuli.* By erasing the face contours of the line drawing faces used in experiment 1 and the scrambled faces used in experiment 2, we created a set of normal internal part pictures and a set of scrambled internal part pictures, respectively (see figure 5 for examples of the normal and scrambled internal parts of a line drawing face). There were still 80 pairs in each stimulus set (40 top = bottom pairs, 20 top < bottom pairs, and 20 top > bottom pairs).



(a) (b)

Figure 5. (a) Normal layout of internal parts. (b) Scrambled layout of internal parts.

4.1.3 *Design.* Participants were randomly assigned to two groups, one group for the normal layout of internal parts and the other group for the scrambled layout of internal parts (N = 20 and 18, respectively).

4.1.4 *Procedure and task.* The procedure and task were the same as those used in experiment 1.

4.2 *Results and discussion*

Table 3 shows the means and standard errors of the rates of the "bottom face is fatter" responses for the three trial types in the conditions of normal layout and scrambled layout of face internal parts. Different response patterns emerged in the two different conditions. For the normal layout of internal parts, comparing response rates with the expected rate, we found: (i) in the top = bottom condition response rate was significantly higher than chance level (68.3% versus 50%; $t_{19} = 4.90$, $p < 0.001$), indicating that the normal layout of internal parts induced the fat face illusion; (ii) in the top < bottom and top > bottom conditions, the combined response rate was significantly higher than the expected rate (54.8% versus 50%; $t_{19} = 3.90$, $p = 0.001$), indicating that with unequal top and bottom faces participants still perceived the bottom one to be fatter.

Table 3. Means (and standard errors in parentheses) of the "bottom is fatter" response rates in normal and scrambled layout of internal face parts.

	Actual image size	"Bottom is fatter" response rate/%	Expected rate/%
Normal layout	top < bottom	95.4 (1.2)	100
	top = bottom	68.3 (3.7)	50
	top > bottom	14.2 (2.1)	0
Scrambled layout	top < bottom	79.7 (3.0)	100
	top = bottom	48.3 (4.0)	50
	top > bottom	18.5 (3.1)	0

For the scrambled layout of internal parts we found that: (i) in the top = bottom condition the response rate for scrambled internal parts was not significantly different from chance level (48.3% versus 50%; $t_{17} = -0.43$, $p > 0.67$), indicating that scrambled internal parts alone did not induce the fat face illusion; and (ii) in the top < bottom and top > bottom conditions the combined response rate was also not significantly different from the expected rate (49.1% versus 50%; $t_{17} = -0.42$, $p > 0.67$), indicating that participants did not perceive the bottom face to be fatter.

Comparing the response rates in the top = bottom condition for normal layout of internal parts with the scrambled layout of internal parts, we found that the difference was significant (68.3% versus 48.3%; $t_{36} = 3.66$, $p = 0.001$), indicating that normal layout was more likely than the scrambled layout to induce the fat face illusion. However, the response rate for the normal layout condition was weaker than that for the empty face condition from experiment 2 (68.3% versus 83.6%; $t_{38} = -3.08$, $p = 0.004$), indicating that the fat face illusion was present but significantly reduced in magnitude for line drawings of intact internal features (with no external contour).

5 Discussion

In the present study we aimed to replicate and extend the findings of the fat face illusion reported by Sun et al (2012), who used color photographs of faces. We investigated the conditions inducing the fat face illusion and found a robust illusion for line drawings with intact internal features, scrambled internal features, and missing internal features. We first replicated the fat face illusion with line drawing faces. Then we used face contours with internal features scrambled or completely removed. The same magnitude of illusory perception as in the whole line drawing faces was obtained with these two types of manipulations. It is clear that face contour plays a crucial role in engendering the fat face illusion.

Given the fact that internal face features provide crucial information about subordinate-level facial information such as race, age, and identity, we can surmise that the fat face illusion may be a phenomenon associated with face processing at the basic level (Tanaka 2001). At the basic level of processing one needs to judge only whether a visual object is a face or not by matching the presently seen object with a general face schematic representation stored in memory. In other words, a face's race, gender, and identity may be irrelevant for the fat face illusion to emerge. We speculate that if this basic-level face processing theory is true, there should be no difference in the size of the fat face illusion when faces belong to one's own race or other races, own age or other ages, or friends versus strangers. The present findings are ambiguous with regard to whether the face schema must be human or primate or even mammalian, an intriguing question to be addressed in future studies.

Internal features were shown to be necessary for the "fat face thin" illusion in Thompson and Wilson (2012), but not for the fat face illusion in the current study. The divergence of the role that face contour played in these two fatness perception illusion studies is consistent with the above arguments about processing levels. Thompson and Wilson used famous faces, and we used relatively novel faces. A famous face may induce processing of identity such that face internal features are necessary for the "fat face thin" illusion. However, fatness judgments on novel faces may invoke little to no processing of subordinate-level information, so that only face contour is sufficient to generate the fat face illusion.

Experiment 3 showed that the internal features in their canonical arrangement are also sufficient to induce the illusion, but the effect is significantly weaker compared with the condition where only the external contour is present, as shown in experiment 2. The absence of a strict face boundary in the faces that contain only internal features might account for the weaker fat face illusion in experiment 3. Collectively, these results are consistent with the basic-level face processing theory in which an empty face contour or the intact configuration of the internal face features was sufficient to activate an internal face schema via top–down mechanisms, which in turn engenders the fat face illusion (eg Ge et al 2006).

Acknowledgments. This study was supported by funding from NSFC (30900398), NSFC (31001204), NSFC (31028010), NIH (R01HD046526), and NSERC.

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