Journal of Illusion

PHENOMENAL REPORT

The reversed letter-row tilt illusion and an underlying geometrical illusion

Hiroyuki Ito[1], Xiaoqian Peng[2] and Yukyu Araragi[3]

[1]Faculty of Design, Kyushu University, Shiobaru, Minami-ku, Fukuoka-shi, Japan; [2]Graduate School of Design, Kyushu University, Shiobaru, Minami-ku, Fukuoka-shi, Japan; [3]Faculty of Human Sciences, Shimane University, Matsue, Shimane, Japan

Abstract

It is known that when a certain set of characters is repeated in a row, the row is perceived to tilt (*letter-row tilt illusion*). This study reports previously unobserved tilt illusions. We found that when the polarity in luminance contrast of characters in the row is alternated, the direction of the illusory tilt is reversed (*reversed letter-row tilt illusion*). We extracted horizontal short line segments with a stairs structure that were utilized in typical *reversed letter-row tilt illusion* figures. We found that the stairs configuration of contrast-alternated short-line segments or dots constitutes a new geometrical illusion (*reversed stairs illusion*) that is assumed to underlie typical *reversed letter-row tilt illusions*. Different effects of contrast-polarity reversals were also shown on character rows that produce a *letter-row tilt illusion* without an explicit stairs structure.

Keywords: *letter-row tilt illusion*; *reversed letter-row tilt illusion*; *contrast polarity*; *geometrical illusion*; *reversed stairs illusion*

Edited by:
Akiyoshi Kitaoka

Reviewed by:
Kohske Takahashi
George Mather

To access the movies for this article, please visit the article landing page or read the html version of the article where all movies are embedded.

Received: 26 January 2026; Revised: 30 April 2026; Accepted: 8 August 2026; Published: 23 September 2026

When a certain set of characters is repeated in a row, the row is perceived to tilt despite its physically horizontal orientation. This illusion was reported on a Japanese Internet bulletin board system in 2005 (Kitaoka, 2007). Anonymous users of the system created a lot of samples employing various letters and characters. Arai and Arai (2005) named this phenomenon the *letter-row tilt illusion*. Figure 1a and b are typical examples of the illusion that consist of Chinese and Japanese characters without lexical meaning. The odd blocks of rows from the top may perceptually tilt clockwise (CW) while the even blocks of rows may perceptually tilt counter-clockwise (CCW) although they are parallel and horizontally oriented. The even blocks of rows differ from the odd blocks in the point that the order of the characters is reversed. Figure 2a and b show the illusion with alphabetical letters. One simplified explanation for the illusion is that, in Fig. 1a and b, the horizontal line segment in each character steps down or up in the odd or even blocks of rows, respectively, when going rightward. When the step arrangement is repeated in the row, the global row may be perceived to tilt toward the step direction (Kohara, 2005). Kohara (2005) suggested that the structure of the stairs was similar to the Fraser phase-illusion (Popple & Sagi, 2000).

We have discovered that when the polarity in luminance contrast of the characters that produce the typical *letter-row tilt illusion* is alternated, the illusory-tilt direction is reversed despite the same character configuration. We named it *the reversed letter-row tilt illusion*. The main purpose of this report is to demonstrate the phenomenon and provide a new geometrical illusion underlying the effect. We also report the effect of contrast-polarity reversals on non-typical *letter-row tilt illusions* that do not include a stairs structure.

*Correspondence: Hiroyuki Ito. Email: ito@design.kyushu-u.ac.jp

Citation: Journal of Illusion 2026, **6**: 13927 - https://doi.org/10.47691/joi.v6.13927

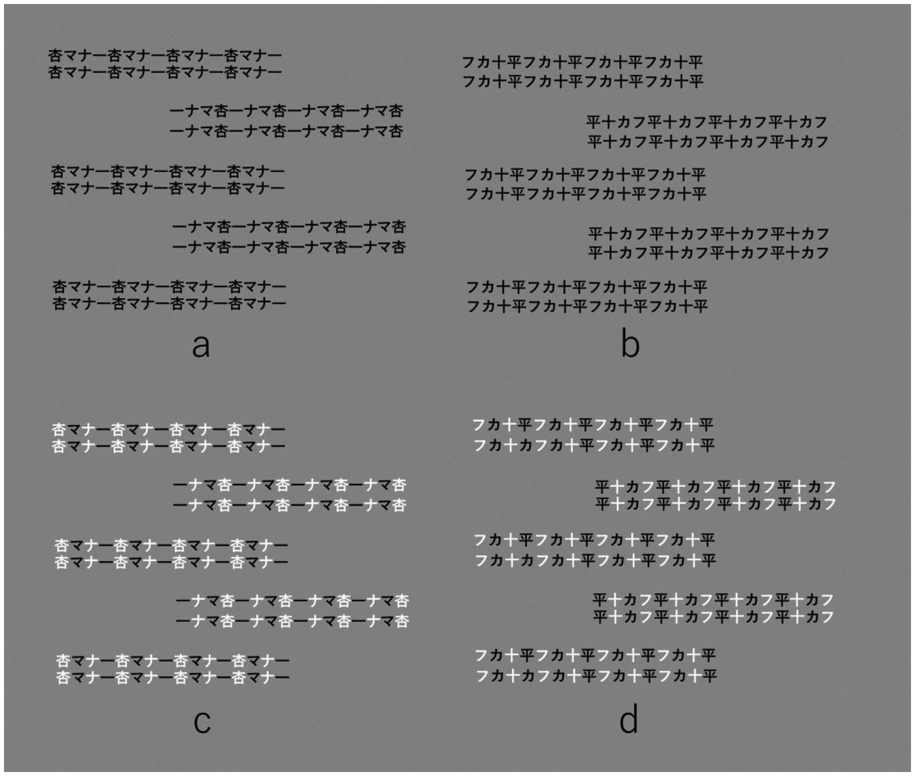


Fig. 1. *Letter-row tilt illusions* with the *Yu Gothic Bold* font. In *a* and *b*, the 1st, 3rd and 5th (from the top) blocks of character rows are perceived to tilt in a clockwise direction while the 2nd and 4th blocks of rows are perceived to tilt in a counter-clockwise direction. *c* and *d* are contrast-polarity alternated versions with the same character configurations as *a* and *b*, exhibiting the *reversed letter-row tilt illusion*. The perceived tilt directions in *c* and *d* are opposite to those in *a* and *b*. *a* and *b* were produced by an anonymous creator and the first author, respectively.

Reversed letter-row tilt illusion

Fig. 1c and d are the same as Fig. 1a and b, respectively, except that the contrast-polarity of each character against the gray background is alternated. However, the perceived tilt directions of rows are opposite between a and c, and between b and d. Similarly, with alphabetical letters, the *reversed letter-row tilt illusions* arise in Fig. 2c and d.

As illustrated in Fig. 3a and c, when horizontal line segments are extracted from Figs. 1a and 2a, the step direction is consistent with the global tilt perception of the row. However, as shown in Fig. 3b and d, the steps of the contrast-alternated horizontal elements produce a perceptually reversed tilt of the global row, that is, the step direction is opposite to the perceived global tilt direction.

Reversed stairs illusion

We have produced illusory figures as shown in Fig. 4, based on the extracted horizontal elements shown in Fig. 3. While repeated local steps suggest a global tilt in a CW direction in *a* and *c*, the contrast-polarity alternated steps (b and d) produce a global tilt perception in a CCW direction although the spatial configuration is exactly the same across Figs. 4a–d. This reversed tilt illusion may be a new type of geometrical illusion. We refer to this phenomenon as the *reversed stairs illusion*. In Fig. 4a and c, although the whole rows are perceived to tilt, the repetition of the five-step staircase structure formed by the short line segments can still be discerned. We observe that, in Fig. 4b and d, the alternating short black and white line segments tend to appear as a single tilted line, rather than repeated five-step staircases. Additionally, some may perceive that short line segments themselves are often perceived to tilt in Fig. 4a–d. Figure 5 shows that the *reversed stairs illusion* is cancelled out by physical tilt of the figure.

According to Kohara (2005), characters with shorter horizontal elements produced a weaker *letter-row tilt illusion*. However, Fig. 6 shows that a dot version of the *reversed stairs illusion* still has the effect, that is, long horizontal line segments and low spatial frequency components are not necessary to produce the *reversed stairs illusion*.

Character rows without a stairs structure

There are examples of character rows that produce the *letter-row tilt illusion* despite not having a stairs structure (Arai & Arai, 2010; Araragi & Ito, 2026). Figure 7a shows an example without a stairs structure. In Fig. 7a, reversing the order of letters reverses the illusory tilt direction (please compare odd and even number of blocks of rows).

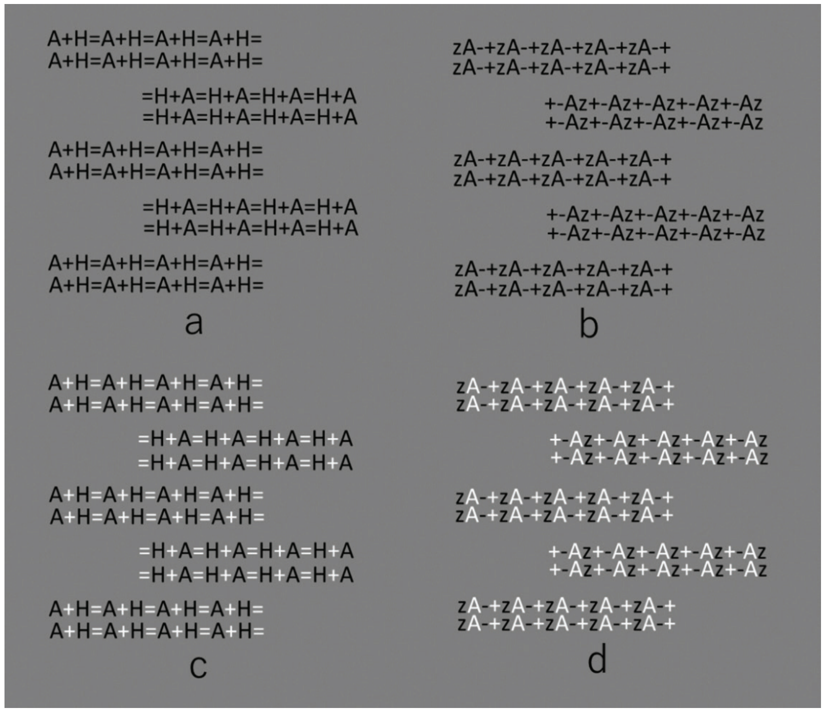


Fig. 2. Examples with alphabetic letters. *a* and *b* are the examples of the *letter-row tilt illusion* with the *Calibri* font, while *c* and *d* are their contrast-polarity alternated versions exhibiting the *reversed letter-row tilt illusion*, produced by the first author.

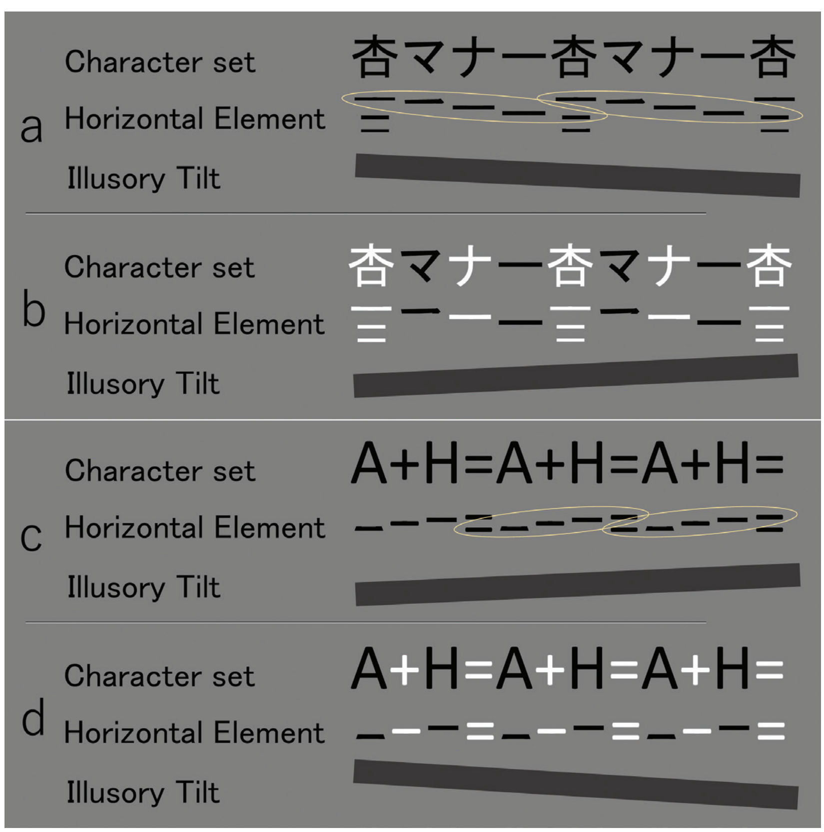


Fig. 3. Horizontal line segments included in the characters in the rows. Horizontal elements in *a* constitute stairs (yellow ellipses), resulting in the illusory tilt of the global row (see Fig. 1a). *b* shows the horizontal elements with contrast-polarity alternation (see Fig. 1c). *c* and *d* show the horizontal elements in Figs. 2a and c, respectively.

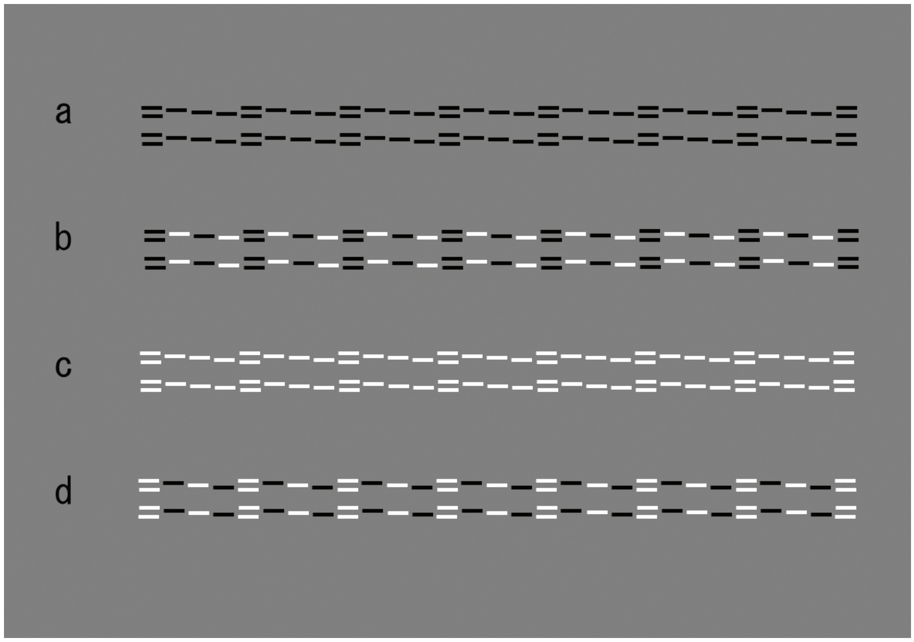


Fig. 4. *Reversed stairs illusion*. *a* and *c* produce a perceived tilt toward the step direction (CW) while *b* and *d* produce a perceived tilt that is opposite to the step direction (CCW).

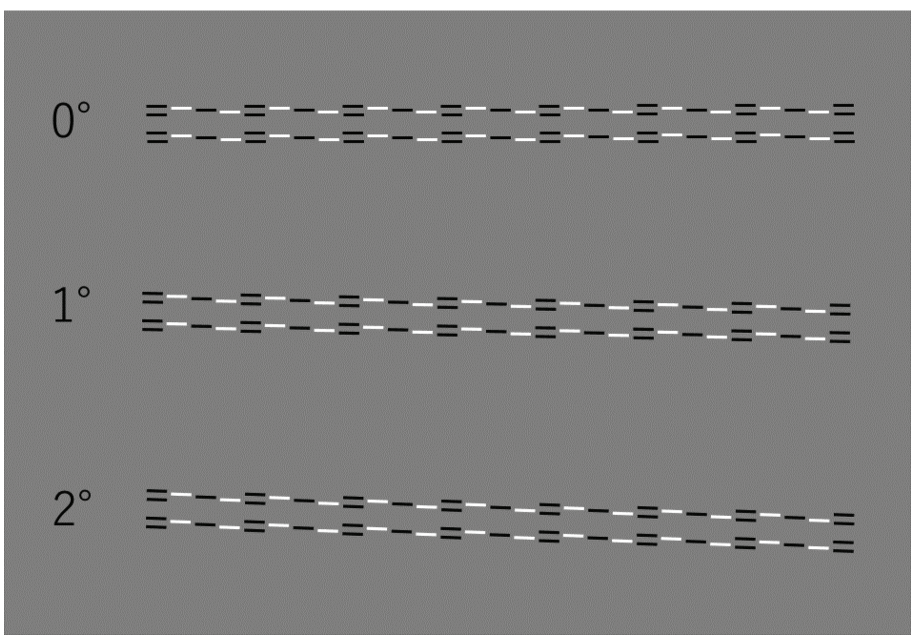


Fig. 5. Cancellation by physical image tilt. *'0 deg'* (horizontal direction) shows the original figure that exhibits the *reversed stairs illusion*. '*1 deg'* and *'2 deg'* show the figures where the original rows are physically rotated in a CW direction to cancel the illusory tilt.

However, in Fig. 7b, the contrast-polarity alternated rows show little illusory tilt or a slight CCW tilt in all rows. Contrarily, Fig. 7c demonstrates that the contrast-polarity alternated letter rows produce clearer illusory tilt in a CW direction while the black letter rows do not produce a tilt effect. Although '242424' includes steps of horizontal elements, the steps do not define a stairs direction (i.e. upward or downward in the rightward direction). Although reversing the contrast polarity of letters affects the perceived tilt effect for letter rows in Fig. 7, it does not always reverse the illusory tilt direction. This indicates that the effect of contrast polarity reversals on the illusory tilt of letter rows is not always based on the *reversed stairs illusion*.

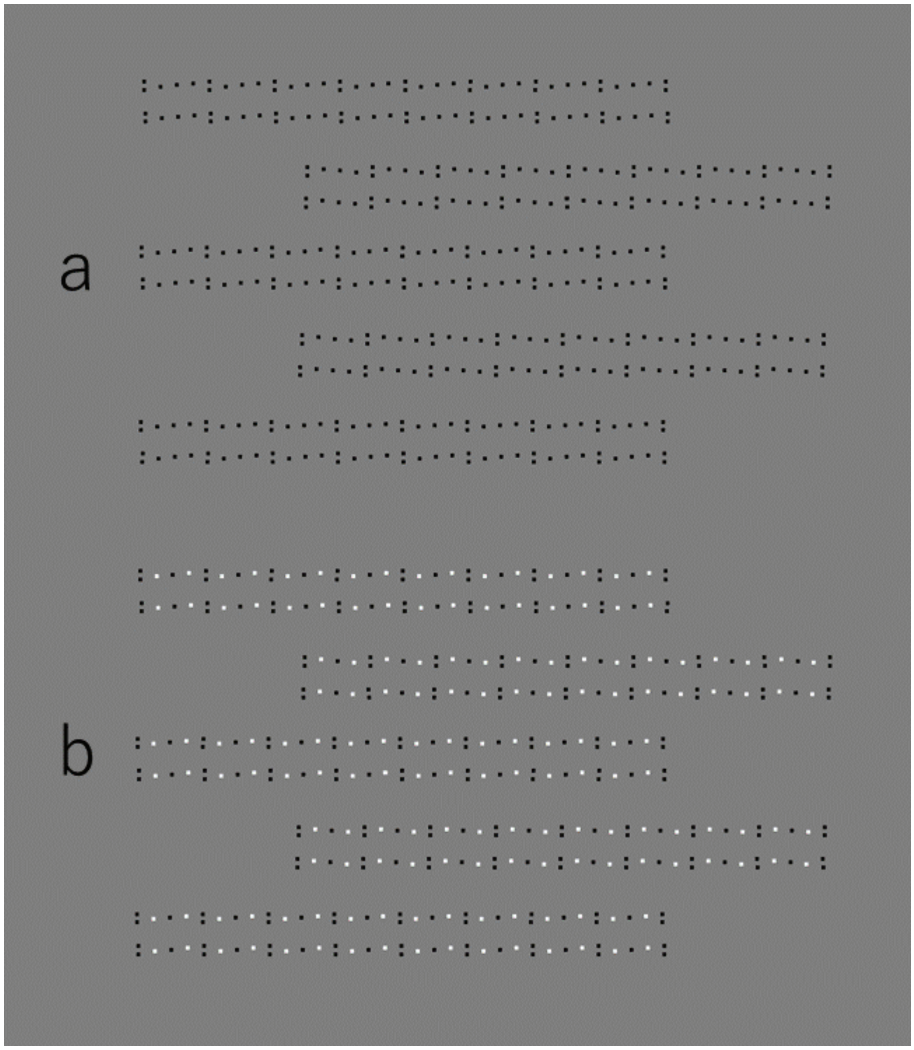


Fig. 6. Illusory tilt by a stairs structure (*a*) and a *reversed stairs illusion* (*b*), produced with dots.

Complicated character rows

The *letter-row tilt illusion* also arises even when the stairs structure is not clearly determined due to the complicated structure of characters such as Chinese ones. We conducted exploratory experiments to see how the contrast-polarity alternation affects the *letter-row tilt illusion* in such cases. The measured values of perceived character-row orientations were compared with 0 (horizontal) using t-tests. Detailed methods are described in Appendix A.

We identified four types of character rows, classified by their tilt illusion outcomes: Type 1 original and contrast-alternated character rows produced tilt illusions in opposite orientations, Type 2 both character rows produced tilt illusions in the same orientation, Type 3 original ones produced tilt illusions but contrast alternated ones did not, and Type 4 only contrast-alternated character rows produced the tilt illusion.

Figures 1 and 2 fall into the Type-1 category. We added another example using complicated Chinese characters. The character rows in Fig. 8a may seem to tilt CW (0.93 deg, p = 0.0002) while those in Fig. 8b may seem to tilt CCW (0.83 deg, p < 0.0001).

Figure 9 shows examples of theType-2 category. Both *a* and *b* produced a CCW tilt illusion (*a* : 0.87 deg, p = 0.0003; *b* : 0.35 deg, p = 0.0033). Thus, the contrast alternation did not reverse the illusory tilt direction although the amount of illusion decreased in *b*. Similarly, both *c* and *d* produced a CCW tilt illusion (*c* : 0.44 deg, p = 0.0032; *d* : 0.57 deg, p = 0.0013).

Figure 10 shows examples of the Type-3 category. a and c produced CCW tilt illusions (*a* : 1.01 deg, p < 0.0001; *c* : 1.25 deg, p < 0.0001). However, *b* and *d* did not produce significant tilt illusions (*b* : 0.08 deg (CCW), p = 0.5753; *d* : 0.19 deg (CW), p = 0.0842). Thus, the contrast alternation disrupted aspects of the stimulus structure that could cause the tilt illusion. Figure 10c and d consist of the same character sets as Fig. 8a and b but the orders are reversed. With black characters, reversing the order of the

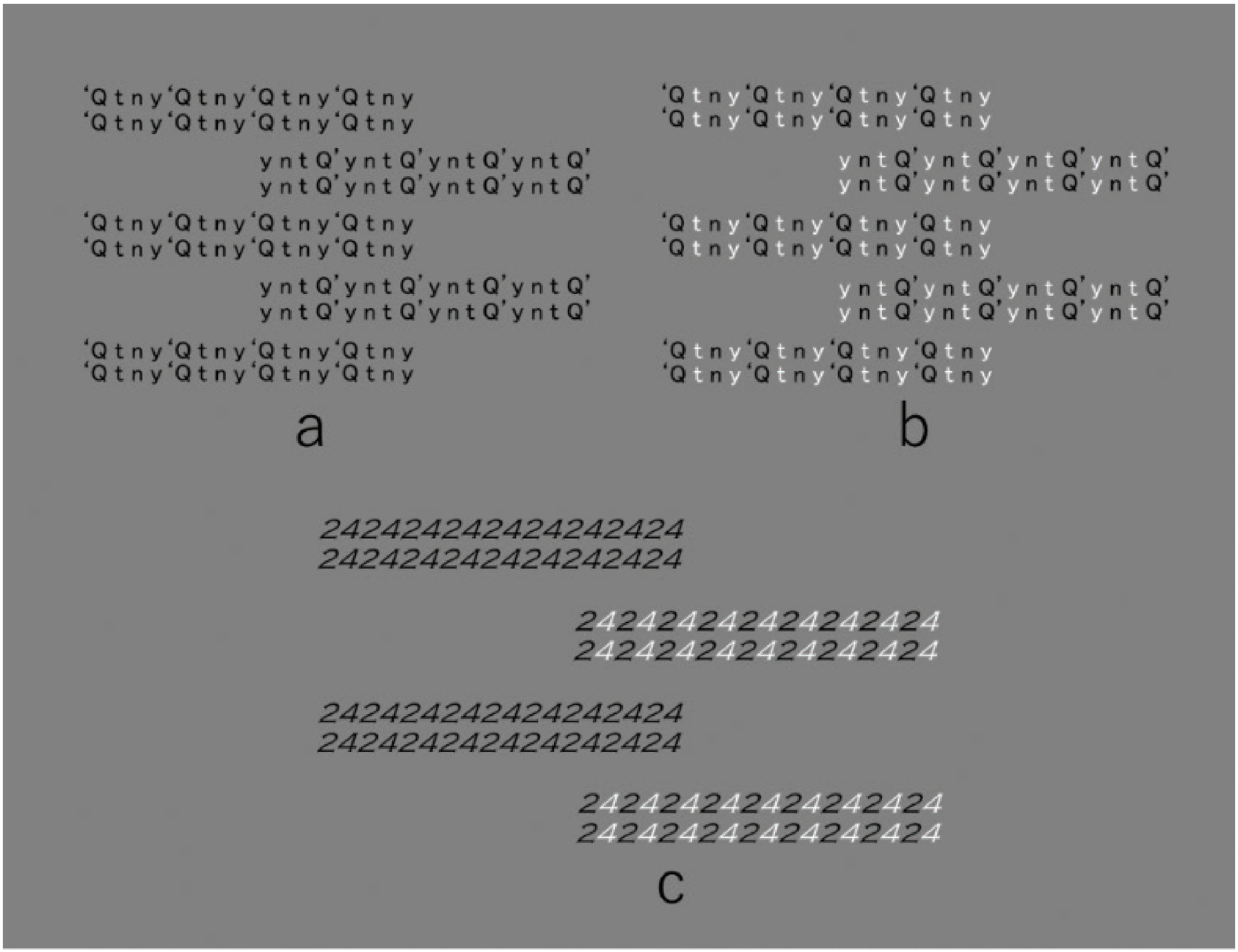


Fig. 7. *Letter-row tilt illusions* without a stairs structure (produced by the first author). *a* and *b* are written in the *Arial* font while *c* is written in the *Copperplate Gothic Light* (Italic) font. Please note that Italic fonts do not cause horizontal line elements to physically tilt.

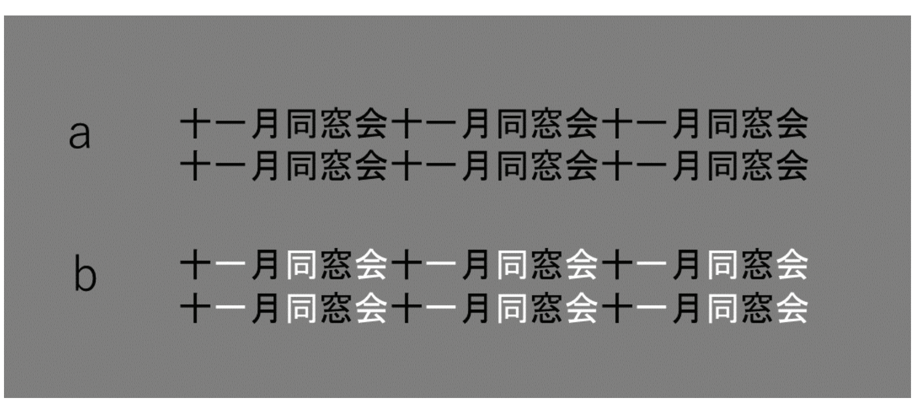


Fig. 8. An example of the Type-1 category. This character string was proposed by Arai and Arai (2010).

characters results in the reversal of the illusory tilt direction (please compare Figs. 8a and 10c). However, with the contrast-alternated versions, the reversed order destroys some illusory inducing factors (please compare Figs. 8b and 10d).

Figure 11 shows examples of the Type-4 category. Figure 11a and c did not produce a significant tilt illusion (*a* : 0.17 deg [CCW], $p = 0.3849$; *c* : 0.14 deg [CCW], $p = 0.2186$). However, Figs. 11b and d produce a significant illusory tilt (*b* : 0.81 deg [CCW], $p = 0.0005$; *d* : 0.41 deg

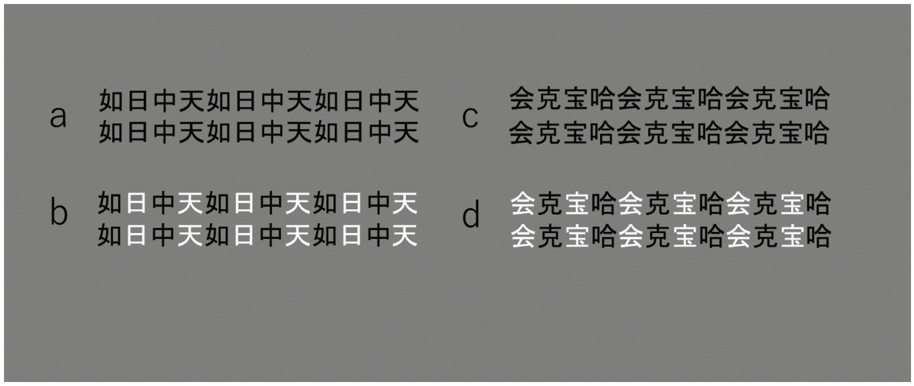


Fig. 9. Examples of the Type-2 category (created by the second author). A Chinese font (*Heiti*) is used.

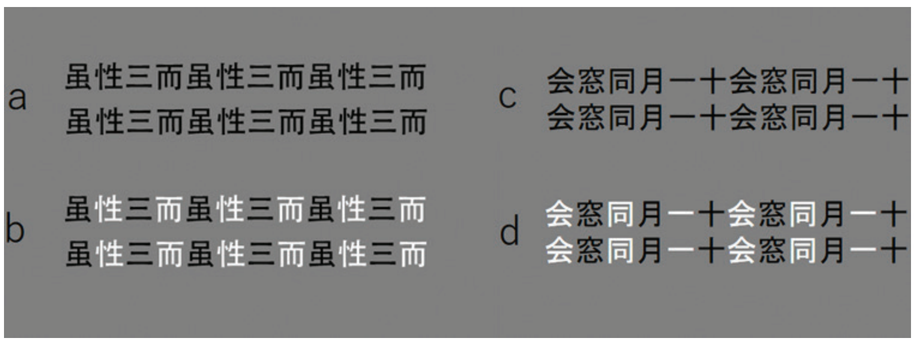


Fig. 10. Examples in the Type 3 category. *a* shows the letter-row tilt illusion created by the second author (produced with a Chinese font (*Heiti*)). *c* shows the *letter-row tilt illusion* created by Arai and Arai (2010) (produced with the *MS Gothic* font). *b* and *d* are their contrast-polarity alternated versions.

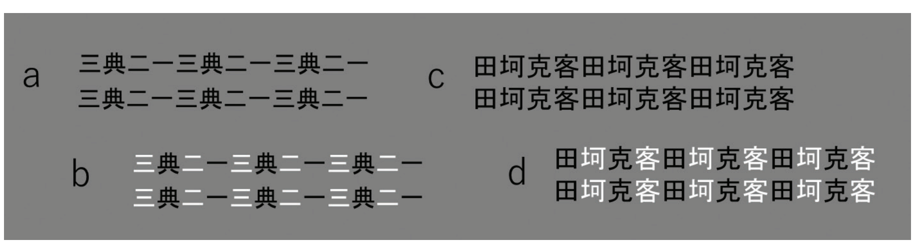


Fig. 11. Examples of the Type 4 category created by the second author. A Chinese font (*Heiti*) was used.

[CW], $p = 0.0073$). Thus, the contrast-polarity alternation for these rows of character strings produced a new factor that caused a tilt illusion. We have not found many examples to induce a strong effect in the Type-4 category. Figure 7c may be also in this category.

Although we classified the character rows based on statistical results, some of the figures in this section (e.g. the letter rows in the Type 4 category) may not convince readers of the effects in their categories as a demonstration. We will continue to collect and test letter rows that more clearly demonstrate this effect across the four categories.

General discussion

Numerous tilt illusions have been reported, such as the Zöllner illusion (Zöllner, 1860), the Hering illusion (Hering, 1861), the Münsterberg illusion (Münsterberg, 1897), the Café Wall illusion (Gregory & Heard, 1979), the Fraser illusion (Fraser, 1908), and the enhanced checkered illusion (Kitaoka, 1998). In a typical *letter-row tilt illusion*, the letters or characters do not have simple geometrical forms. In addition, the letter row is perceived to tilt as a whole unlike a tilt illusion like the Zöllner illusion in which the short line segments induce the perceived tilt of the long line segments. In the *letter-row tilt illusion*, tilt-inducing elements are not always clear. Even when a stairs structure is obvious, the whole row is perceived to tilt.

A tilt illusion that is most relevant to the *reversed stairs illusion* may be the *illusion of shifted edges* produced by (Kitaoka, 1998; Kitaoka et al., 2004). Figure 12 shows the difference between the two illusions. The *illusion of shifted*

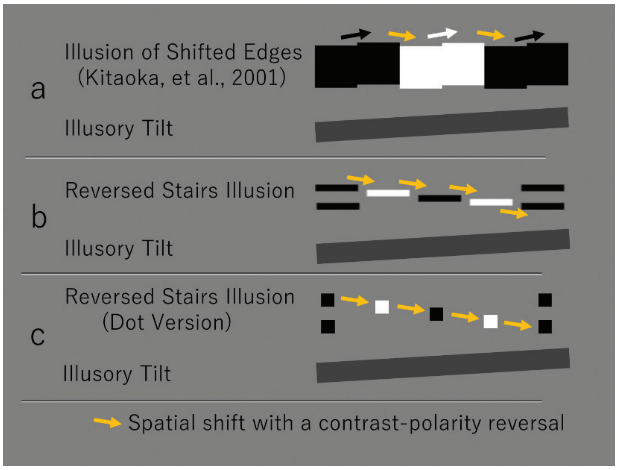


Fig. 12. Spatial shift with contrast reversals. *a* shows the *illusion of shifted edges* (Kitaoka, 1998). *b* and *c* show the *reversed stairs illusions*. See details in text.

edges consists of upward position shifts of black edges (black arrows), those of white edges (white arrows), and downward position shifts of edges with contrast-polarity reversals (yellow arrows) when going rightward (Fig. 12a). Figure 12b and c show the *reversed stairs illusion* and its dot version, respectively. They consist of vertical position shifts of elements with contrast-polarity reversals, but not including those with the same contrast-polarity edges (black and white arrows in a). An illusion of contour detection in a contrast polarity reversing condition is also relevant. Takahashi (2017) showed that reversing contrast polarity at the 'peak' or 'bottom' of a sinusoidal curve makes the curvature detection difficult (*curvature blindness illusion*) and promotes another type of contour integration. It is possible that inter-character contour integration in the *letter-row tilt illusion* figures is affected by the contrast polarity alternation.

The *reversed stairs illusion* may correspond to the *reversed phi* phenomenon (Anstis, 1970) in the domain of motion perception. The x axis in Fig. 12 corresponds to the t axis in *reversed phi*. The analogy between spatial arrangement in tilt perception and spatio-temporal arrangement in motion perception has often been reported (Mather, 1991; Takeuchi, 1997; Kitaoka, 2006, 2012).

At this stage, it is difficult to propose a comprehensive hypothesis for the *reversed letter-row tilt illusion* that includes strings of complex characters or those without a staircase structure. However, we propose a tentative hypothesis for the *reversed stairs illusion* as a simplified geometric illusion, as shown in Fig. 13. Field et al. (1993) proposed the association field model for contour integration, which is based on good continuity. We hypothesize that contrast-alternating step stimuli activate V1 simple cells with small receptive fields and that these activities become associated only when smooth contour integration

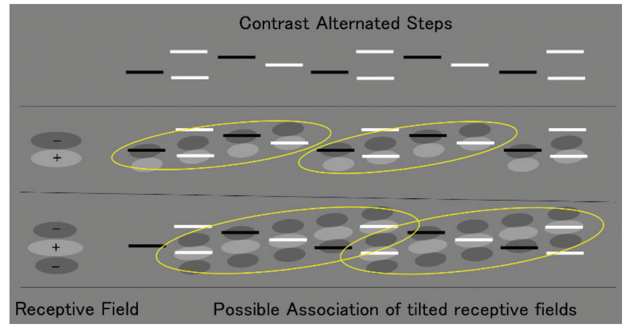


Fig. 13. Hypothesized association of simple cell activities.

is possible in terms of the location and orientation of the receptive fields of the responding cells. The yellow ellipses in the figure indicate the possible association of these cell activities, which would result in reversed tilt perception. Complex cells may fail to create the illusion because their responses are independent of the contrast polarity or the position of the stimulus within the receptive field (Hubel, 1963). Once these connections have been established, the activity of cells with slightly tilted receptive fields may be enhanced by collinear facilitation from predictive coding or feedback modulation (e.g. Hupé et al, 1998). Cells with larger receptive fields covering the area indicated by the yellow ellipses in Fig. 3a and c may directly process the tilted association of horizontal line steps with the same contrast polarity.

In this report, we have phenomenally reported the *reversed letter-row tilt illusion* and proposed the *reversed stairs illusion* as a geometrical illusion underlying the *reversed letter-row tilt illusion*. As shown in the latter half of this report, there are also character rows that produce the *letter-row tilt illusion* but do not include an explicit stairs structure. Such character rows may include other kinds of tilt clues or structures (such as the Zöllner illusion) and respond differently to the contrast polarity reversals. Araragi and Ito (2026) reported that *letter-row tilt illusion* figures that do not include a stairs structure show varied results in tilt perception when the aspect ratios of the figures were changed. We showed four types of character rows that caused different tilt perceptions to the contrast polarity reversals. The *reversed stairs illusion* we proposed here may be just one of the possible causes of the various effects of contrast-polarity reversals in the *letter-row tilt illusion*. However, the *reversed stairs illusion* is a newly found geometrical illusion and convenient for quantitative experiments because of the simple stimulus structure. Detailed research on the *reversed stairs illusion* is under progress in our laboratory.

Acknowledgement

We would like to thank Dr. Sheryl Anne Manaligod de Jesus for her English editing.

Conflict of interest and funding

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Anstis, S.M. (1970). Phi movement as a subtraction process. *Vision Research*, *10,* 1411–1430. https://doi.org/10.1016/0042-6989(70)90092-1

Arai, H., & Arai, S. (2005). Mojiretsu keisha sakushi no kaiseki 1. 'Koniaga' no ueibu retto ni yoru kaiseki). *Shikaku Sugaku e Kenkyushitsu Houkoku*, No. 1. (in Japanese). Retrieved from https://researchmap.jp/multidatabases/multidatabase_contents/detail/233631/a04cee170004a99cb4baf64eaab9d03d?frame_id=748143

Arai, H., & Arai, S. (2010). *Science museum of illusions.* Retrieved from http://www.araiweb.matrix.jp/Exhibition/illusiongallary4.html

Araragi, Y., & Ito, H. (2026). The different effects of aspect ratios of letters on the letter-row tilt illusion in staircase and non-staircase stimuli. *Attention, Perception & Psychophysics*, *88*, article number 72. https://doi.org/10.3758/s13414-025-03204-5

Field, D.J., Hayes, A., & Hess, R.F. (1993). Contour integration by the human visual system: Evidence for a local 'association field'. *Vision Research*, 33, 173–193. https://doi.org/10.1016/0042-6989(93)90156-q

Gregory, R.L., & Heard, P. (1979). Border locking and the Café Wall illusion. *Perception*, *8*, 365–380. https://doi.org/10.1068/p080365

Hubel, D.H. (1963). The visual cortex of the brain. *Scientific American*, 209(5), 54–63. https://doi.org/10.1038/Scientific American1163-54

Hupé, J.M., James, A.C., Payne, B.R., Lomber, S.G., Girard, P., & Bullier, J. (1998). Cortical feedback improves discrimination between figure and background by V1, V2 and V3 neurons. *Nature*, 394(6695), 784–787. https://doi.org/10.1038/29537

Kitaoka, A. (2006). Configurational coincidence among six phenomena: A comment on van Lier and Csathó (2006). *Perception, 35*, 799–806. https://doi.org/10.1068/p5319b

Kitaoka, A. (2007). Tilt illusions after Oyama (1960): A review. *Japanese Psychological Research*, *49*(1), 7–19. https://doi.org/10.1111./j.1468-5884.2007.00328.x

Kitaoka, A. (2012). *4-stroke tilt and motion*. Retrieved from http://www.psy.ritsumei.ac.jp/~akitaoka/4-stroke-tilt-and-motion.html

Kitaoka, A. (1998). Apparent contraction of edge angles. *Perception, 27*, 1209–1219. https://doi.org/10.1068/p271209

Kitaoka, A., Pinna, B., & Brelstaff, G. (2004). Contrast polarities determine the direction of Café Wall tilts. *Perception*, *33*, 11–20. https://doi.org/10.1068/p3346

Kohara, M. (2005). The role of horizontal components in the tilting letter-row illusion. *Ritsumeikan Bungaku Gakusei Ronshu* (Student Journal of Ritsumeikan University College of Letters), *12*, 83–103. (in Japanese). Retrieved from http://www.psy.ritsumei.ac.jp/~akitaoka/Kohara-mojiretsu-tilt2006.pdf

Mather, G. (1991). First-order and second-order visual processes in the perception of motion and tilt. *Vision Research*, *31*, 161–167. https://doi.org/10.1016/0042-6989(91)90083-H

Münsterberg, H. (1897). Die verschobene Schachbrettfigur. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, *15*, 184–188.

Popple, A.V., & Sagi, D. (2000). A Fraser illusion without local cues? *Vision Research*, *40*, 873–878. https://doi.org/10.1016/s0042-6989(00)00010-9

Takahashi, K. (2017). Curvature blindness illusion. *i-Perception*, *8*(6). https://doi.org/10.1177/2041669517742178

Takeuchi, T. (1997). The motion analogue of the cafe wall illusion. *Perception, 26*, 569–584. https://doi.org/10.1068/p260569

Zöllner, F. (1860). Ueber eine neue Art von Pseudoskopie und ihre Beziehungen zu den von Plateau und Oppel beschriebenen Bewegungsphänomenen. *Annalen der Physik*, *186*, 500–523. https://doi.org/10.1002/andp.18601860712

Appendix

Method

Observers

Ten observers participated in the experiment. They were Kyushu University students aged between 22 and 26. Nine were female and one was male. Informed consent was obtained prior to the experiment.

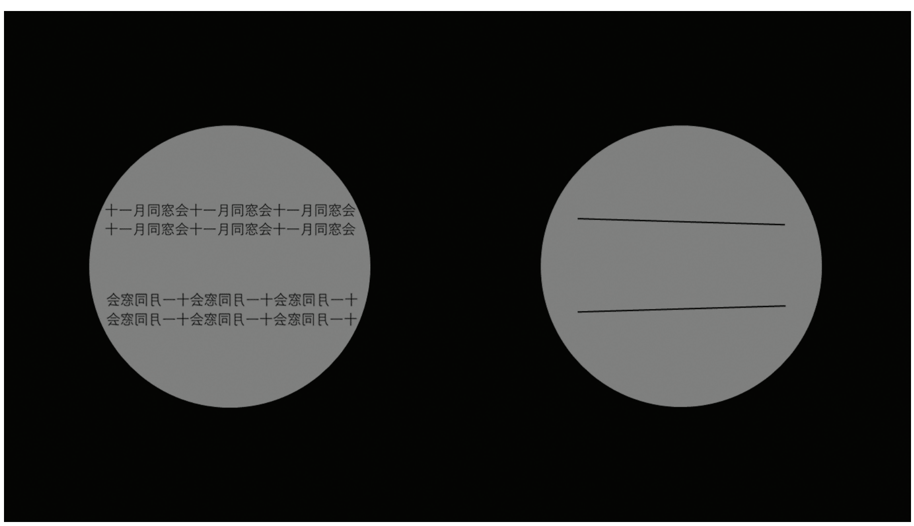
Apparatus and stimuli

The stimuli were created using a computer (Apple, MacBook Air 2020) and presented on a 23-inch LCD monitor (Mitsubishi, RDT233WX-3D). The screen was treated as a 1,920 × 1,080 pixel matrix. The figure below shows an example of the stimulus screen. There were two circular windows on a black background (0.2 cd/m²). The inside of the windows was painted grey (10.7 cd/m²). The diameter subtended a visual angle of 5.7 degrees. In the left window, paired character rows (i.e. the original character row and its horizontally reversed image) were presented above and below, respectively. It was expected that the two rows would appear to tilt in opposite directions. These rows consisted of either black characters or alternated between black and white characters, as shown in Fig. 8a and b. The luminance of the black characters was 0.2 cd/m², while that of the white characters was 42.5 cd/m². In the right window, two lines were used to reproduce the perceived tilt of the character rows.

Procedure

The experiment was conducted in a darkened room. The viewing distance was 120 cm. A chinrest was used. The method of adjustment was employed to measure the perceived orientation of the character rows. The physical tilt of the lines in the right window was adjusted by pressing the keys. Changes in tilt were produced in opposite directions for the two lines in 0.2 degree steps. Each observer performed three trials for each of the two contrast polarity conditions (black only and black-white alternation) for each character row. Observers viewed the stimuli in the left window and the lines in the right window freely without a fixation point.

Sample of the stimulus display.



Citation: Journal of Illusion 2026, **6**: 13927 - https://doi.org/10.47691/joi.v6.13927