Hiroyuki Ito
Faculty of Design, Kyushu University, 4-9-1 Shiobaru, Minami-ku, Fukuoka 815-8540, Japan, and Research
Center for Applied Perceptual Science, Kyushu University, 4-9-1 Shiobaru, Minami-ku, Fukuoka 815-8540, Japan;
e-mail: ito@design.kyushu-u.ac.jp

Xie Yang
School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, 800 Dongchuan RF, Minhang
District, Shanghai 200240, China; e-mail: xyqq07816@sjtu.edu.cn

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Abstract. When a short straight line segment moves across a zigzag line and is viewed in one’s
depth vision, it appears to exhibit nonrigid squirming motion (the squirm effect). This phenomenon
demonstrates that the form, orientation, and motion direction of a short line are influenced by those of
a longer one when they are viewed in one’s peripheral vision.

Keywords: motion illusion, motion streak, line orientation, motion direction, corner detection, assimilation.

Here we describe a new motion illusion, consisting of a static zigzag line with a short straight line seg-
ment moving across it, as seen in Figure 1(a). When viewed in one’s peripheral vision, the short line
segment is seen to squirm in phase with the zigzag line like a wriggling fish or worm, as seen on the
right in Figure 1(a). We call this nonrigid motion the squirm effect.

That the perceived direction of motion of a dot is contrasted with the orientation of background
lines when it crosses the tilted lines has been demonstrated (Cesaro & Agostini, 1998; Khuu, 2012;
Swanston, 1984). The motion streak in a contrasted orientation is thus considered to be a component
of motion direction perception (Geisler, 1999). Recently, Anstis (2012) found that a moving object is
seen to move along a background contour when seen in one’s peripheral vision (the furrow illusion).

We also observed that when a dot moves across a zigzag line and is viewed in one’s peripheral vision,
the perceived motion path is biased toward the path of the zigzag line. This may be a version of the
furrow illusion. However, when the moving dot is replaced by a short line segment, the line segment
is seen to move, squirming along the zigzag line.

We tested the effects of orientation of the short line segment in relation to the direction of move-
ment as well as the contrast polarity of the short line segment on the nonrigid impression from the
display. As shown in Figure 1(b), we used a static black zigzag line (0.0 cd/m²) and a black/white short
line segment (0.0 or 100 cd/m²) that moved on an oblique path, crossing the zigzag line. Lines were
presented on a gray background (49.9 cd/m²) and viewed in the participant’s peripheral vision. The
stimuli were produced by a Dell XPS8300 computer and displayed on a Sony PVM-2541 organic
light-emitting diode (OLED) display. The viewing distance was 67 cm. The zigzag line subtended a
visual angle of 11.8 deg, with an overall path that was oriented 45 deg from the horizontal. The dis-
tance between the fixation point and the center of the zigzag line was 8.4 deg. To produce the zigzag
wave, we alternated the local line orientation between 10 (45° ± 35°) deg and 80 (45° ± 35°) deg. The
short line segment subtended a visual angle of 0.7 deg. We used seven different orientations for the
short line segment, i.e., 0, 15, 30, 45, 60, and 90 deg, rotated from the moving direction to a clockwise
or counterclockwise direction. The short line segment moved with a speed of 3.9 deg/s and made two
identical round trips, starting from the bottom right of the zigzag line. Five graduate students were
asked to rate their impression of nonrigid movement on an 11-point scale (0–10), with “10” indicating
an impression of totally nonrigid movement (“like a squirming worm”) and “0” indicating an impres-
sion of rigidity (“like a pencil”). Each participant completed four trials for each combined condition
(two contrast polarity × six orientations), conducted in a random order.

Figure 2 shows our results. The nonrigid impression arose only when participants viewed the short
line segment move within a limited orientation range. When the orientation exceeded the local line
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The nonrigid impression was gradually replaced by a type of furrow illusion (we believe), i.e., the rigid short line segment tended to be seen to move along the zigzag line. A two-way analysis of variance (ANOVA) was conducted for the nonrigidity ratings. The main effect of orientation of the short line segment was significant ($F(5, 20) = 46.578, p < 0.0001$). Multiple comparisons revealed a significant difference ($p < 0.05$) between the pairs in the orientation conditions, although this excluded the pairs oriented at 45, 60, and 90 deg and the pair oriented at 30 and 45 deg. The effect of contrast polarity ($F(1, 4) = 1.611, p > 0.05$) and the interaction between the orientation and the contrast polarity ($F(5, 20) = 0.296, p > 0.05$) were not significant. Reversing the polarity relationship between the short and zigzag lines did not affect the impression of nonrigidity. Thus, the squirm effect appearing on the short line segment may not have simply been caused by the low resolution of peripheral vision.

Is the squirm effect a version of the slalom effect (Cesaro & Agostini, 1998)? We observed that when the short line segment was tracked by eye movements, the slalom effect was predominant, i.e., the motion path had a phase opposite to that of the zigzag wave. However, in peripheral vision, the path of perceived motion was in phase. Thus, the slalom effect cannot explain the squirm effect.

Figure 1. Schematic illustration of the illusory motion (movie is available online at http://i-perception.perceptionweb.com/journal/1/volume/4/article/i0573sas). Panel (a) shows the physical and perceived motion and (b) shows a sample of the stimulus display.

Figure 2. Rated nonrigidity as a function of the orientation of the moving short line segment in relation to the direction of motion. Open (filled) symbols indicate data from the white (black) short line condition. Error bars indicate standard errors.
Short line squirms along zigzag

squirm effect a version of the furrow illusion? The squirm effect appears to arise in a special case that could produce the furrow illusion, because when the short line segment has a relative orientation of more than 45 deg (in our experiment), the furrow illusion arises without nonrigid motion impression. Is the squirm effect a kind of orientation assimilation within the short line and/or its motion path? The nonrigid motion impressions occur mainly at the corners of the zigzag line, i.e., its motion path is assimilated in terms of orientation and the short line is seen to bend at the corners. We hypothesize that assimilation between forms occurs at the corners, i.e., corner or curvature detection at the corners of the zigzag line is simultaneously applied to the short line when it passes near the corner. This assimilation at the corner/curvature detection processes may produce the impression of nonrigid squirming motion (the squirm effect).

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