Length Illusion Induced by Contours?

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Introduction. The overestimation of the length of the filled interval of the Oppel-Kundt stimuli may arise due to spatial and temporal integration of excitations caused by real continuous contours of a solid block or imaginary contours induced by regular sequences of the filling segments. To favour our view, a set of experiments was performed. The illusion strength was measured for the Oppel-Kundt stimuli with a solid filling and unfilled rectangles in combination with a regular sequence of uniform stripes and without them.

Methods. The stimuli of fixed presentation duration (1300 ms) with uniformly filled or outlined rectangles were used (Fig. 1). Also, combinations of the filled and outlined rectangles with a regular sequence of uniform stripes were taken. In the experiments, two-alternative forced-choice method (2AFC) was used to measure the illusions magnitude. The subjects were asked to indicate the longer part of the figure by pressing the corresponding keyboard buttons after each stimulus termination.

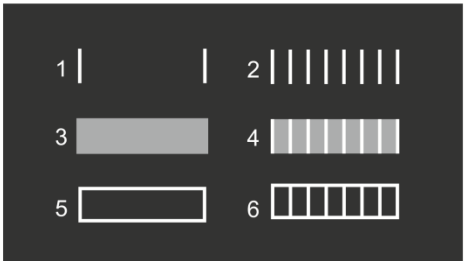

Fig. 1. Six types of the referent stimulus parts used in the experiments.

The line luminance was 52 cd/m^2, the uniformly filled parts were 20 cd/m^2 and the background luminance was 0.1 cd/m^2. The height of the figure was 28 arc min. In a darkened room, the stimuli were presented in random order on the *EIZO* monitor with gamma correction. The length of the referent stimulus part remained constant and fixed at 70 arc min, while the length of the test part varied within an interval of the 70 - 110 arc min. The monocular view with artificial pupil of 3 mm in diameter was applied. A chin holder was used to limit the subject's head movements. Psychometric functions were obtained for all referent stimulus types. Each data point was the result of four experimental runs. The psychometric function midpoint 0.5 was taken as the illusion

strength. Three subjects (teachers of LUHS; age – 36, 52 and 70; all three were males) participated in the experiments.

Results and discussion. Various modes of filling in the Oppel-Kundt stimulus were tested (Fig. 2). Stimulus 1 had no filling in the referent part and was used for assessment of the subject-specific biases (influenced by the visual field anisotropy, gaze fixation, and probably some other physiological-psychological factors) in the length judgment task. The obtained individual values of the biases: -2.0, 1.0, and 0 arc min can be applied in correcting the absolute values of the distortions produced by the illusory stimuli.

The illusory stimulus 2 with seven stripes in the referent part produces distortions about 11.5, 8.5, and 6.5 arc min for subjects LE, ER, and AD, respectively. Stimulus 3 with the filling bar causes an illusion less (by 2 - 3 arc min) than stimulus 2 for subjects LE and ER ($P < 0.05$) but not for AD. Stimulus 4, which is a composition of 2 and 3, causes illusion approximately as strong as stimulus 2 alone indicating the absence of magnitude summation of the illusions. Stimulus 5 with a line-rectangle in the referent part has an effect similar to the previous ones, and the illusion strength does not differ significantly ($P > 0.05$) between them. Stimulus 6 is a combination of stimuli 2 and 5, but again the illusions do not integrate and the resulting value remains at the main level.

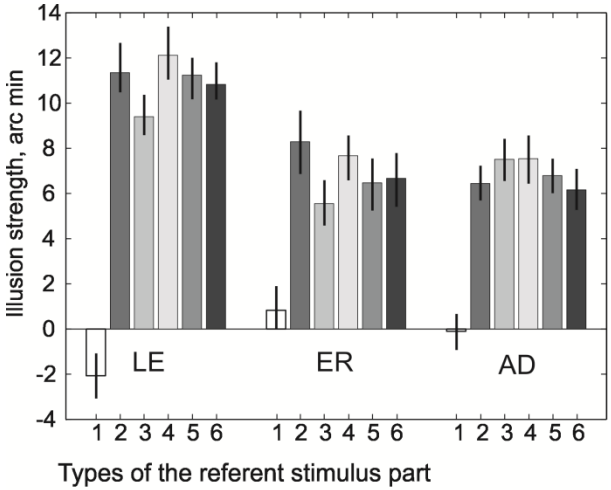

Fig. 2. The filled-unfilled illusions caused by different stimuli modifications. The data for three subjects: LE, ER, and AD. Vertical lines, 95% confidence intervals. The control stimulus, (1) has empty reference. The mode of reference filling in the rest five stimuli varied: a regular sequence of 7 stripes, (2); solid block, (3); stripes on the block, (4); contour rectangle, (5); and stripes within the rectangle, (6).

The present experimental results support the statement that the visual system processes the complex image as a single stimulus without fragmenting it into its components when performing the size equality task. In general, five

illusory stimuli used in the present experiments determine practically the same strength of the perceived distortions of spatial extent. Only individual differences of the illusion magnitude between subjects are present.

The salient property of the Oppel-Kundt illusion is an interpretation and cognition of the sequence of filling elements like a single object in the visual pathways. It is noteworthy that the illusion magnitude increases to maximum with an increase of the density of filling up to some optimal number of stripes, but slightly weakens or remains at the saturation level afterwards. For some observers, an optimum number of stripes might be more effective than a solid block, and for some subjects might not (Fig. 2). At any rate, the illusion effect does not drop to zero when the tightly spaced stripes forming a solid filling are exposed [2, 3]. Moreover, the illusion is present, and its magnitude does not cease when only the contour is shown instead of uniformly filled rectangle within the stimulus (Fig. 2). Still more, a sequence of stripes superimposed on the filled or open rectangles does not increase the illusion strength, irrespective that the sequence of stripes affects at the same distortion values as the geometric figure produces alone. The two illusory effects do not integrate. Apparently a single and quite the same procedure unrolls in processing any stimulus applied. Likely, all five illusory stimuli shown in Fig. 1 do not differ in their effectiveness, therefore, one may suspect that there is some common structural feature for all the stimuli tested. One may suppose that these quantitatively equal misperceptions in length judgments can be caused by the presence of the horizontal contours either real or interpolated. The filled and open rectangles provide the true borders of the stimulus referent part while the sequences of the top and bottom dots on the regular stripes create the continuous illusory contours. Perception of continuity is easily induced by a row of dots in dependence on the spacing and collinearity factors [1,6,7]. Each inducing element causes a neural activation field in a local space and limited time. If the activations overlap within the limits of this spatiotemporal window, they automatically combine into an associated excitation path [5]. Consequently, the illusory contours like the real ones are quite capable to induce the continuous excitation paths, "associated fields" [4]; the spatial and temporal densities lower than critical produce less effective "association fields".

Conclusions. When the filled and unfilled rectangles in the Oppel-Kundt stimulus are combined with a regular sequence of uniform stripes, the strength of the perceived distortions of the combined stimuli is the same as that of each separate stimulus.

The converging evidence both from the previous investigations of various authors and the current study strengthen the claim that the Oppel-Kundt illusion is the effect mainly caused by processing the continuous contour rather than the filling density. Density is concerned in the filled-unfilled illusion performance as much as it influences on the illusory contour percept.

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In psychophysical experiments, the stimuli with uniformly filled or outlined rectangles of fixed duration were used; various combinations of the rectangles with the regular sequences of filling stripes were also taken. It was demonstrated that the superposition of the stimuli did not change the illusion strength noticeably. The results obtained in the study support the suggestion that the filled interval overestimation in the Oppel-Kundt stimulus may be related to spatiotemporal integration along a continuous path of neural excitation evoked by the real and illusory contours of the filling.