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Robust size illusion produced by expanding and contracting flow fields

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ABSTRACT

A new illusion is described. Randomly positioned dots moved radially within an imaginary annular window. The dots' motion periodically changed the direction, leading to an alternating percept of expanding and contracting motion. Strikingly, the apparent size of the enclosed circular region shrank during the dots' expanding phases and dilated during the contracting phases. We quantitatively measured the illusion, and found that the presence of energy at the local kinetic edge could not account for the illusion. Besides, we reproduced the illusion on a natural scene background seen from a first-person point of view that moved forward and backward periodically. Blurring the boundaries of motion areas could not reverse the illusion in all subjects. Taken together, our observed illusion is likely induced by optic flow processing with some components of motion contrast. Expanding or contracting dots may induce the self-motion perception of either approaching or leaving way from the circle. These will make the circle appear smaller or larger since its retinal size remains constant.

1. Introduction

Investigations on visual illusions demonstrate that perception does not necessarily correspond to the physical stimulus properties such as orientation (Cavanagh & Anstis, 2013), size (Rock & Kaufman, 1962) and position (Ramachandran & Anstis, 1990). For example, the perceived position of a stationary window appears displaced in the direction of the enclosed motion (Ramachandran & Anstis, 1990). This illusion, termed motion-induced position shift (MIPS), has been repeatedly observed in later work (Kohler, Cavanagh, & Tse, 2015; Mather & Pavan, 2009; Whitney et al., 2003).

Here we report a reversed illusion that was serendipitously observed (Dong & Bao, 2015). Random black and white dots radially moved within an imaginary annular window centered on a mid-gray background. Their moving direction periodically changed, leading to alternating perception of expanding or contracting motion (see Fig. 2a and c or Video S2). According to the findings in MIPS, one would predict that the circular region within the motion-defined boundary dilates during the "expansion" phases and shrinks during the "contraction" phases. However, we observed the reversed. In four experiments, we quantitatively measured the illusion. Since the illusion corresponds with the perceived size changes of the circular region, we call it "size illusion" for simplicity.

2. General methods

2.1. Subjects

Eight naïve subjects (3 males and 5 females, ages ranging from 20 to 24 years) participated in Experiments 1–2. Eight naïve subjects (4 males and 4 females, ages ranging from 20 to 25 years) participated in Experiments 3. Another fifty naïve subjects (20 males and 30 females, ages ranging from 18 to 27 years) participated in Experiment 4. All of them had normal or corrected-to-normal vision. Experimental procedures were approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences, and informed consent was obtained from all the subjects. The work was carried out in accordance with the Code of Ethics of the World Medical Association.

2.2. Apparatus

Stimuli were generated in MATLAB using PsychToolbox version 3 extensions (Brainard, 1997), and were presented on a Dell P1230 CRT monitor with a resolution of 1024 × 768 pixels and a refresh rate of 85 Hz. Subjects viewed the monitor from a distance of 57 cm in a dark room. A chin-rest was used to help minimize head movement.

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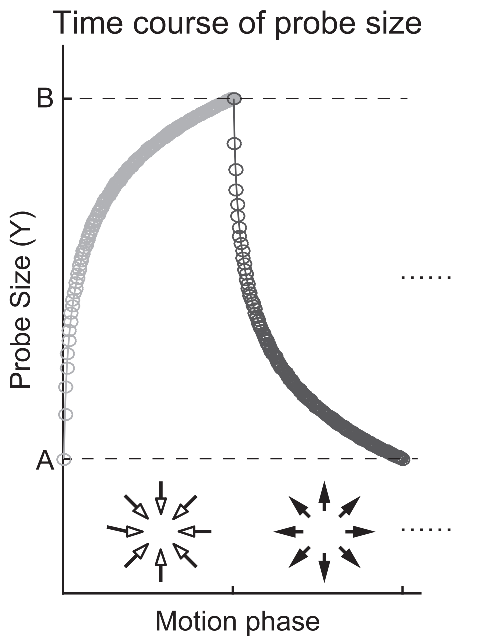

$$Y = A \times N^{(\log B - \log A)/\log N_T} \quad (1)$$

$$Y = A + B - A \times N^{(\log B - \log A)/\log N_T} \quad (2)$$

Fig. 1. The time course of probe size that was simulated with two power functions. Subjects adjusted the minimum and maximum probe size, which correspond to A and B in the equations, to match the perceived size of the central circular region. Then the time course of probe size of each frame during the contraction and expansion phase will be calculated with Eqs. (1) and (2), respectively. Light gray curve represents the probe size during the contracting phase (Eq. (1)), dark gray curve represents the probe size during the expanding phase (Eq. (2)). Open circle denotes the probe size at each frame.

3. Experiments

3.1. Experiment 1

3.1.1. Stimuli and procedures

All the stimuli were displayed on a mid-gray background (45.73 cd/m^2). A black central fixation point (0.1°) was always presented during the experiment. Each frame in a motion sequence consisted of 333 black (0.58 cd/m^2) and 333 white (89.77 cd/m^2) dots (0.15° in diameter) displayed within an imaginary annular window (outer radius: 3°, inner radius: 1.5°) centered on the screen. The dots moved at a speed of 5°/s, whose luminance and initial positions were randomly determined at the beginning of each trial.

In the 24 trials with induction, all the dots moved either towards or away from the fixation point, and changed the direction of motion every 3 s, leading to an alternating percept of expanding or contracting motion. The dots' motion also gave rise to an illusory contour along the inner edge of the imaginary annular window. When viewing such periodic motion in a pilot demo, the authors perceived the illusion that such motion-induced illusory contour dilated during the "contraction" phases and shrank during the "expansion" phases. As a baseline estimation, in another 24 trials, 50% of the dots were randomly selected to move towards the fixation point, while the rest of the dots moved away from it. To examine the role of the contour, we ran additional 24 baseline and induction trials where a black circle was displayed along the inner edge of the imaginary annular window. These four types of trials (see Fig. 2a–c or Video S1–S4 in the Supplemental Material, baseline without physical contour, induction without physical contour, baseline with physical contour, and induction with physical contour) were interleaved randomly throughout the experiment in a counterbalanced order.

Subjects were first asked to complete a questionnaire about their perception during the viewing of a demo of the stimuli. Nobody reported detecting any change of size for the central circular region in the baseline condition, but all reported seeing periodic

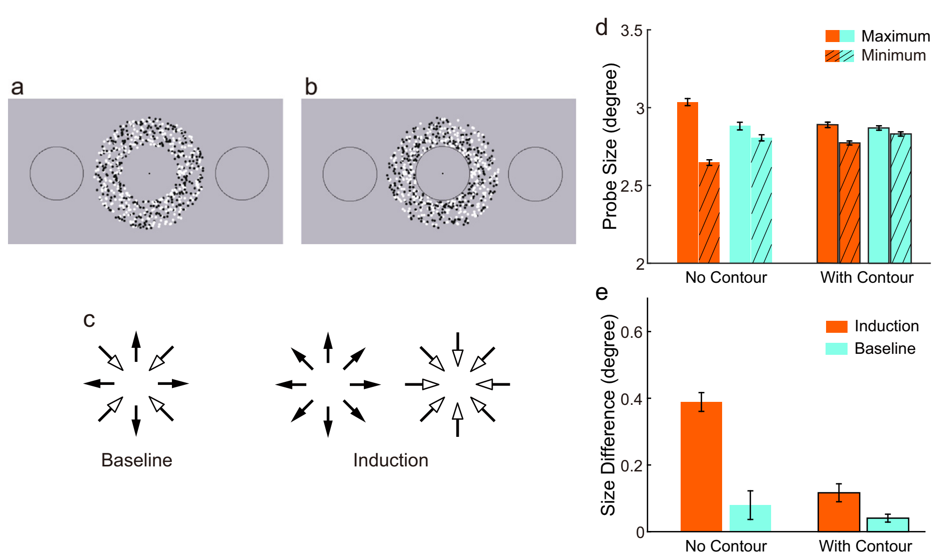

Fig. 2. Stimuli and results of Experiment 1. (a) Stimulus without a physical contour. (b) Stimulus with a physical contour. (c) Two motion patterns. In the baseline trials, 50% of the dots were randomly selected to move towards the fixation point, while the rest of the dots moved away from it. In the induction trials, all the dots moved either towards or away from the fixation point, and changed the direction of motion every 3 s. Subjects were asked to adjust the size of probes, which located on either side of the dot inducer, to match the perceived contour size. (d) The minimum and maximum probe size for the induction trials (orange bars) and baseline trials (cyan bars). Here, "With Contour" stands for the condition with a physical contour along the inner edge of the inducer, while "No Contour" corresponds to the original condition with only the motion-defined higher-order contour. The results for the with contour condition are displayed using bars with black borders. (e) The size difference (i.e. the difference between the minimum and maximum probe size) in the induction (orange bars) and baseline trials (cyan bars) of the "No Contour" and "With Contour" conditions. Error bars represent standard errors of means.