Introduction. There are certain reasons to recognize the Müller-Lyer (M-L) and Oppel-Kundt (O-K) illusions as distinct phenomena. Firstly, the inducing stimuli differ in structure distinctly: flanking wings in the M-L figures, and filled/unfilled intervals in the O-K patterns. Secondly, the two illusions may differ in their origin. Irrespective of the presence of numerous controversial concepts, the M-L illusion tends to be related basically to the perceived positional shifting of the gravity centre of the excitation profile formed by stimulus terminals and distracters [5]; the O-K illusion, presumably, arises due to the spatial and temporal integration along associated excitation path elicited by the filling [4]. Moreover, the two illusions show different temporal dynamics: strengthening of the O-K illusion and weakening of the M-L illusion during the first 1000 ms of stimuli presentation [4].

However, some affinity between these two phenomena can be recognized: the illusions magnitude may reach 20 – 35% of the reference, both remain rather stable in a subject’s repetitive testing [1], and both vary among subjects due to the visual processing differences.

The aim of the present study is a further investigation of similarity and dissimilarity in the O-K and M-L illusions manifestation and variabilities.

Materials and methods. The modified stimuli possessing three spatial intervals [4] were taken for the psychophysical experiments (Fig.1). In the M-L figures (Fig. 1A and Fig. 1B), four pairs of wings, designated the three intervals. The wings (length, 34 arc min; internal angle, 90°) were formed of spots or line segments. The distance between the apexes of the wings in the lateral (referential) stimuli intervals was 90 arc min; in the medial (testing) interval, the distance between the apexes was adjusted by subjects. When the testing interval length altered, the referential intervals were moved without any structural and metrical changes. The shaft lines in the M-L figures were not present. In the O-K stimulus, two filled (referential) intervals (90 arc min in length) were situated on both sides of the medial empty (testing) interval the length of which was varied by subjects. The regular sequences of seven spots (Fig. 1C), or a horizontal line segment (Fig. 1D), or seven vertical stripes (66 arc min height; Fig. 1E) served as the fillers of the lateral intervals.

The spot diameter and line width in all stimuli was 2.2 arc min; luminance of the stimuli and that of the background were set to 55 cd/m² and 0.1 cd/m², respectively. The subjects observed the stimuli monocularly through an artificial pupil of 3 mm in diameter. No instructions concerning the gaze fixations during testing were given; the observation time was unlimited. The subjects adjusted the test interval to be perceptually equal in length to the
reference one, and the errors made were considered as the values of the illusion strength. Biases of the judgment criteria were reduced by randomizing stimuli with different parameters in the presentation sequences. For each stimulus, the subjects carried out four experimental sessions on different days with five trials outright (i.e., 20 trials for each data point).

Twenty nine observers, the University students, 20 – 30-year-old males and females took part in the study. They had no practice in such experiments before and were naïve in respect with the goals of the investigation. One of the authors completed the experimental program as well. The observers were normally sighted or were wearing their usual optical corrections.

**Results.** Experimental data on both illusions demonstrate a considerable inter-individual variability. The individual values of the M-L illusion arranged in an increasing rank order (Fig. 1A and Fig. 1B) show a rather wide dispersion of the length matching errors caused by two stimulus versions: 2%–38% of the reference for lines (Fig. 1B) and 4% – 43% for spots (Fig. 1A). One may conclude that the M-L wings formed of lines and those of spots elicit quite similar errors because their extremal values are nearly the same: 2.2 arc min and 3.6 arc min at minimum; 34.6 arc min and 38.5 arc min at maximum. Though the two rankings in Fig. 1A and Fig. 1B correspond to different observer orderings, twenty one observers (1, 2, 3, 5, 7, 8, 9, 12, 13, 14, 17, 19, 26, 20, 21, 22, 23, 24, 25, 28, and 29) appeared to be good enough to maintain rather close results (with difference not exceeding 3 arc min) for two different stimuli structures. The data from other nine subjects yielded significantly larger divergence (4–18 arc min) in the illusions strength.

Three O-K value rankings correspond to different subject ordering as well (Fig. 1C, 1D, and 1E). The observers’ judgments are evidently influenced by the stimulus structure, but at different extent. For instance, subject 11 shows similar illusion values concentrated within the 3 arc min interval, whereas the data for subject 10 are dispersed within the 10 arc min interval.

According to the data obtained (Fig. 1F), the O-K illusion for the stimulus with spots appears greater (by 2.2 arc min) than that for the stimulus with continuous lines (paired t-test, p<0.05). The illusion with the vertical stripes is still greater (by 3.7 arc min) than that with the horizontal line (paired t-test, p<0.05). The M-L illusion strength does not changes significantly (16.6 arc min and 16.2 arc min; paired t-test, p>0.05) when the stimulus with spots turns to that with lines. This is to say, the M-L and O-K stimuli formed of lines produce distortions similar in strength: 17.6 arc min and 16.6 arc min (paired t-test, p>0.05). The O-K stimuli with spots evoke stronger misperceptions than the M-L stimuli (19.8 against 16.2 arc min), but the difference is not significant (paired t-test, p>0.05). Only the O-K illusion caused by the vertical stripes is stronger than the M-L illusion (21.3 against 16.6 arc min; paired t-test, p<0.05).
Discussion. The present experimental findings demonstrate an extensive variability of strength of the two geometrical illusions. The errors vary among subjects from relatively small (2–3% of the referential distance) to quite large values (43–50%). A wide dispersion of subjects’ reaction to the M-L and O-K stimuli indicates that different factors influence the visual mechanism of size estimation during the length-matching procedure. Certainly, the perceptual responses depend on spatial filtering, integration along the continuous excitation paths, centroid extraction but can be corrected by signals from the higher-level mechanisms [6] and influenced by gaze fixation and attentional pooling [5], duration of observations [4], training, motivation, age, culture, and visual ecology [1]. One may assume that the side factors rather than the illusions’ proper inducers cause the wide dispersion of the experimental data.
The illusions strength variation is twice smaller for a subject individual data (Table. 1A) than for the inter-subject data (Table. 1B).

**Table 1.** Variation of the Oppel-Kundt and Müller-Lyer illusions’ strength. The data from Fig. 1.

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Line segment</th>
<th>Spots</th>
<th>Vertical stripes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: Individual</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O-K</td>
<td>4.2</td>
<td>4.6</td>
<td>4.5</td>
</tr>
<tr>
<td>M-L</td>
<td>4.3</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td><strong>B: Inter-individual</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O-K</td>
<td>9.5</td>
<td>10.5</td>
<td>10.4</td>
</tr>
<tr>
<td>M-L</td>
<td>9.0</td>
<td></td>
<td>10.4</td>
</tr>
</tbody>
</table>

In summary, all the data obtained (Fig. 1, and Table 1) demonstrate the two illusions of extent rather comparable at their minimum, maximum, and average values. The average of standard deviations and standard deviation of averages within each data set (Table. 1) are about the same.

**Conclusion.** The experimental results collected from thirty subjects refer both to certain rigidity in the underlying illusory mechanisms and to evident flexibility in the individual accomplishment of experiments, that makes the Müller-Lyer and Oppel-Kundt effects and their variabilities comparable.

**References**


**Müller-Lyer and Oppel-Kundt Illusions Compared**

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The modified Müller-Lyer and Oppel-Kundt stimuli possessing three spatial intervals were taken for psychophysical experiments in which subjects adjusted the length of the test interval (the middle one with inward wings or just empty) to be equal perceptually to that of the references (two lateral intervals with outward wings or fillings of spots, line segment, or stripes). The data obtained showed the two well-known illusions being similar in their manifestation stiles and variabilities.