Misalignment of the Filling Elements in the Three-Part Oppel-Kundt Figure

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Introduction. In the Oppel-Kundt stimulus, observers usually overestimate the spatial interval filled by a regular sequence of uniform elements when it is compared to the empty one of the same length. Although the Oppel-Kundt illusion is rather well studied experimentally, at present, there is no generally accepted theoretical explanation for its occurrence. It was demonstrated that uniformity and regular distribution of the filling elements are critical for the illusion manifestation [1, 2]: if the elements are irregularly spaced or unequal in height, thickness, or brightness, then the effect of the illusion is less prominent. The three-part Oppel-Kundt figure (with two filled intervals flanking the empty one) induced the illusion, which was about 25% stronger than that caused by conventional two-part figure with one filled interval [3].

The possible role of the processes of contour integration in the formation of the Oppel-Kundt illusion was recently considered [4]. It was found that a regular sequence of stripes in the Oppel-Kundt stimulus superimposed upon the filled or outlined rectangles induces illusion approximately equal in strength to that caused by the stripes or rectangles separately. These results together with the experimental data on the limited duration of stimulus presentation support a suggestion that overestimation of the filled interval in the Oppel-Kundt stimulus can be related to a spatiotemporal integration along the continuous paths of excitations evoked by the real or illusory contours of the filling. In the present pilot study, we used the modified Oppel-Kundt figure with disrupted unity of contour but preserving the horizontal regularity of the filling elements: the vertical positions of dots and stripes were distributed randomly within a certain interval. It was expected that this misalignment of stimulus elements should significantly decrease the illusion magnitude.

Stimuli and procedure. The stimuli were drawn by the *Cambridge Research Systems VSG 2/3* and displayed on the monitor *EIZO T562*, which was calibrated and gamma corrected by using a *Cambridge Research Systems OptiCAL* photometer. A chin holder was used to limit the subject's head movements. The stimuli (luminance 55 cd/m^2) were presented horizontally against a dark (0.1 cd/m^2) background and viewed monocularly. The Oppel-Kundt figures (Fig. 1) with the empty test interval flanked by the two filled referential intervals (length 90 arc min) were used. The filled intervals were formed of ten regularly horizontally spaced dots (1×1 arc min) or stripes (1×80

arc min). The vertical positions of the dots or midpoints of the stripes were distributed randomly within an imaginary band, *DB*, centered with the horizontal stimulus axis. The width of the band (the independent variable) varied from 0 to 95 arc min for the stripes and from 0 to 22 arc min for the dots. In the experiments, the subjects manipulated the keyboard buttons to adjust the empty interval in order to make all stimulus intervals perceptually equal in length. The initial length of the empty interval was selected randomly form the interval of 90 and 100 arc min. The magnitude of misjudgments was measured as a function of the width of *DB*.

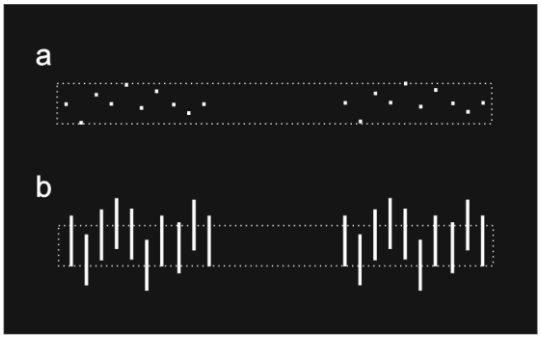

Fig. 1. Examples of the three-part Oppel-Kundt figure formed of dots (a) or stripes (b). The referential part length, 90 arc min. Dashed squares, imaginary bands, *DB* were not part of the actual display.

Three experienced subjects (2 male: 37 and 45 years old; 1 female 55 years old) participated in the study, each carrying out at least twelve experimental runs on different days. The subjects gave their informed consent before taking part in the experiments which were performed in accordance with the ethical standards of the 1964 Helsinki Declaration.

Results and discussion. As can be seen from the graphs in Fig. 2, there are individual variations of the illusion magnitude among the observers. However, for all three observers, the experimental curves obtained show a regular gradual decrease of the illusion magnitude with increasing vertical irregularity of the stimulus elements (i.e., with the width of *DB*). In order to evaluate quantitatively the parameters of the illusion magnitude changes, the experimental curves were fitted by the Gaussian function with the standard deviation σ (Formula 1):

$$Y(x) = a * e^{-0.5(x/\sigma)^2} + c, \quad (1)$$

where a and c are the coefficients, and x represents the width of *DB*.

A good resemblance between the computational and experimental data was obtained (Fig. 2, solid curves); the values of coefficient of determination R^2 were higher than 0.92 in all the cases. The values of σ's obtained in approximations of the data for stimulus made up of dots were 7.2±1.9, 5.8±1.9, and 8.0±2.6 arc min for subjects 1, 2, and 3, respectively; for the data obtained

with a figure formed of stripes, the corresponding σ values were 17.6±4.0, 27.1±9.6, and 25.2±5.9 arc min. In all three cases, the fitting results showed that the σ's for the stimuli with stripes was about 3 times larger than that for the stimuli with dots.

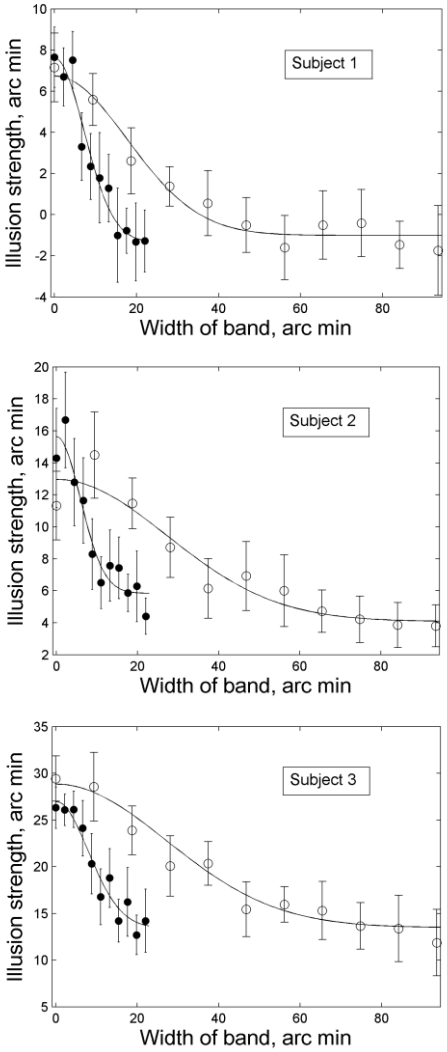

Fig. 2. The magnitude of the Oppel-Kundt illusion as a function of vertical irregularity of filling elements. The filling elements were stripes (open circles) or dots (filled circles). Solid lines, the least squares fitting by function (1). Vertical bars, confidence intervals (0.95). The data for three observers.

Based on the results obtained, we assume that there is a certain narrow region of spatial information integration in a close vicinity of the horizontal axis of the Oppel-Kundt stimulus, and that the width of this region is commensurable with the value of the standard deviation, σ of the Gaussian function obtained for the stimulus formed of dots. Then, the larger values of σ for stimuli with stripes can be explained by the fact that for relatively small widths of *DB* some alignment of the stripes' parts along the horizontal stimulus axis still remains.

The present results may weaken the role of the processes of contour integration in the Oppel-Kundt illusion emergence. However, further studies are obviously needed to clarify the issues.

Conclusion. It was demonstrated that misalignment of the filling elements significantly influences the magnitude of the Oppel-Kundt illusion. Such a result is consistent with the suggestion on the presence of some narrow area of spatial information integration about the horizontal stimulus axis.

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The present study is concerned with a role of the misalignment of the filling elements in the occurrence of the Oppel-Kundt illusion. The data of the psychophysical experiments demonstrated that the results obtained are consistent with the suggestion on the presence of some narrow area of spatial information integration about the horizontal stimulus axis.