Research of orientation characteristics of visual intersection illusion

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Abstract. During visual perception of an inclined line, partially passing behind an opaque object, an error (Poggendorff illusion) arises associated with an inadequate extrapolation of the line extension after its passing behind the object. The quantitative relations of the illusion values of displacement from the geometric and orientational parameters of the Poggendorf configuration are determined.

1. Introduction
The term “visual illusions” combines a wide range of phenomena, related to various aspects of visual perception and reflecting obvious errors in the estimation by the human vision system of any properties or spatial parameters of the objects under consideration-localization, size, shape, color, etc. In Great Soviet Encyclopedia, the concept of illusion is defined as in-adequate ideas about the perceived object that go beyond the usual errors of perception, mostly unconscious and not amenable to arbitrary correction.

A special place among all objects, that are visually perceived altered, is occupied by relatively simple flat images that create geometric illusions. Such illusions include systematic deviations of the geometry of the perception pattern from the objective parameters of the metric configuration under consideration. These deviations may relate to the estimation of the size or area of the figure, the slope or curvature of straight lines, the interposition of parts, proportions, etc. [1]-[3]. It is quite easy to perform the quantitative estimation of the geometric illusions and therefore they are widely used in engineering psychology to study visual perception [1]-[11].

Errors of sensory perception in the form of visual illusions have been known since ancient times, their study is associated with such names as Aristotle, Vitruvius, Lucretius. Systematic studies of visual illusions, resumed from the mid-19th century, led to the creation of many test images, demonstrating the steady presence of significant systematic errors in estimating the size and shape of geometric figures, and hypotheses about the nature of their occurrence. Most modern studies are aimed at confirming the existence of visual illusions and identifying groups of people most susceptible to these illusions [4]-[7]. Significantly fewer works contain studies of mathematical rules that determine the quantitative characteristics of visual illusions and the ways of their compensation [8]-[10].

For specialists of some professions, the influence of illusions on the result of their professional activity, based on visual estimations of metric characteristics, is very critical. In this regard, it seems
important to study the nature of visual illusions, their variability with respect to geometric factors, as well as the possibility of compensating for these illusions, providing a more adequate solution to professional tasks [10].

This work is devoted to an experimental study of the visual illusion of intersection (Poggendorff) arising from the strip intersection by a line. In case of the visual perception of an inclined line partially passing behind an opaque object, an error occurs, associated with inadequate extrapolation of the line continuation after its passing behind the object. In case when the line “passes” through the strip, its continuation moves in visual perception by a significant value (figure 1).

![Figure 1](image)

**Figure 1.** The scheme of the optical Poggendorff illusion.

The objective of the work was a qualitative and quantitative study of metric factors affecting the value of distortion of the intersection illusion and its intensity. Orientation factors were considered in this work following the research [10] and to determine the succession of the results, devoted to the influence on illusion of such well-known factors as the width of the screening strip and the inclination angle of the straight line.

2. **Methods**

To carry out the experiment, a selection of subjects of 30 people aged 17 to 25 years (students) was formed. The experiment was carried out on a computer in vivo, binocularly. During testing, the subject sat in the most comfortable position for working with the mouse, so that the monitor screen was at a distance of about 40-50 mm from his/her eyes. On the screen, a test object (TO) was presented to the subject, consisting of a strip with a given width (S) and an adjacent “input fragment” of a straight line at a given angle (α) of the relative strip. The test subject was asked to use the mouse to draw the “output fragment” of this line as its continuation behind the strip (figure 1). The program recorded the values of the variable of the resulting displacement (L). The subjects performed a series of tests, the data of which were averaged, for each of the values of the experimental parameters.

The experimental study was carried out in two steps:

1) the study of the dependence of the illusion L on the inclination angle of the line α and the strip S width;

2) the study of the value of the illusion L from the orientation (γ) of the entire test configuration.

The first step included two series of experiments: a) with various parameters of the strip S width at a fixed value of the inclination angle (α = 45°) of the input line; b) with various parameters of the inclination angle α of the input line at a fixed value of the width (S = 30 mm) of the strip. The range of values S varied from 10 mm to 60 mm (10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm), and the range of values α varied from 22.5° to 157.5° (22.5°, 30°, 45°, 60°, 90°, 120°, 135°, 150°, 157.5°).
The second step included a series of experiments with different orientation parameters $\gamma$ of the entire experimental construction at a fixed width ($S = 30$ mm) of the strip and fixed inclination angles ($\alpha = 22.5^\circ, 45^\circ, 67.5^\circ$) of the input line. The values $\gamma$ ranged from 0 to 360$^\circ$ of the strip orientation with a step of 22.5$^\circ$.

A total of 45 test objects were formed: 6 - to study the illusion depending on the strip width (figure 2a), 9 - to study the illusion depending on the inclination angle of the input line (figure 2b), 48 - to study the illusion from orientation of the test construction (figure 2c).

![Figure 2](image)

Figure 2. Variations of test objects for studying the dependence of the illusion $L$: a) on the strip $S$ width; b) on the inclination angle of the straight line $\alpha$; c) on the orientation $\gamma$

3. Results

The results are presented below in figure 3, 4. Figure 3a shows a graph of the dependence of the value of displacement $L$ illusion on the strip $S$ width for a fixed value of the line inclination angle $\alpha = 45^\circ$. The linear relationship estimation is confirmed by the $t$-criterion at the 5% significance level. The linear regression equation has the form: $y = -0.05 + 0.39$, i.e. we have: $L \approx 0.4S$.

![Figure 3](image)

Figure 3. a) illusion $L$ linearly depends on $S$, b) illusion $L$ nonlinearly depends on $\alpha$.

Figure 3b shows a graph of the dependence of the value of the illusion $L$ on the inclination angle $\alpha$ of the input fragment of the line at a fixed value $S = 30$ mm. The graph indicates a non-linear dependence of the displacement $S$ illusion on the inclination angle $\alpha$, i.e. with increasing sharpness of the inclination angle of the input fragment of the line relative to the strip, the displacement $L$ value increases disproportionately. In addition, the graph indicates the symmetry of the manifestation of the illusion $L$ with respect to the vertical inversion of the input fragment of the line. The data in this graph is approximated by a polynomial of degree 4.
Figure 4a shows the dependence of the displacement illusion $L$ on the orientation angle $\gamma$ in the range $0 \div 2\pi$ at fixed values of $S = 30$ mm and $\alpha = 22.5^\circ$. The above results show that the illusion exists in the entire range, but the value of the illusion $L$ substantially depends on the orientation angle $\gamma$. This dependence demonstrates $\pi/2$ periodicity, where the extremes of the value of the illusion are clearly expressed (4 max and 4 min). The illusion periodicity is observed within the range of $\gamma$: $0 \div 90^\circ$, from $90^\circ$ to $180^\circ$, from $180^\circ$ to $270^\circ$ and from $270^\circ$ to $360^\circ$, i.e., in accordance with the angular quarters of the coordinate plane. The maximum points are fixed at the boundaries of these periods when the TO rotation reaches the orientation at which the strip takes a horizontal-vertical position [11]. Moreover, in the vertical position of the strip, the value of the illusion $L$ is significantly higher than in the horizontal one.

![Figure 4](image)

**Figure 4.** The dependence of the illusion $L$ on orientation $\gamma$: $a)$ with fixed inclination angle $\alpha = 22.5^\circ$, $b)$ with different inclination angles $\alpha$.

Within each period, a minimum point is also fixed that characterizes the situation when a straight line [11] takes a horizontal-vertical position. Therefore, unlike the maxima, the minima of the illusion change their position depending on the given value of the angle $\alpha$ between the line and the strip (figure 4b). So, for $\alpha = 45^\circ$ (the average curve), the minima fall at the center of each period, while the dependence curve itself has a symmetrical shape (up to amplitude differences). The nature of the curve changes in all cases when $\alpha \neq 45^\circ$. In addition to this curve, figure 4b shows two more curves with different levels of average and ranges of amplitude variations, which corresponds to the above curve (figure 3b). The lower curve is obtained for $\alpha = 67.5^\circ$, and the upper one ($\alpha = 22.5^\circ$) repeats the amplitude-normalized curve in figure 4a. As opposed to the average curve, the upper and lower curves have minimal, shifted from the center to the boundaries of periods: for $\alpha = 22.5^\circ$ - towards the end, and for $\alpha = 67.5^\circ$ - towards the beginning of the period. The dependency curves themselves have an asymmetric form, inverted with respect to the center of the period. These are the main orientational characteristics of the illusion of intersection.

4. **Conclusions**

The performed study allows us to draw the following conclusions.

Between the width of the strip and the value of the displacement illusion, a direct proportional dependence is confirmed, the wider the shielding strip, the proportionally “brighter” the illusion appears. Between the sharpness of the deflection angle of the line from the shielding strip and the value of the displacement illusion, the inverse nonlinear dependence is confirmed: the smaller the angle, the greater the displacement coefficient. The manifestation of the displacement illusion is symmetrical with respect to the vertical inversion of the input fragment of the line.

Poggendorff illusion exists in almost any configuration of the intersection of a line with a strip. The dependence of the value of the illusion on the orientation factor has a quarter periodic asymmetric character, transforming for the $45^\circ$-th sharpness of the line into a symmetric one. As expected, the average level of the displacement illusion and the orientation range of its variations decrease with decreasing sharpness of the angle between the line and the strip.
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