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THE INFLUENCE OF MÜLLER-LYER ILLUSION ON LENGTH ASSESSMENT: THE ALTERNATIVE WAY OF MEASURING THE STRENGTH OF THE ILLUSION

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Abstract
Two experiments were conducted in order to investigate whether Müller-Lyer's illusion of two forms ("fork" and "arrowhead") influences the length assessment of a given line if they are used as a standard for measuring that line. The first experiment consisted of reproductive tasks in which respondents should asses the length of a given (test) line using lines with three types of endings (fork, arrowhead, or vertical) as measuring tools. The assessment of the test line length was expected to be dependent on the type of endings used on measuring lines. The result showed that the same given test line was assessed as consisting of a smaller number of lines ending with fork endings and a greater number of lines ending with arrowhead endings compared to the number of lines with vertical endings. The second experiment consisted of productive tasks in which the participant should produce the line consisting of the given number of connected lines with endings, the same endings from the first experiment were used. Results showed that participants produced the test line of the same given length as consisting of a smaller number of lines ending with fork endings and a greater number of lines ending with arrowhead endings compared to the same number of used lines with vertical endings.

Keywords: illusion, Müller-Lyer's illusion, length assessment

UTICAJ MILER-LAJEROVE ILUZIJE NA PROCENU DUŽINE: ALTERNATIVNI NAČIN MERENJA JAČINE ILUZIJE

Apstrakt
Sprovedena su dva eksperimeta kako bi se ispitalo da li dva oblika Miler-Lajerove iluzije („viljuška" i „vrh strele") utiču na procenu dužine linije koja je zadata ako se koriste kao standard za „merenje" te linije. Prvi eksperiment se sastojao od reproduktivnih zadataka u kojima ispitanik trebalo da proceni dužinu date (testne) linije koristeći linije sa tri tipa završetka („viljuška", „vrh strele" ili „vertikala") kao „merni alat". Očekivalo se da će procena dužine „testne" linije zavisiti od tipa završetaka koji se koristi na „mernim" linijama. Rezultat je pokazao da je ista zadata test linija procenjena kao da se sastoji od manjeg broja linija koje se završavaju „viljuškom" i kao sastavljena od većeg broja linija koje se završavaju „vrhom

strelice“ u poređenju sa brojem linija sa „vertikalnim“ završecima. Drugi eksperiment se sastojao od produktivnih zadataka u kojima je ispitanik trebalo da proizvede liniju koja se sastoji od zadatog broja povezanih linija sa završecima, korišćeni su isti završeci kao u prvom eksperimentu. Rezultati su pokazali da su učesnici reprodukovali test liniju iste zadate dužine kao sastavljenu od manjeg broja linija koje su se završavale „viljuškom“ i kao sastavljenu od većeg broja linija sa završetkom „vrh strele“ u poređenju sa brojem korišćenih linija sa „vertikalnim“ završecima. Rezultati eksperimenata idu u prilog pretpostavkama da su različiti mehanizmi odgovorni za iluzorni efekat u dvema formama Miler-Lajerove iluzije.

Ključne reči: iluzija, Miler-Lajerova iluzija, procena dužine

INTRODUCTION

The term illusion refers to the inaccurate perception of the properties of objects (events or sensory qualities) under the influence of contextual variables. It is important to note that essentially the same mechanisms that normally contribute to the correct perception of constant properties of objects lead to wrong perceptions of color, brightness, shape, size, etc. in inappropriate situations. If visual illusion produces a faulty perception of geometrical attributes (e.g. length, shape, or layout) of real objects or drawings, we refer to it as geometrical illusion. Müller-Lyer, Ponzo, and horizontal-vertical illusion belong to the class of geometrical illusion in which the size of the given line is perceived as being longer or shorter than it actually is. The Müller-Lyer effect is probably the best-known of the classical geometrical illusions since it was the subject of hundreds of studies since its introduction in the late 19th century (Müller-Lyer, 1889). The perceptual effect consists of two straight lines of the same length that appear to be different in length when they are terminated with arrowheads that extend inward or fork endings that extend outward.

Müller-Lyer (1889) published an optical illusion that has since become one of the most discussed examples in psychology. Brentano (1892) gave his own version and explanation of this illusion, but it seems, he was unaware of Müller-Lyer discovery since he wrote his paper without mentioning Müller-Lyer. From the beginning Brentano's solution met with severe criticism. Lipps (1892) and Auerbach (1894) argued against Brentano’s explanation. Numerous studies showed that the effect persisted if lines were terminated with a variety of other endings, and the illusory increase or decrease in length amounts up to 10% (Howe & Purves, 2005).

Gregory referred to the three-dimensional (depth) cues, as an explanation of the effect, so that the 2D <–> or >–< line endings are interpreted as drawings of 3D corners in linear perspective. Convex corners (closer to the observer) of the cube are represented by <–> junctions, while >–< junctions represent concave corners that are further from the observer (Gregory 1997; 1968). Apparent distances of these figures seem to have an impact on the perception of the inner line length, as predicted by Emmeret's law. This explanation is not complete because it can't explain the fact that some animals are also susceptible to an illusory effect (Van Heerden & Draaisma, 1992). Another common explanation refers to the assumption that we learned to correct variation of angular size when judging the absolute size of the object (Krueger, 1972). There is also the assumption that the anatomy of the eye and neural processing causes the effect (Bermond & Van Heerden, 1996). Nevertheless, some results of the fMRI studies go

in favor of the depth cue-based explanations (Weidner & Fink, 2007). Kohler and Fishback (1950) invoked the Gestalt psychology field principles in order to explain the Müller-Lyer illusion effect.

Since it was established that urban people differ from rural in susceptibility to the illusory effect, the so-called "Carpentered world hypothesis" is introduced. It states that illusion susceptibility is the consequence of inference habits acquired in the early visual environment (Ahluwalia, 1978; Segall, et al. 1963). Since the children from Western world are brought up in the visual world rich with edges, lines, and vertices they will be more susceptible to the Müller-Lyer illusion than the children brought up in rural communities in primitive cultures where there are no houses, streets, furniture with sharp edges and corners. This hypothesis was the subject of many experiments, and some of them didn't confirm it (McCauley & Henrich, 2006; Ahluwalia, 1978).

Numerous experiments were conducted in order to validate the perspective theory and her variants which refer to learning mechanisms and in the susceptibility to Müller-Lyer illusion. Some of these experiments were conducted on children of various ages from different parts of the world. An interesting finding is that susceptibility to the Müller-Lyer illusion decreases with increasing age and increases with the "carpenteredness" of the environment (Stewart, 1973). Although, Ahluwalia (1978) obtained different results regarding carpenteredness of the environment and since experiments were obtained in the same culture (Zambia) they are not in favor of the hypothesis that suggests that cross-cultural variations in susceptibility to Müller-Lyer illusion could be attributed to genetic factors, such as macular pigmentation (Pollack & Silvar, 1967).

Johnson and Jackson (1974) examined susceptibility to Müller-Lyer illusion in the group of children with normal IQ and IQ lower than average and found that only the variant in which arrowheads were pointing out changed in strength in the group of children with normal IQ between 8 and 18 years, which is inconsistent with explanations that both forms of illusion change in strength with increasing age and repeated exposure. These results are in contradiction to theories that assume that both forms of illusion change in strength with increasing age and repeated exposure. These results as well as those obtained earlier point to the important fact that two forms of Müller-Lyer illusion could be considered as induced by different mechanisms (Porac & Stanley, 1981; Porac, 1994).

Most of the illusion effect is due to form with fork endings (Gregory, 1968). The shaft length overestimation is typically larger in configuration with fork endings than the arrowhead endings shaft underestimation (Müller-Lyer, 1889; Pollack & Chaplin, 1964; Sekuler & Erlebacher, 1971). The two configurations are not equally resistant to ending alternations and their removal. The configuration with fork endings is less affected by variations in wing length, placement, or angle than the arrowhead configuration (Sekuler & Erlebacher, 1971).

Restle and Decker (1977) reviewed Heymans's (1896) and Fisher's (1970) findings in their paper and did some new measurements. They found that the apparent length of a test shaft with fork endings increases as the angle between the wing and shaft increases up to the limit of roughly 160°. There is a connection between the test shaft's apparent length and the wing length in the form of an inverted U function, which is strongest when the wing and shaft length are the same.

The authors note that all effects are roughly proportional to the shaft length, with the angle influencing a small area near the tip– approximately one-seventh of the shaft length. These findings align with results from earlier experiments. The experiments demonstrated that the strongest illusion occurs when the wings measure about 30% to 40% of the shaft's length. Additionally, the optimal angle between the wings and the shaft for maximum illusion strength falls between 10° and 30°. The illusion's strength notably diminishes when the angle exceeds 50°. In these studies, the shaft length was 75 mm, while the wings were 20 mm long (see Restle & Decker, 1977).
It was shown that Müller-Lyer illusion occurs also in touch, this kind of results shed new light on the previous theoretical interpretation of the Müller-Lyer illusion. This theoretical interpretation was based mainly on the data obtained by measuring the effects of this illusion on estimated length using the information from the visual domain (Mancini, et al., 2010; Mancini, Bolognini, et al., 2011).
The aim of the present study was to examine how the two forms of the Müller-Lyer illusion (fork and arrowhead) influence on the length assessment of a given line if they are used as a standard for measuring that line.

EXPERIMENT 1

Method; Participants

Thirty-two high school students (16 female; age *M*= 16.4375 years, *SD*= 0.9817) took part in the experiment as volunteers.

Material and procedure

Stimuli for this experiment were printed on papers whose dimensions were 21cm x 15cm. These papers were in landscape orientation and they were joined at one end to look like a notebook. Instruction for all tasks was printed on the first page, and each subsequent page contained three tasks, which were separated by a horizontal line. Each task consisted of two lines placed one below the other. The top line had no endings (test line), while the bottom line had one of three types of endings. The bottom line was terminated on both ends by either fork (>-<), arrowhead (<->), or vertical (|-|) endings. The angle between the wings and shaft for fork and arrowhead lines was 45°, and for lines terminated with vertical endings, the angle was set to 90°. In each condition, the length of all wings was set to 1\3 of the length of a given shaft. These parameters were set with the aim of achieving the maximum effect of Müller-Lyer illusion based on the results of the earlier experiments we briefly mentioned in the introduction.
The respondent's task was to assess how many lower lines (lines with endings) should be connected together in order to obtain a line as long as the top line and to write down the answer in the box located on the right side below each task. Respondents were instructed to use decimal values if they deemed necessary in any case (we will refer to this number as a multiplier). A total of eighteen tasks as there were in this experiment can be obtained as follows 3x3x2. As we saw there were three types of

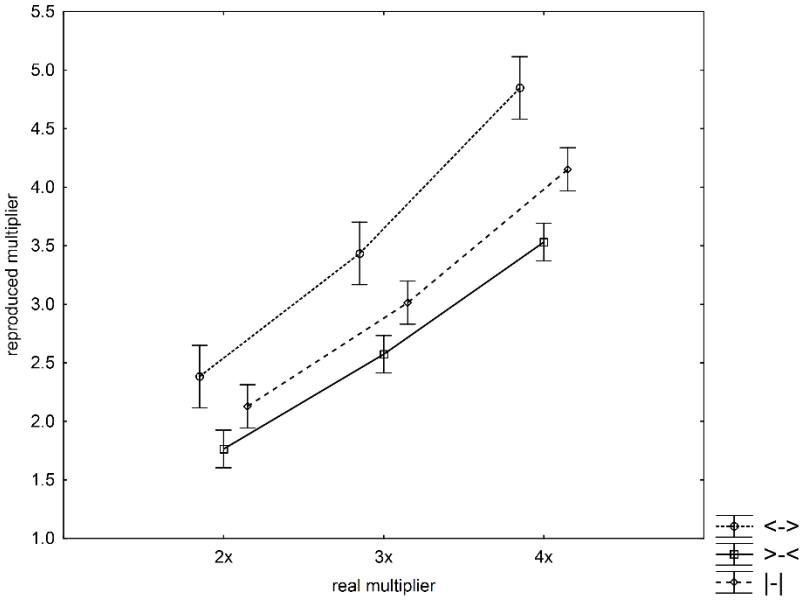
endings, in each task either 2, 3, or 4 lines with endings had to be connected in order to obtain a line as long as the test line, and 2 tasks for each combination.

Results

Data were organized and processed through a two-way within-subject ANOVA design. A significant main effect was found for the type of endings, F (2, 186)= 125.40, $p< 0.01$, and also for the multiplier, F (2, 93)= 144.06, $p< 0.01$. The two-way interaction was found to be significant, F (4, 186)= 6.18, $p< 0.01$. Figure 1 represents graphically the dependence of the reproduced multipliers (vertical axis) from the type of endings and real multiplier (horizontal axis) in reproductive tasks.

Figure 1.

Reproduced multipliers (vertical axis) and their dependence on the type of endings and real multiplier (horizontal axis) in reproductive tasks



EXPERIMENT 2

Method; Participants

The same participants from the first experiment participated in this experiment. It's important to mention that half of the participants initially took part in the experiment described above, while the other half participated in this experiment first.

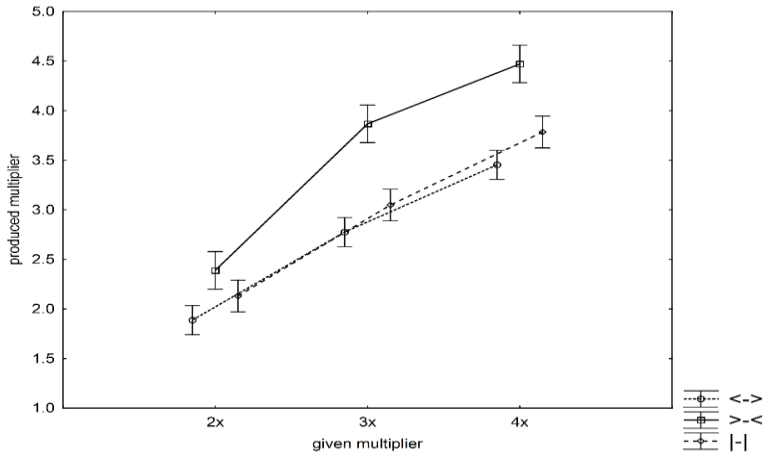
Material and procedure

Stimuli for this experiment were printed on papers of the same size and orientation as in the experiment described above. Instruction for all tasks was printed on the first page, and each subsequent page contained three tasks, which were separated by a horizontal line. Each task consisted of two lines placed one below the other. The top line (test line) had no endings, while the bottom line had one of three types of endings. The bottom line was terminated on both ends by either fork (>-<), arrowhead (<->), or vertical (|-|) endings. These lines were the same ones that we used in Experiment 1. Each test line was more than five times longer than the given bottom line.
In this experiment, the respondent's task was to produce the line by connecting a specified number of lines with endings. Respondent had to multiply the length of the line with endings with the number written in the box positioned below the task and mark that assessed length on the test line by placing a short horizontal line. The length of the line with endings should be multiplied by the number written in the box positioned below the task and that assessed length should be marked on the test line by placing a short horizontal line. A total of eighteen tasks as there were in this experiment can be obtained as follows 3x3x2. As we saw there were three types of endings, in each task either 2, 3, or 4 lines with endings had to be connected in order to produce a line as long as the test line, the number of tasks, and the overall layout of the experiment was the same as in the first experiment.

Results

In order to compare results of two experiments, the length of the lines produced was divided by the length of the lines with endings, and data obtained (analogous to multiplier from the first experiment) were organized and processed through two-way within-subject ANOVA design. Significant main effect was found for type of endings, F (2, 186)= 171.78, $p< 0.01$, and also for multiplier, F (2, 93)= 168.13, $p< 0.01$. The two-way interaction was found to be significant, F (4, 186)= 9.23, $p< 0.01$. The Figure 2 represents graphically the relationship between assessed (vertical axis) and real multipliers (horizontal axis) in productive tasks.

Figure 2. *Produced multipliers (vertical axis) and their dependence from the type of endings and real multipliers (horizontal axis) in productive tasks*



DISCUSSION

The main purpose of our study was to investigate whether two forms (fork and arrowhead) of the Müller-Lyer's illusion influence on the length assessment in reproductive and productive tasks. This kind of examination has not been reported previously and is one of the ways for measuring the illusion strength.

Experiment 1 showed that the assessed line length depended on the type of endings since a significant effect of the "endings" factor was obtained. The same given test line was assessed as consisting of a smaller number of lines ending with fork endings and as consisting of a greater number of lines ending with arrowhead endings in comparison to the number of lines with vertical endings, as it could be seen in Figure 1. The factor multiplier was also found to be significant. It can be seen from Figure 1 that given lines tend to spread for larger multipliers, in other words, participants make smaller errors in length assessment of the test line when it is consisted of 2 lines with endings, then when it is consisted of 3 or 4 lines with endings.

One-sample t-tests were conducted to determine whether the assessed length of the test line when vertical endings were used for assessment were statistically different from the real values (situation in which participants have known exactly from how many lines with endings the given test line consisted of). The results showed that there was no significant difference between these measures, so the length assessment using lines with vertical endings as standard seems very accurate and easy for the participants to accomplish. But, if lines terminated with fork or arrowhead endings are used as a tool for measuring the test line, the situation becomes much different and participants make underestimations or overestimations respectively. It is clear from the results displayed in Figure 1 that the fork endings have a stronger effect on length assessment than the arrowhead endings which is consistent with the previously obtained data (Meller-Lyer, 1889; Pollack & Chaplin, 1964; Sekuler & Erlebacher,

1971). The average effect, calculated on the basis of data from Experiment 1, was for fork endings 15.36% and the effect of arrowhead endings was 14.74% in comparison to vertical endings. The effect sizes were calculated as follows: first, we calculated the average assessments for all three kinds of endings, then, we subtracted the average assessments for fork and arrowhead endings from that for vertical endings, these differences were converted to percentages relative to the average assessment for vertical endings.

The results from Experiment 2 are, as expected, somewhat different. First of all, the productive task seems to be more difficult for participants than the reproductive task in Experiment 1. From Figure 2 it can be seen that multipliers are mostly shifted toward higher values, this means that participants tend to exaggerate their assessments when they produce a line of the given length. It is clear that the task in this experiment is less suggestive of correct answers than that in Experiment 1. It should be noted, also, that the distribution of lines on the graph in Figure 2 is different than in Figure 1, due to differences in tasks.

Experiment 1 showed that the assessed line length depended on the type of endings and the same conclusion can be drawn for Experiment 2. Participants produced the test line of the same given length as consisting of a smaller number of lines ending with fork endings and as consisted of greater number of lines ending with arrowhead endings in comparison to the same number of used lines with vertical endings, as could be seen on Figure 2. The factor multiplier was found to be significant and, as could be seen from Figure 2, given lines tend to spread for larger multipliers, in other words, the trend of making smaller errors in length assessment of the test line when it is consisted of 2 then from 3 or 4 lines with endings was kept, but lower than in Experiment 1.

Results from the Experiment 2 showed that the fork endings have a stronger effect on length assessment in comparison to the arrowhead endings. The average effect, calculated in the same way as in Experiment 1 was for fork endings 19.7% and the effect of arrowhead endings was 9.44% in comparison to vertical endings. These results differ from those obtained in Experiment 1, probably due to errors in assessments made in Experiment 2. However, this explanation is not fully supported by the data from one sample t-test comparisons drawn in order to verify whether the assessed length of the test line when vertical endings were used for assessment was statistically different from the real values. The results showed that there was no significant difference between these measures, meaning that participants were as good at producing lines of given lengths using lines with “vertical” endings as they were at reproducing the length using these lines as a “measuring tool”.

CONCLUSION

The main purpose of our study was to investigate whether two forms (fork and arrowhead) of the Mueller-Lyer’s illusion influence on the length assessment in reproductive and productive tasks. This kind of examination has not been reported previously and is one of the ways of measuring the illusion strength.

The results we described go in favor of theories that emphasize that different mechanisms are responsible for two forms of the Müller-Lyer illusion. Using two

forms of the Müller-Lyer illusion as measuring tools for length assessment in order to measure the strength of the illusion is, certainly, not the most elegant way to achieve this goal, but important fact is that the Müller-Lyer persists even in these conditions.

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REZIME

Miler-Lajerova iluzija je jedna od najstarijih, najpoznatijih i najistraživanijih geometrijkih iluzija. Pored velikog broja ekeprimentalnih istraživanja i brojnih proverenih hipoteza, još uvek nije dato celovito i zadovoljavajuće objašnjenje mehanizma koji je u osnovi pogrešnog opažanja dužine linija. Pouzdano je utvrđeno da iluzorni efekat opstaje iako su linije završene različitim tipovima završetaka, i da iluzorno povećanje, odnosno smanjenje, dužine linija u iluziji, mereno na različite načine, iznosi do 10%. U radu se prikazuju rezultati dva eksperimenta u kojim se na nov način mere snaga i osobine Miler-Lajerove iluzije.
Eksperimeti su sprovedeni s ciljem da se ispita da li dva oblika Miler-Lajerove iluzije („viljuška" i „vrh strele") utiču na procenu dužine linije koja je zadata ako se koriste kao standard za „merenje" te linije i da se na taj način izmeri jačina iluzije. U

eksperimentima je učetvovalo 32 učenika (16 ženskog pola, uzrast *M*= 16.4375 godina, *SD*= 0.9817), polovina ispitanika je prvo učestovala u prvom eksperimentu pa u drugom, dok je druga polovina ispitanika učestovala u eksperimentima obrnutim redom. Prvi eksperiment se sastojao od reproduktivnih zadataka u kojima ispitanik trebalo da proceni dužinu date (testne) linije koristeći linije sa tri tipa završetka („viljuška", „vrh strele" ili „vertikala") kao „merni alat". Očekivalo se da će procena dužine „testne" linije zavisiti od tipa završetaka koji se koristi na „mernim" linijama. Podaci koji su dobijeni obrađeni su upotrebom analize varijense za ponovljena merenja. Utvrđen je statistički značajan glavni efekat fakotra „tip završetaka" F (2, 186)= 125.40, $p< 0.01$, i faktora „umnožak" F (2, 93)= 144.06, $p< 0.01$, da je interakcija među faktorima statistički značajna F (4, 186)= 6.18, $p< 0.01$. Dobijeni rezultati pokazuju da ispitanici istu zadatu test liniju procenjuju kao sastavljenu od manjeg broja linija koje se završavaju „viljuškom" i kao sastavljenu od većeg broja linija koje se završavaju „vrhom strelice" u poređenju sa brojem linija sa „vertikalnim" završecima. Prosečni izračunati efekat iluzije bio je 15,36% za završetke tipa „viljuška" i 14,74 za završetke tipa „vrh strele".

Drugi eksperiment se sastojao od produktivnih zadataka u kojima je ispitanik trebalo da proizvede liniju koja se sastoji od zadatog broja povezanih linija sa završecima, korišćeni su isti završeci kao u prvom eksperimentu. Rezultati su pokazali da su učesnici reprodukovali test liniju iste zadate dužine kao sastavljenu od manjeg broja linija koje su se završavale „viljuškom" i kao sastavljenu od većeg broja linija sa završetkom „vrh strele" u poređenju sa brojem korišćenih linija sa „vertikalnim" završecima. Podaci koji su dobijeni obrađeni su upotrebom analize varijense za ponovljena merenja. Utvrđen je statistički značajan glavni efekat fakotra „tip završetaka" F (2, 186)= 171.78, $p< 0.01$, i faktora „umnožak" F (2, 93)= 168.13, $p< 0.01$, da je interakcija među faktorima statistički značajna F (4, 186)= 9.23, $p< 0.01$. Prosečni efekat iluzije bio je 19,7% za završetke tipa „viljuška" i 9,44 za završetke tipa „vrh strele". Rezultati eksperimenata idu u prilog pretpostavkama da su različiti mehanizmi odgovorni za iluzorni efekat u dvema formama Miler-Lajerove iluzije.