Anomalous motion illusion and stereopsis

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Abstract

A strong resemblance in stimulus configuration among the optimized Fraser-Wilcox illusion Type IIa, reversed phi movement, phi movement, positional illusion, and related 3D effects, is discussed. Although these phenomena cannot be explained by a single mechanism, a limited number of shared mechanisms are thought to underlie them.

Key Words: Optimized Fraser-Wilcox illusion, reversed phi movement, phi movement, positional illusion, binocular stereopsis

1. Anomalous motion illusion

The Fraser-Wilcox illusion [1,2] is a typical one of anomalous motion illusions, those characterized by apparent motion in a stationary image. We optimized this illusion [3], in which the direction of apparent motion was thought to be "black to dark-gray" or "white to light gray".

Here I classify the optimized Fraser-Wilcox illusion into four categories: Type I, Type IIa, Type IIb, and Type III. Type I is characterized by luminance gradients being the critical configuration. Type II refers to a three-field configuration in that the center field is a narrow band flanked by two broad fields of different luminances. Moreover, Type II is classified into two subtypes. Type IIa is the "line" type where the narrow band is brighter or darker than both flankers. Type IIb is the "edge" type where the narrow band is the intermediate luminance between those of the flankers. Type III consists of two fields of different luminances. These characteristics are shown in Figure 1.

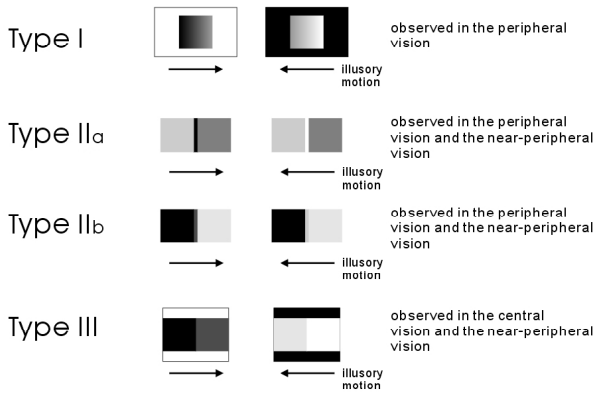

Figure 1. Temporary classification of the optimized Fraser-Wilcox illusion.

Figure 2 shows images giving global motion. Figure 2a shows Type I, Figures 2b and 2c demonstrate Type IIa and Type IIb,

respectively. Figure 2d is based on Type III.

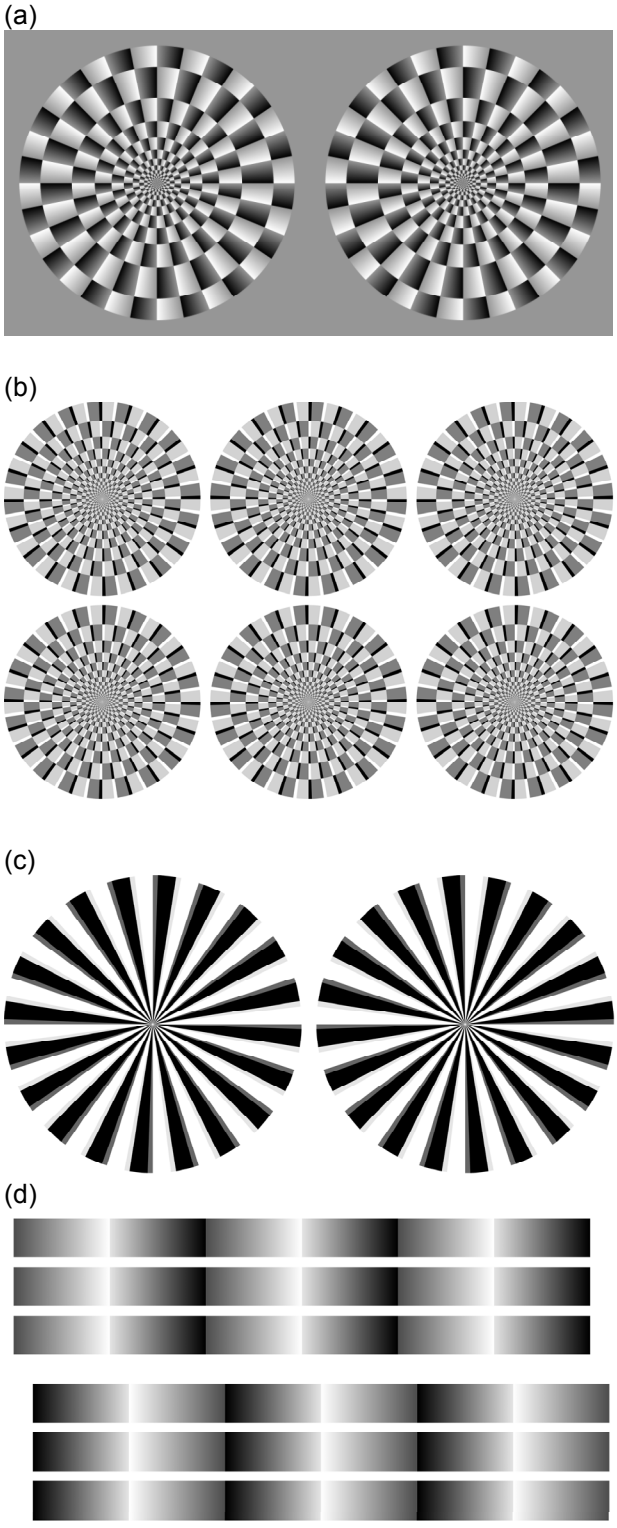

Figure 2. (a)-(c) Apparent rotation is observed in each disk. (d) Apparent slides in the horizontal direction are observed.

In addition, the apparent motion of the "Rotating snakes" illusion (Figure 3) [4], which has recently drawn attention [5-7], can be regarded as Type IIa.

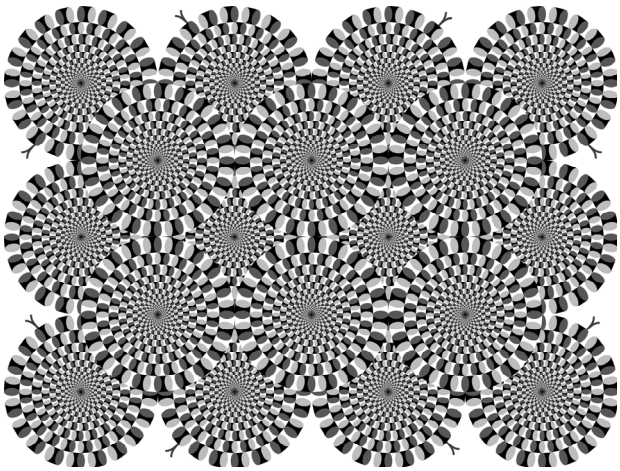

Figure 3. "Rotating snakes". Apparent rotation is observed in each disk.

2. Reversed phi, phi, positional illusion and stereopsis

Reversed phi movement refers to an illusory motion in the direction opposite to the positional shift of an object [8,9]. Figure 4a shows an example, in which the right flank of the inset is always bright and the left flank is constantly dark while the luminances of the inset and surround are dynamically changing. When the luminance of the inset increases and that of the surround decreases, the inset shifts rightward in position accompanied by a negative-to-positive change while the perceived motion is leftward.

Gregory and Heard [10] found that the dynamic change of only the surround is sufficient to generate such a motion illusion. Figure 4b shows an example, in which the lumimance of the inset is constant while that

of the surround dynamically changes.

In this paper, I regard the Gregory-Heard motion illusion as sharing the same mechanism as the reversed phi movement, and call them "luminance-change-dependent motion illusion".

There is another luminance-change-dependent motion illusion. It was called "phi movement" by Anstis and Rogers [9]. Figure 4c shows an example, in which the luminance of the inset is always dark and that of the surround is constantly bright while the luminances of both flanks are changing. When the luminance of the right flank decreases and that of the left flank increases, the inset appears to shift rightward in position as well as in motion

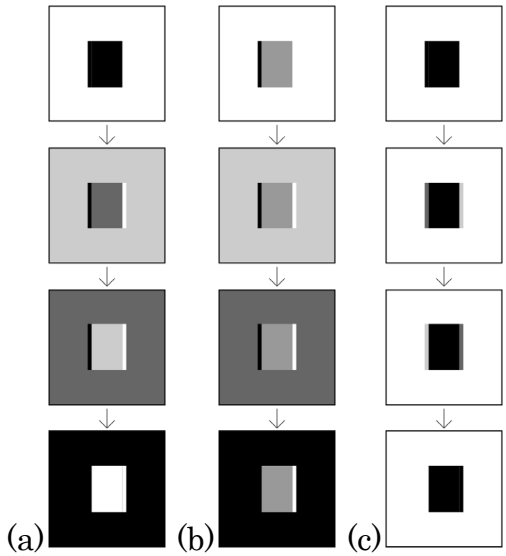

Figure 4. (a) Reversed phi movement proposed by Anstis and Rogers [8,9]. The thin flanks of the inset are constant in luminance (dark or bright) while the inset changes from dark to bright and the background simultaneously changes from bright to dark. In this sequence, the perceived motion of the inset is leftward whereas the positional shift is rightward. (b) The illusory motion investigated by Gregory and Heard [10]. The only configurational difference from the reversed phi movement is that the inset is constant in luminance. In this sequence, the perceived motion is leftward while the positional shift is rightward. (c) Phi movement demonstrated by Anstis and Rogers [9]. The inset and surround are constant in luminance while the right flank changes from bright to dark and the left one changes from dark to bright. In this sequence, the perceived motion as well as the apparent positional shift of the figure is rightward.

In these situations, there are two types of positional illusions and two types of binocular stereopsis. These are described in the legend of Figure 5.

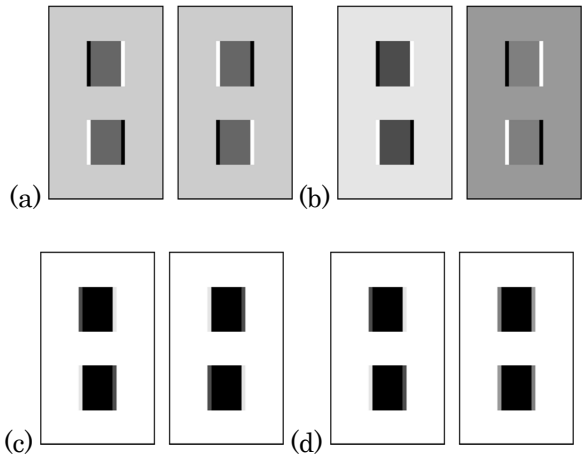

Figure 5. (a) Gregory and Heard's [10] stereogram. In the right column, the upper rectangle appears to shift rightward in position as compared with the lower one, though they are vertically aligned. In the left column, the apparent positional shift is the reversal. If observers cross-fuse (uncross-fuse) the two columns, the upper rectangle appears to be in front of (behind) the lower. This indicates that the perceived depth agrees with the binocular disparity of the apparent positional shifts. (b) Anstis and Rogers' [9] stereogram. In the left column, the upper rectangle appears to shift leftward in position as compared with the lower one. In the right column, the apparent positional shift is small. If observers cross-fuse (uncross-fuse) the two columns, the upper rectangle appears to be behind (in front of) the lower. This indicates that the perceived depth disagrees with the binocular disparity of the apparent positional shifts. (c) A stereogram made up of the stimuli of Anstis and Rogers' [9] phi movement. The apparent positional shift as well as the binocular depth perception are similar to those in panel (a). (d) An unmentioned stereogram of the stimuli of the phi movement. The configuration is

similar to panel (b), but the perceived depth agrees with the binocular disparity of the apparent positional shifts. That is, the upper rectangle in the left column appears to shift leftward in position as compared with the lower one while the upper rectangle in the right column do not appear to shift so much, and the cross-fused (uncross-fused) upper rectangle appears to be in front of (behind) the lower.

In sum, there are six different illusions or effects [11]: (1) luminance-change-dependent motion illusion Type A or reversed phi movement (Figures 5a and 5b), (2) luminance-change-dependent motion illusion Type B or phi movement (Figures 5c and 5d), (3) position illusion in the configuration of the luminance-change-dependent motion illusion Type A (Figures 5a and 5b), (4) position illusion in the configuration of the luminance-change-dependent motion illusion Type B (Figures 5c and 5d), (5) Gregory-Heard's stereopsis (mirror images with luminances being constant) (Figures 5a and 5c), and (6) Anstis-Rogers' stereopsis (non-mirror images with different luminances) (Figures 5b and 5d).

These phenomena can be grouped into three types: the first group (Anstis-Rogers' stereopsis-compatible group) includes (1) and (6) (under the condition of the luminance-change-dependent motion illusion Type A), the second group (Gregory-Heard-stereopsis-compatible group) contains (3) and (5) (under the condition of the luminance-change-dependent motion illusion Type A), and the third group (phi movement-compatible group) covers (2), (4), (5) and (6) (under the condition of the luminance-change-dependent motion illusion Type B).

Furthermore, the elemental motion in the reversed phi movement or the phi movement is summarized in Figure 6 [11,12], where luminance changes in three fields of different luminances are critical. Moreover, the central field should be narrow.

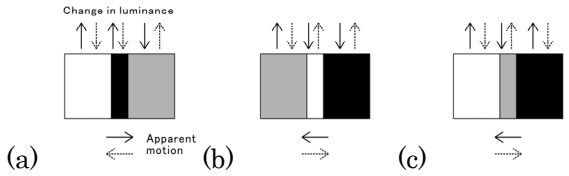

Figure 6. Perceived motion in the three elemental spatio-temporal configurations. Upward-pointing arrows show the increase in luminance in each region while downward-pointing arrows mean the decrease in luminance in each region. Right-pointing or left-pointing arrows indicate the direction of the apparent motion. For example, when the bright region in (a) increases in luminance as indicated with the upward-pointing real-line arrow, the apparent motion is rightward as shown with the rightward-pointing real-line arrow. Panels (a) and (b) correspond to the luminance-change-dependent motion illusion Type A (*e.g.*, the reversed phi movement and the Gregory-Heard motion illusion) whereas panel (c) corresponds to the luminance-change-dependent motion illusion Type B or the phi movement. In addition, the apparent positional shift is leftward in (a), that is rightward in (b), and in (c) the apparent positional shift depends on the luminance of the thin region, where that is leftward when the thin region is relatively dark while that is rightward when the thin region is relatively bright.

3. The optimized Fraser-Wilcox illusion Type II and the luminance-change-dependent motion illusion (reversed phi and phi)

Here I point out two pieces of similarity in stimulus configuration. One is the similarity between the optimized Fraser-Wilcox illusion Type IIa and the luminance-change-

dependent motion illusion Type A, while the other is the similarity between the optimized Fraser-Wilcox illusion Type IIb and the luminance-change-dependent motion illusion Type B. The former share the same configuration of line appearance (Figures 6a and 6b), while the latter do the same configuration of edge appearance (Figure 6c). Both consist of three fields of different luminances where the central field is narrow.

The relationship between them is depicted in Figure 7. As a result, the optimized Fraser-Wilcox illusion Type IIa just behaves as the luminance-change-dependent motion illusion Type A or the reversed phi movement (Figures 7a and 7b). On the other hand, the optimized Fraser-Wilcox illusion Type IIb behaves as the luminance-change-dependent motion illusion Type B or the phi movement (Figures 7c and 7d).

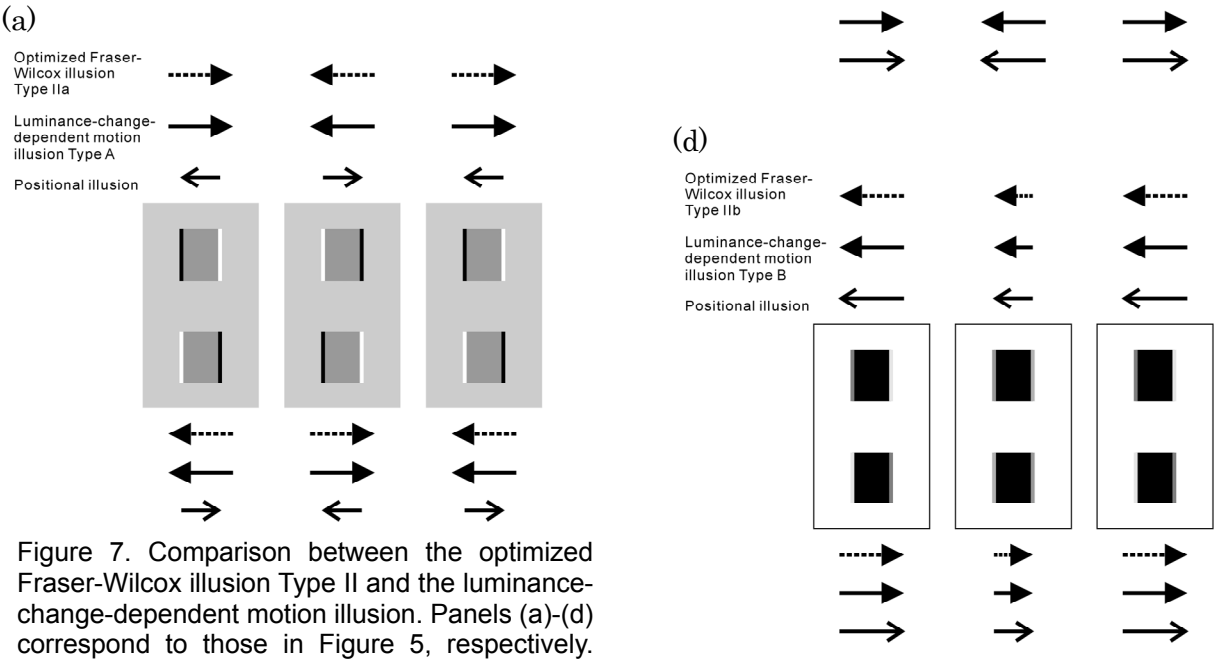

Figure 7. Comparison between the optimized Fraser-Wilcox illusion Type II and the luminance-change-dependent motion illusion. Panels (a)-(d) correspond to those in Figure 5, respectively. These images are stereograms, too.

It is thus suggested that the Fraser-Wilcox illusion Type II strongly resembles the reversed phi movement and phi movement. This may suggest that the same neural mechanisms underlie them.

4. The optimized Fraser-Wilcox illusion Type II and stereopsis

Since the optimized Fraser-Wilcox illusion behaves like the reversed phi movement or phi movement, it is correlated with Anstis-Rogers' stereopsis (Figures 5b and 7b) and with the stereopsis in the configuration of the phi movement (Figures 5c, 5d, 7c and 7d). This resemblance depends on the viewpoint of apparent positional deviation. Actually, illusory motion in depth has never been observed [13].

5. Prospects

A strong resemblance in stimulus configuration between anomalous motion illusion and stereopsis is focused on. Although there is no clear evidence for the same underlying mechanism, this similarity is so striking that it should not be a mere coincidence. Further research may give fruitful information on visual processing.

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