The Aftereffects of Visual Illusions (Ponzo and Müller-Lyer): Hand-Dependent Effects in Sensorimotor Domain

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Abstract. We examined the effects of perceptual set on Ponzo and Müller-Lyer illusions, revealing the existence of the illusory aftereffect in a sensorimotor domain. Our findings demonstrate that the effects of exposure to illusory stimuli in a sensorimotor domain are hand dependent and that there is a correlation between the direction of the aftereffect and the variant of illusion as well as a correlation between the speed of the hand movements over the neutral stimuli during test trials and the type of visual illusion shown during the exposure phase. The results support our hypotheses that: (i) the different illusions have their origins at different stages of the processing of visual information and (ii) effects of illusory perceptual set depend on hemispheric-specific mental representations, which might be activated by the movements of the right or the left hand.

Keywords: Ponzo · Müller-Lyer · Aftereffect · Sensorimotor domain

1 Introduction

Since Uznadze and Piaget, perceptual aftereffects have been investigated using pairs of stimuli that really differ from one from another at a perceptual set stage, e.g. different loads for right and left hand [1, 11]. However, eliciting stimuli that are equal to each other have rarely been used. Typically, the aftereffects of such stimuli were studied using verbal responses [8, 17]. More recently, Milner and Goodale have shown that the responses to visual illusions in the sensorimotor domain (e.g. using grasping tasks) are fundamentally different from the verbal responses due, the authors have claimed, to the activation of the dorsal rather than the ventral stream [13]. In our recent work [12] we have studied the aftereffects of Ponzo and Müller-Lyer illusions using a pointing task with just the right hand. However, the influence of the hand used (right or left) on the aftereffect is also of great interest because the movements sequences of the right hand

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are activated by regions of the left hemisphere in the brain, while the movements sequences of the left hand are activated by regions of both hemispheres [5]. Thus, the aim of the present study is to investigate the influence of the hand used on aftereffects in the sensorimotor domain.

2 Methods

One hundred participants took part in the study, all students of the St. Petersburg State University, with normal or corrected vision, right-handed, according to the Edinburgh handedness inventory [15]. They were divided onto ten groups: eight experimental and two control groups. Five of the groups of participants (four experimental and one control) executed the task using their right hand and five - their left hand.

Stimuli of the Ponzo illusions ((1) inverted version, (2) classical one) as well as stimuli of the Müller-Lyer illusion ((3) with outgoing fins on the lower shaft, (4) with outgoing fins on the upper shaft) were used (Fig. 1a, b, c, d). Stimuli of different shaft length (from 4.5 to 11.5 cm with a 1.5 cm interval) were presented ten times to the eight experimental groups during the exposure phase on the touch-screen. Different variants of the corresponding illusion types were shown to each of the eight different groups of participants. In exposure trials, the size of the shafts was varied to avoid a situation when participants remember the length of shafts. However, we expected the participants to produce the perceptual set with the general rule "longer-shorter".

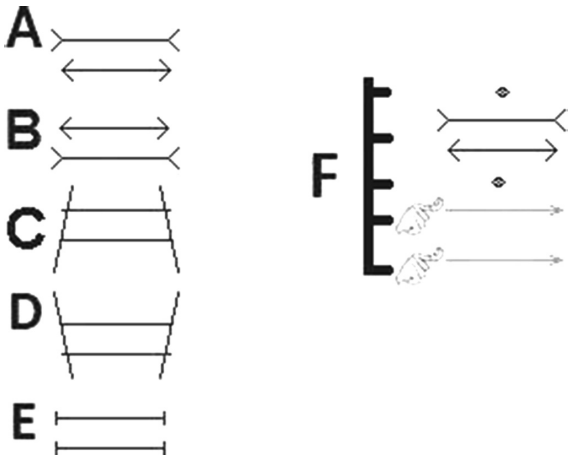

Fig. 1. Stimuli and methods

Neutral stimuli were demonstrated thirty times during the subsequent test trials. In addition it should be mentioned that the control groups observed the neutral stimuli (two equal length lines without flanks, 6 cm length) during all phases of the experiment. The equal length of these stimuli in all test trials allowed us to estimate the resistance of a perceptual set [9, 10].

The distance was 80 cm (between the touch screen and the participant). Each time, after disappearance of stimulus, participants were asked to track their hand across a touch screen to reproduce lengths of the each shaft of that stimulus. First, we asked them to track the hand along a top shaft. After that participants track the same hand along a lower shaft. Each participant moved his or her hand from left side to the right side, according to instructions (Fig. 1f). There was no feedback in the experiment. The start and the end points of a trajectory of their movements of the hand as well as the duration of each hand movement were monitored. As a result we could observe any deviation of the participant's visual perception of the neutral stimuli during the test trials.

We used the Mann-Whitney U test to measure the significance of the aftereffect sizes, as the responses were not normally distributed, and R2010b Matlab (version 7.11.0.584, Matworks Inc.).

3 Results and Discussion

In previous studies, we used the two illusions (Ponzo and Müller-Lyer) because they have similar visual effect (two lines of equal size look like different) but, according to some theoretical perspectives, they could have different mechanisms. The Ponzo illusion is classified as a "cognitive contrast illusion" while the Müller-Lyer illusion is classified as an "overestimation illusion" [3]. Our previous studies [6, 7] have revealed the existence of the effect of perceptual set in the sensorimotor domain for right hand movements.

The mean aftereffects in the present study are shown in Fig. 2. All values were expressed as the difference of the length of stimuli shafts (%). Comparing the results of the movements of the right hand, (that were examined in our previous studies [12]), with the results of movements of the left hand, it is necessary to point out that the number of illusory stimuli that cause a significant aftereffect differs. For the right hand movements, only the classical Ponzo illusion results in an aftereffect (positive and prolonged) that we can indicate as significant. For movements of a left hand, an inverted version, a classical version of the Ponzo as well as one version (outgoing fins on the upper shaft) of the Müller-Lyer illusions resulted in distortions to the motor responses of subsequently-presented neutral stimuli. The mean aftereffects were $7.14 \pm 0.81\%$, $9.04 \pm 0.94\%$ and $4.93 \pm 1.31\%$ respectively. For the left hand, only the participants of the control group and one experimental group (outgoing fins on the lower shaft) of the Müller-Lyer illusion failed to produce a significant aftereffect ($-0.89 \pm 0.64\%$ and $0.40 \pm 0.63\%$).

For the right hand, there were differences between the groups in the distribution of the hand movements speeds in test trials. The slowest hand movements were found after exposure to the inverted version of Ponzo illusion over neutral stimuli (their central parts). We need to mention, that the fastest hand movements were found also for neutral stimuli after exposure to (i) the classical version of Ponzo illusion and (ii) the neutral stimuli. The speed of the movements over neutral stimuli (their central parts) was found to be similar to each other after exposure to two different versions of Müller-Lyer

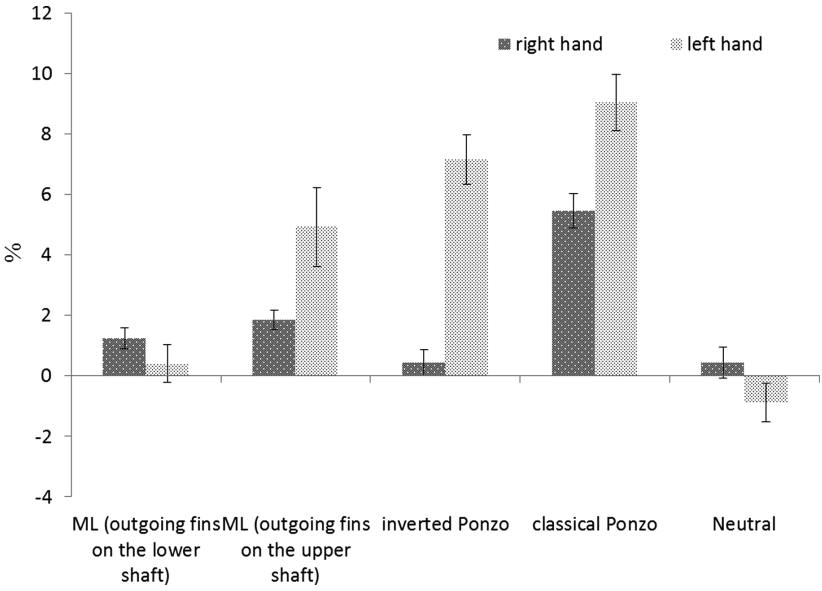

Fig. 2. The strength of the aftereffects for the right and left hands, %

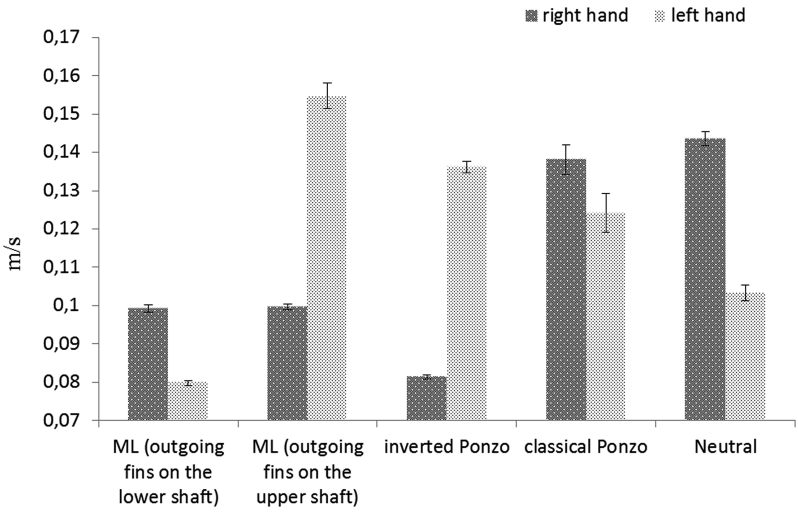

Fig. 3. The mean speeds of the right and left hand movements, m/s

illusion. In the same time it was faster significantly than the speed of the movements over the neutral stimuli after exposure to the inverted version of the Ponzo (Fig. 3).

For the left hand, the slowest movements over the central shafts were found after exposure to the Müller-Lyer illusion (outgoing fins on the lower shaft) (0,07 $\pm$ 0,012 m/s and 0,08 $\pm$ 0,001 m/s respectively), during both the acquisition trials and the test trials.

The fastest movements over the central shafts were found after exposure to the Müller-Lyer illusion (outgoing fins on the upper shaft) (0,15 ± 0,006 m/s; 0,15 ± 0,006 m/s). A similar difference in speeds during acquisition and test trials was found for the group exposed to the Ponzo inverted illusion (0,13 ± 0,007 m/s; 0,13 ± 0,005 m/s). Comparing these data with the speeds for the control group (exposed to the neutral stimuli), we conclude that exposure to both versions (inverted and classical) of the Ponzo and one version (outgoing fins on the upper shaft) of the Müller-Lyer illusion resulted in increases in the speed of movement of the left hand.

There was no difference in movements over the shafts (the upper part as well as the lower part) of neutral stimuli. This fact indicates the absence of any bias to the wrong estimation of the upper as well as of the lower parts of the stimuli by participants. In visual domain, visual illusions generally unaffected the sensitivities, such as just noticeable differences (thresholds) [14], which may be evaluated by looking at dispersion (variance) in the responses of the participants. All groups showed approximately equal SEs of estimate in case of the neutral stimuli as well as of the illusory effects, thus confirming the results of Morgan et al. (1990) in sensorimotor domain: exposure to an illusion has an effect on the lengths of movements of the hand and does not affect their dispersion.

During the presentation of the test stimuli movements of the hand were not planned feed-forward. Otherwise the speed of the hand movements did not depend on the stimulus variant. On the contrary the hand movements were under constant conscious control (the constant feed-back). Moreover, the speed of the hand movements during the test phase was influenced by the stimuli presented previously during the set stage. Here we suggest that for the simplest stimuli (neutral) used in the experiment the conscious control is minimal. And presumably the aftereffect is possible only in these cases.

Different patterns of aftereffect following exposure to Ponzo and Müller-Lyer illusions suggest that aftereffects may have originated at different stages of the processing of visual information. The clinical data showing a difference in strength of these two illusions in schizophrenic and autistic patients support this hypothesis. Persons suffering from schizophrenia for a short time were less inclined to show a Ponzo illusion and more inclined to show a Müller-Lyer one compared to subjects that had no history of mental illness [16]. The cognitive operations that underlie global processing in the Müller-Lyer illusion are different from those in the Ebbinghaus and Ponzo illusions, and these operations are affected in autism [2]. Also, in haptic domain, it is established that there is evidence for the existence of the Müller-Lyer illusion, but it is contradictory that there is the evidence for the existence of the classical version of the Ponzo illusion [4].

4 Conclusions

The results of our experiment show that prior exposure to both versions (classical and inverted) of the Ponzo and one version (out-going fins on the upper shaft) of the Müller-Lyer illusions for the left hand, and the prior exposure to the classical Ponzo illusion for the right hand result in distortions of the motor responses of

subsequently-presented neutral stimuli as well as in increases in the speed of hand movements for the correspondent cases.

Our findings demonstrate the existence of hand-dependent illusory aftereffect during motor response at visual illusions. The direction of the aftereffect depends on the variant of illusion, thereby defending our hypotheses that: the different illusions have their origins at different stages of the processing of visual information and the effects of illusory perceptual set depend on hemispheric-specific mental representations, which might be activated by the movements of the right or the left hand.

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References

1. Bjalava, I.T.: Psychology of Set and Cybernetics, 251 p. Nauka, Moscow (1965) (in Russian)
2. Chouinard, P.A., Noulty, W.A., Sperandio, I., Landry, O.: Global processing during the Muller-Lyer illusion is distinctively affected by the degree of autistic traits in the typical population. Exp. Brain Res. **230**(2), 219–231 (2013)
3. Coren, S., Girgus, J.S., Erlichman, H., Hakstian, A.R.: An empirical taxonomy of visual illusions. Percept. Psychophys. **20**, 129–137 (1976)
4. Gentaz, E., Hatwell, Y.: Geometrical haptic illusions: the role of exploration in the Müller-Lyer, vertical-horizontal, and Delboeuf illusions. Psychon. Bull. Rev. **11**(1), 31–40 (2004)
5. Grafton, S.T., Hazeltine, E., Ivry, R.B.: Motor sequence learning with the nondominant left hand. A PET functional imaging study. Exp. Brain Res. **146**, 369–378 (2002)
6. Karpinskaia, V., Lyakhovetskii, V.: The differences in the sensorimotor estimation of the illusions Ponzo and Müller-Lyer. Exp. Psichol. **7**, 3 (2014). (in Russian)
7. Karpinskaia, V., Lyakhovetskii, V., Allakhverdov, V., Shilov, Y.: The peculiarities of perceptual set in sensorimotor illusions. In: Cheng, L., Liu, Q., Ronzhin, A. (eds.) ISNN 2016. LNCS, vol. 9719, pp. 706–711. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-40663-3_81
8. Kasatov, A.P., Obvinceva, A.V.: Qualitative features of perceptual set, measured by estimation of the magnitude, and crossmodal selection. Psychol. Bull. Ural State Univ. **2**, 163–169 (2001). (in Russian)
9. Kostandov, E.A., Kurova, N.S., Cheremushkin, E.A., Iakovenko, I.A.: The role of unconscious sets formed on the basis of the perception of concrete visual stimuli and of illusory representations in conscious cognitive activity. Zh. Vyssh. Nerv. Deiat. Im. I. P. Pavlova **48**(3), 438–448 (1998). (in Russian)
10. Kostandov, E.A.: Formation of the perceptual set on the basis of illusory representations and at perception of concrete visual stimuli. Hum. Physiol. **25**(1), 5–14 (1999). (in Russian)
11. Leontiev, A.N., Zaporogec, A.V.: The Restoration of Movements, 231 p. Soviet Science, Moscow (1945). (in Russian)
12. Lyakhovetskii, V., Karpinskaia, V.: The aftereffects of Müller-Lyer and Ponzo illusions: differences revealed in sensorimotor domain. Proc. Latvian Acad. Sci. **71**(5), 352–358 (2017)
13. Milner, D., Goodale, M.: Visual Brain in Action. Oxford University Press, Oxford (1995)

14. Morgan, M.J., Hole, G.J., Glennerster, A.: Biases and sensitivities in geometrical illusions. Vis. Res. **30**(11), 1793–1810 (1990)
15. Oldfield, R.C.: The assessment and analysis of handedness: the edinburgh inventory. Neuropsychologia **9**, 97–113 (1971)
16. Shoshina, I.I., Perevozchikova, I.N., Konkina, S.A., Pronin, S.V., Shelepin, Iu.E., Bendera, A.P.: Features of perception of length of segments under conditions of Ponzo and Müller-Lyer illusions in schizophrenia. Zh. Vyssh. Nerv. Deiat. Im. I.P. Pavlova **61**(6), 697–705 (2011). (in Russian)
17. Valerjev, P., Gulan, T.: The role of context in Müller-Lyer illusion: the case of negative Müller-Lyer illusion. Rev. Psychol. **20**, 29–36 (2013)