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The Differences of Sensory and Motor Evaluations of the Müller-Lyer and Ponzo Illusions[1]

Отличия сенсорных и моторных оценок иллюзий Мюллера-Лайера и Понзо

Abstract

This experiments were designed to measure sensory and motor size judgements of the Müller–Lyer, the Ponzo and the Trapezoidal illusion. The touch screen was used to record the movements of the right and the left hands when the participants estimated the length of the horizontal lines in illusory context or without illusion. There were two types of tasks: memorization and reproduction. There was an illusory effect for movements of both the right and left hand, but there is less of an illusory distortion when the left hand was used. The explanation could be that different systems of representation are involved in the process underlying size estimation using the right and the left hands: based on a metric system of representation in the right hemisphere and a categorical representational system in the left hemeisphere.

The size of the Müller-Lyer and Ponzo effects are different in memorization and reproduction tasks. The Müller-Lyer illusion exists in both situations whereas the Ponzo illusion generally exists only in reproduction task. This suggests that the two illusions have different underlying mechanisms.

Аннотация

Проведенные эксперименты были предназначены для регистрации сенсорной и моторной оценки иллюзий трех видов: Мюллера-Лайера, Понзо и трапециевидной иллюзии. Сенсорный экран использовался для регистрации движений правой и левой руки испытуемых, перед которыми была поставлена задача оценить длину горизонтальных отрезков в иллюзорном контексте и вне действия иллюзии. Использовалось два типа задач: на запоминание и на воспроизведение. Иллюзорный эффект был выявлен при движении обеих рук, но при использовании левой руки иллюзорных искажений было меньше. Объяснение может заключаться в том, что в процессе, лежащем в основе оценки размера, участвуют различные системы представления при использовании правой и левой руки: основанная на метрической системе представления в правом полушарии и категориальная репрезентативная система в левом полушарии.

Величина иллюзорных эффектов Мюллера-Лайера и Понзо отличается при запоминании и воспроизведении. Иллюзия Мюллера-Лайера существует в обеих ситуациях, тогда как иллюзия Понзо преимущественно проявляет себя в задачах воспроизведения. Это позволяет говорить о том, что указанные иллюзии имеют в своей основе разные механизмы.

Keywords: sensory and motor size judgements, Müller-Lyer, Ponzo, right and left hand

Ключевые слова: сенсорная и моторная оценки, Мюллер-Лайер, Понзо, правая и левая рука

Introduction

Numerous psychological and physiological studies have investigated the human ability to estimate size. One technique that has been used extensively to study size perception is to look at the errors that occur when a person compares identically-sized objects. The errors that are produced in an illusory situation represent a special case of this technique. The effects of these visual distortions emerge immediately; they are vivid; they remain virtually unchanged through replications; and they are revealed almost identically to everybody who has ever observed them – some lines appear elongated, others appear shortened, the still others bent or even shifted. The assessment of illusory size is not always unambiguous and often varies according to the test conditions. Some studies have demonstrated a significant improvement (towards veridicality) in size judgments during the motor evaluation of the objects where visual control was eliminated. (Milner, Goodale, 1995). In addition, a number of recent studies have investigated the characteristics of grasping movements for the component parts of different visual illusions (ex. Kaniza, Müller-Lyer, Ponzo) (Bruno, Bernardis, 2003; Franz, 2003; Stottinger, Pfusterschmied, Wagner, Danckert, Anderson, Perner, 2012).

Is the discussion about distinct visual systems for perception and vision for action still alive? In one of the first studies, Aglioti made video-recordings of participants grasping the central segments of the Titchener illusion (Aglioti, DeSouza, Goodale, 1995). They showed that the distance between the fingers of the hand approaching the figure was identical and was not subject to the typical illusory distortion. Since that time, various experiments have been carried out to demonstrate a dissociation between visual judgements and motor perception based on a number of different illusions. In addition, there has been the criticism of using visual illusions as an appropriate tool to investigate the dissociation (Schenk, McIntosh, 2009; Franz, Gegenfurtner, 2008; Stöttinger, Soder, Pfusterschmied, Wagner, Perner, 2010). Stottinger et al. (2010) has identified five requirements for any experiment that aims to provide a reliable demonstration of the dissociation of

action and perception using visual illusions. We should mention that the majority of previous experiments have used grasping as the method of size estimation. Bruno and Franz (Bruno, Franz, 2009) have criticized such experiments and suggested that the perceptual and motor effects of the illusion differ only because of involvement of online, feedback-driven corrections and, as a consequence, they do not provide support for the idea of independent spatial representations for vision-for-action and vision-for-perception.

Do these effects depend on the particular procedures used and the particular illusion or does is there some general effect in the motor estimation of visual objects as revealed by Creem and Proffitt's experiments (Creem, Profffitt, 1999)? In Franz's experiments, he compared manual size estimation, grasping and perceptual (adjustment) estimation. His results did not show the difference between vision and motor perception in the tasks of grasping and perceptual adjustment. Grasping also shows the illusory effect, contrary to the findings, that were described by Milner and Goodale (1995). Moreover, the manual estimation of size showed larger Ebbinghaus-Titchener effect than either grasping or perceptual adjustment.

Creem and Proffitt demonstrated that considerably more accurate evaluations (that were totally independent of the subjective state at the time) could be obtained by requesting the participants to adjust a mobile platform with their hand or foot, "by sight" (but excluding the visual control of movements, as such) to a position that was approximately equal to the slant of a hill. The importance of excluding visual control was also mentioned by Milner and Goodale (1995).

It is really surprising that motor estimation without visual control is more precise? Is it really so? It may be possible that when the participant is not viewing his/her hand, he/she is deprived of the additional monitoring and self-evaluation of actions. Extensive research in the field of implicit learning has demonstrated that the lack of conscious control in the acquisition of skills, learning, and problem-solving often leads to better results (Moroshkina, Gershkovich, 2008). The same

experiments have confirmed that inclusion of an additional cognitive load (an additional task) when performing basic tasks can improve the chances of solving the main problem (Allakhverdov, 2003). When the main task is not particularly complicated for the tested subject, conscious control may lead to poorer results. It follows that the inclusion of a more complicated incidental task may lead to a shift of conscious control from the main to the additional task. As a consequence, the main task is performed automatically, which produces better results.

To explore this phenomenon we modified the experiments and used three different illusions – the Müller-Lyer, the Trapeze and the Ponzo illusions – and two conditions for the tasks. The Müller-Lyer illusion was chosen as it was described in Milner and Goodale publication. The Trapeza and Ponzo illusions were chosen because these illusions also have the similar perceptual consequence – two equal length lines look different – and we wanted to compare the strength of the illusory effect using different configurations. Rather than using a grasping task, we asked participants to estimate the length of the lines by moving the finger across the touchscreen and compared the length of the lines on the screen with the length of the lines that the participant traced out on the touchscreen.

In the first condition, the participants estimated the length of the lines by looking at them. The lines were presented on the screen with the touchscreen *either* on the table *or* under the surface of the table, so that the participant could not control the movement of his/her hand with his/her eyes (Karpinskaia, Lyakhovetskii, 2013). In the second condition the lines were presented on a screen with a touch surface, so that the participants could move his/her finger along the lines. In this condition, he/she had to memorize the length of the line by moving his finger along the lines and immediately reproduce the length of the lines on the white screen, after the lines had disappeared. We also recorded the differences in performance for the participant's right and left hands. Previous research has shown that the results for the right and the left hand can be different. Moreover, there are hemispheric-specific subsystems difference in the systems of representation in the

left and the right hemisphere (Lyakhovetskii, Bobrova, 2009; Bobrova, Ljahoveckij, Borshhevskaja, 2010). It has been argued that right hemisphere is specialized for metric judgments and the left hemisphere for categorical categorical judgements. As a consequence, using the left and right hands might involve different systems of representation.

Method

Pilot experiment

This experiment was designed to measure sensory and motor size judgements of (i) the Müller–Lyer, (ii) the Ponzo and (iii) the Trapezoidal illusion as well as control stimuli consisting of two horizontal lines of equal length. A version of the Müller-Lyer illusion in which upper line looks larger was used (Figure 1a). In the Trapezoidal illusion, the target lines were two lines: the upper line in each figure (Figure 1d). The stimuli were presented on the screen. The length of horizontal lines was either 70, 100 or 150 mm in separate trials. A touch screen was used to record the movements of the hands when the participants estimated the length of the lines. During the presentation of each stimulus, the participant moved his/her finger (using either the left or right hand) along the touch screen, first along upper shaft and then along lower shaft (from the right to the left for left hand, or from the left to the right for the right hand).
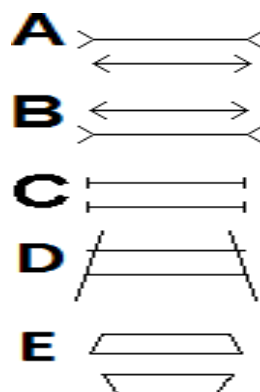

Figure 1 – The "illusory" line configurations: a, b, d and e; and "control" line configuration: c

The experiment was performed without feedback. Four groups of right-handed participants participated in the experiment, eight participants in each using an independent subjects design. The dominated hand was determined using Oldfield's procedure (Oldfield, 1971). Participants in the first two groups ('Visual control' conditions) had the touch screen on the table and saw their working hand during the trials. Participants in the third and fourth groups ('Without visual control' conditions) had the touch screen under the table and they had to move their hands under the table, so that they could not see the touch screen or their hands. Participants in the 'Visual control' and 'Without visual control' conditions were further sub-divided into two groups (two groups started the task using their left hand (Visual control, Group L; Without Visual Control, Group L), and two groups started with their right hand (Visual control, Group R; Without Visual Control, Group R). The instruction to participants was: "On the screen you will see two horizontal lines which may appear to be of different sizes. The two lines will appear together with the vertical lines, shafts included in figure, or without any context. You should reproduce the length of the line with your finger by moving your finger over the touch screen. Please, reproduce the length of each line as you see it on the screen. Reproduce the upper line first and the lower line second. Move your hand from left to right, when moving your right hand, and from right to left, when you moving your left hand." The Euclidean distance between starting and end points of touch was extracted. Then the difference between lengths of upper and lower lines was calculated. The significance of illusory effect were measured with the help of Mann-Whitney criterion, because the analyzed variables (strength of illusion) are not normally distributed.

Table 1 – The results of sensorimotor evaluation of stimuli length. All the bolded differences are significantly different from zero

Stimulus\Group	Visual control				Without Visual Control			
	Group L		Group R		Group L		Group R	
	LH, mm	RH, mm	LH, mm	RH, mm	LH, mm	RH, mm	LH, mm	RH, mm
Ponzo	**24,4**	*15,1*	9,7	**13,6**	**15,6**	**23,5**	**13,3**	**20,6**
Muller-Lyer	**14,2**	*15,2*	**16,7**	**10,4**	4,4	**12,7**	**19,2**	**21,5**
Neutral	0,4	4,5	2,0	-2,0	6,5	**5,9**	-3,6	0
Trapezoidal illusion	**15,29**	**13,12**	**18,92**	**12,41**	**14,33**	**16**	5,375	**12,46**

The results (Table 1) show the overall existence of illusory effect – the volunteers overestimated upper line of the stimulus (i.e. all the average differences were positive). It is worth noting that the effect is somewhat weaker for the left hand. Note that the illusory effect is absent for Ponzo illusion for left hand movements in Visual control, Group R, and for Muller-Lyer illusion Without visual control, Group L; for Trapezoidal illusion in Without Visual Control, Group R, left hand. Second, all illusory effects for the group without visual control conditions were significantly smaller for left hand than for the right hand. It is important to mention that we found a significant difference from zero for neutral stimuli in only one group (Without visual control, Group L, RH). The results correspond to the findings of Franz, who showed the illusory effect not only for vision and adjustment, but also for grasping and manual estimation.

In general, the results did not show that the illusory estimation of length using a motor task without visual control is more veridical than with such control. However, this could be the consequence of the procedure: the screen and the touch screen had different orientation.

As a consequence, the conditions were changed for the second experiment for two reasons. First, we no longer used the Trapezoidal illusion because it has four horizontal lines and we could not be sure, that the participants based their responses on the correct lines. Second, the procedure was changed: the lines were presented on the screen which was touch sensitive so that the participants could

move their fingers along the lines. Hence, if the difference in the orientation of the screen for displaying the lines and the touch surface for recording the motor reproductions of the lines plays role, we could eliminate that difference. To make the conditions without visual control stronger, we also asked participants to perform the task with closed eyes.

Main Experiment

In Experiment 2, we analyzed the memorization and the immediate reproduction of hand's movements along the horizontal lines for the Ponzo and the Müller-Lyer illusions. Three types of stimuli were used: (i) the shaft flanked by outward-pointing (<>) and inward-pointing (><) arrows evoking the Muller-Lyer illusion, (ii) the shaft flanked by straight cuts (control stimuli) and (iii) the shaft without any flanks in Ponzo illusion. Forty stimuli were presented on a monitor screen located at 60 cm in front of the participant in random order. The shaft's length was either: 5cm, 6.6 cm, 8.3 cm or 11.6 cm. For the presentation of each stimulus, the volunteer led his hand (the left hand or right hand) along the sensory screen that was located directly in front of the monitor, first along upper shaft and then along lower shaft (from right to left or from the left to the right). This constituted the memorization phase. After the participant had finished his/her movements, the stimulus disappeared and participant had to immediately reproduce the length of two shafts on touch sensitive screen. This constituted the reproduction phase. The experiment was performed without feedback. Each participant had two tasks for each of the twenty presentations in each (for right and left hand). In the first task, the eyes of the participant were open during the reproduction phase. In the second task, the eyes were closed during the reproduction phase. We determined the start and end points of the shafts using the touch screen outputs. The coordinates of the points were used to calculate the strength of the illusion, which was calculated, as in Experiment 1, from the difference between the length of the upper and the lower shaft. Two groups of

right-handed volunteers participated in experiment. The dominant hand was determined using Oldfield's procedure (Oldfield, 1971). The ten participants in Group R first performed the task using the right hand and then using the left hand. The ten participants in Group L – vice versa. Group R participants first performed the task using their right hand with their eyes open, before they performed the same task using their right hand with their eyes closed. Afterwards, the participants performed the same task using their left hand with their eyes open, before performing the same task using left hand with their eyes closed. Group L participants first performed the task using their left hand with their eyes open, before performing the same task using task using their left hand with eyes closed. Afterwards, the participants performed the same task using their right hand with eyes opened, before performing the same task using their right hand with eyes closed.

Prior to the start of the experiment the participants were instructed as follows: "On the screen you will see two horizontal lines which may appear to be of different sizes. The two lines will appear together with the vertical sections, angles and lines. Your task is to trace the lines on the touch screen with your index finger as precise as possible, marking the starting and the end points of the section. Please, reproduce the length of each line as you see it on the screen. Reproduce the upper line first and the lower line second. First, move your finger along the upper line before moving it along the lower line. The right hand movement should proceed in a left-to-right direction. The left hand movement should proceed in a right-to-left direction. Next, the experimenter will press a key and a blank screen will appear. You are requested to reproduce the lines on the touch screen from memory. There will be no feedback until the end of the experiment."

Results

Memorization Phase

Analysis of the results shows that the participants experienced a significant Müller-Lyer illusion during the 'memorization' phase despite the fact that they could see both their hands and the lines as they traced out their lengths. However, there was no comparable effect with the Ponzo illusion in the 'memorization' phase (Figure 2).

Figure 3 shows that there was an illusory effect in all the trials with Muller-Lyer illusion, in which the lower line appeared to be longer (all 4 trials for Group R participants, and for 3 out of 4 trials for the Group L participants). There was no any difference between the results for the lower and upper lines for the control stimuli with no arrowheads. (Figures 2 and 3)
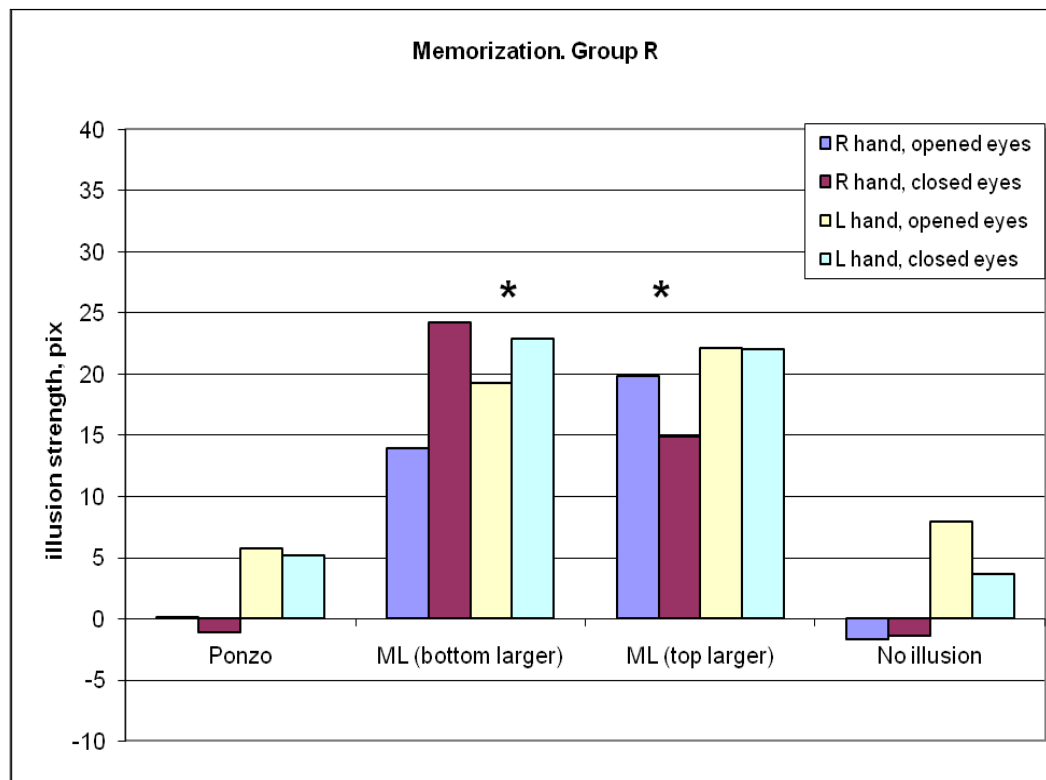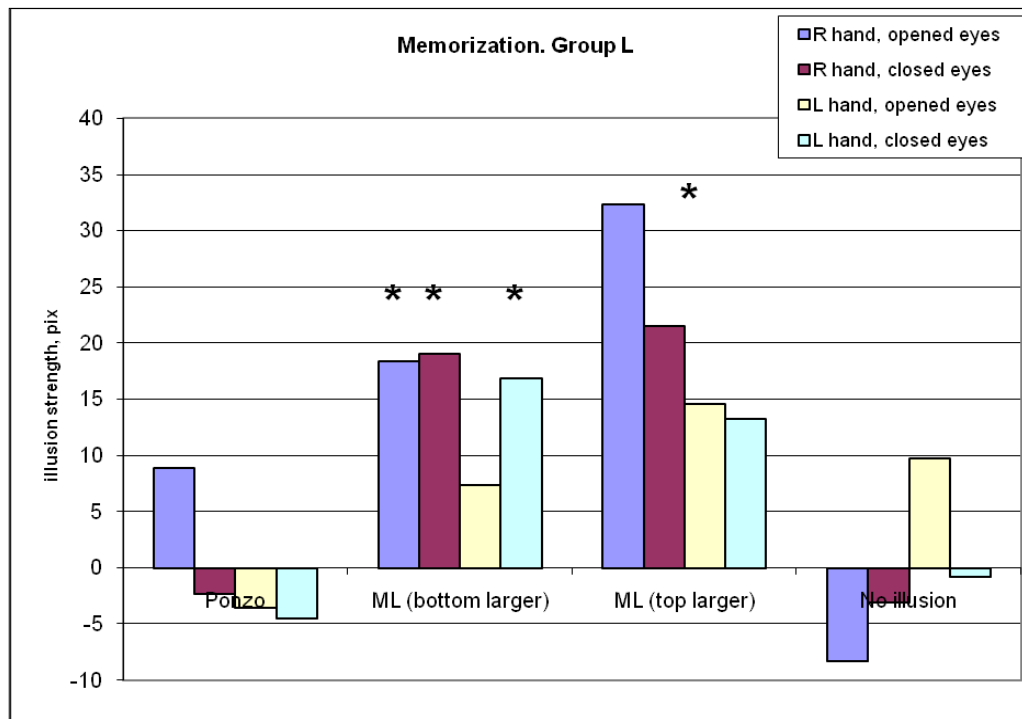

Figure 2 – Memorization, Group R

Figure 3 – Memorization, Group L

During the 'reproduction' phase, at least one of the variants of the Müller-Lyer and the Ponzo illusions (Figures 4 and 5) produced an illusion in all four tasks for the Group R participants. Similarly, the Group L participants experienced at least one of the variants of Müller-Lyer illusion in all four tasks. However, the Ponzo illusion was only evident in the two conditions: "left hand with eyes open", and the "right hand with eyes closed". This leads us to speculate that the Ponzo and Müller-Lyer illusions are influenced by hemispheric-specific characteristics of visual processing at the *different* levels of visual system.
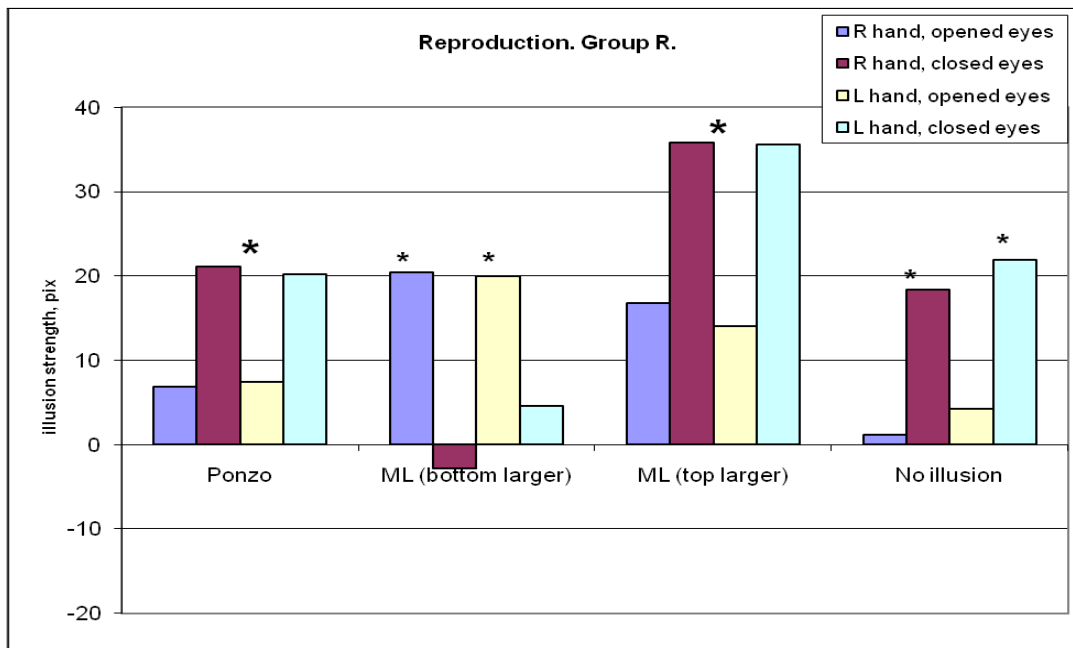
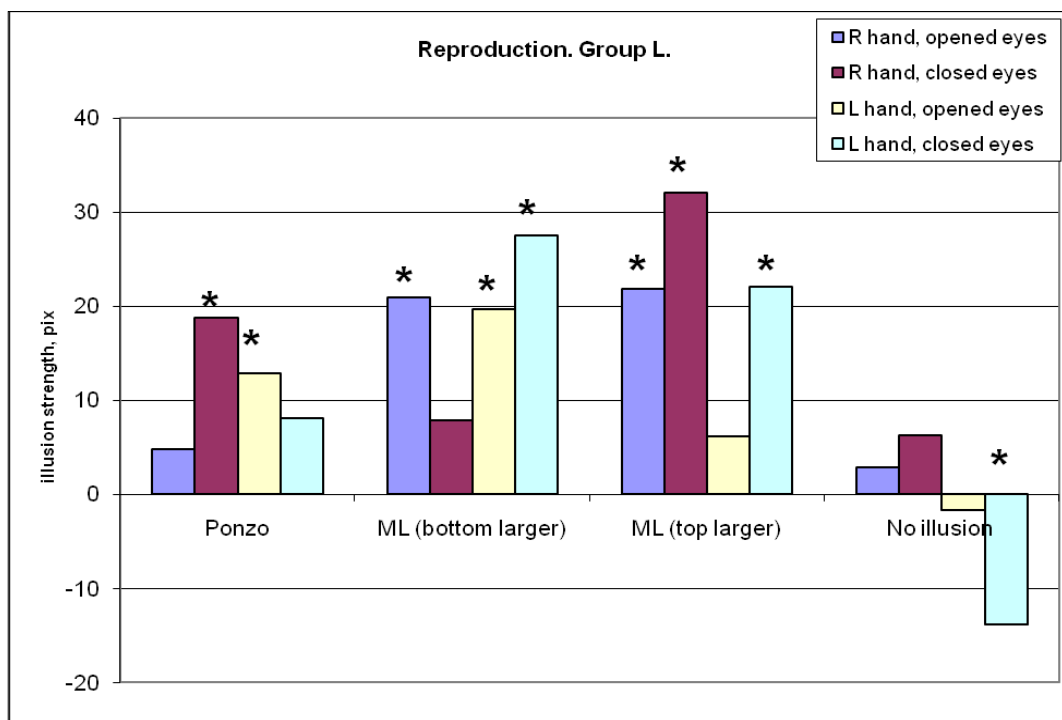Figure 4 – Reproduction, Group R

Figure 5 – Reproduction, Group L

In addition, we found that only the Group R participants showed a significant positive correlation between the strength of Müller-Lyer illusion and Ponzo illusion (Table 2).

Table 2 – Correlations between strengths of the Muller-Lyer and Ponzo illusions. Memorization phase

	Left hand, eyes open	Left hand, eyes closed	Right hand, eyes open	Right hand, eyes closed
Group R				
Müller-Lyer illusion (upper shaft appearslonger)/Müller-Lyer illusion (bottom shaft appears shorter)	0.46	-0.06	0.25	-0.19
Müller-Lyer illusion (upper shaft appears longer)/Ponzo	0.57	0.73*	0.51	0.69*
Müller-Lyer illusion (bottom shaft appears longer)/Ponzo	0.23	-0.03	0.32	-0.19
Group L				
Müller-Lyer illusion (upper shaft appears longer)/Müller-Lyer illusion (bottom shaft appears shorter)	-0.06	-0.65*	0.10	-0.68*
Müller-Lyer illusion (upper shaft appears longer)/Ponzo	0.92*	0.46	0.78*	0.77*
Müller-Lyer illusion (bottom shaft appears longer)/Ponzo	-0.01	0.10	0.09	-0.77*

For the Group L participants, we found both positive correlations and statistically significant negative correlations between the strengths of the Muller-Lyer and Ponzo illusions, and between two types of Muller-Lyer illusion. It is possible that these differences in the correlations were the result of a different type of perceptual set (assimilative or contrast).

Overall, some 50% of the stimuli produced the illusion of over-estimation of the upper shaft and only 25% of the stimuli produced the illusion of over-estimation of the lower shaft. This asymmetry of stimuli was responsible for the emergence of a perceptual set, based on the illusion. As a consequence, the participants also made systematic errors during the reproduction of the shaft lengths of neutral stimuli (Figure 1c). This type of set was different for the R and L

groups. A contrast perceptual set was found in the Group L participants for the "left hand with eyes closed" task where the participants overestimated the *lower* shafts of the control stimuli. An assimilative perceptual set was found in the Group R participants for the "right or left hand with eyes closed" tasks, where the participants overestimated the *upper* shaft of the control stimuli.

Discussion

The experiments described in this paper were designed to answer two questions: (1) Is the estimation of line length using a motor task always more veridical than a visual estimation? (2) Does visual control of length estimation using a motor task lead to fewer mistakes and less effectiveness? The first experiment showed that the estimation of line length using a motor task shows an illusory effect. Our participants made illusory mistakes and therefore our results differ from those described by Aglioti et al. (1995), Milner and Goodale (1995) or Stottinger et al. (2010, 2012). Our results support the view that illusory effects exist for both perceptual and motor estimation.

It is important to mention that the use of the left hand to reproduce line length was more effective and gave more veridical results than the use of the right hand. Either there was no illusion for the left hand in several trials or the illusory effect was weaker, compared to the right hand. This could be explained as the difference in the systems of representation in the left and the right hemisphere. These hemispheric-specific subsystems could be differentially activated when the participant uses his or her right or left hand to make sensorimotor judgments. The systematic error (i.e. the strength of the illusion) was smaller for the left handed reproductions, the motions of which are governed not only by the left but by the right hemisphere as well. The use of the right hand involves mechanisms that are used for coding of ordered structure of the memorized motions sequence whereas the use of the left hand also involves the coding of the positions of the motion's goals. In this case, it is likely that a metric system of representation prevails and

this leads to a more precise estimation of the line length. Motions of the right hand, on the other hand, are governed by the left hemisphere. In this case, the categorical spatial system of inner representations may be devoid of such a system of exact measurement. At the same time, the assignment of presented stimuli to a certain category suggests that consciousness may be involved in the given process. It also means that there will be an additional controlling system when making the decision on how the object is to be estimated. A categorical system implies conscious control to a greater extent than for a metric one. It may be that we are dealing with the consequences resulting from those described above – decreased conscious control when the task is carried out by the left hand and increased conscious control when the task is carried out by the right hand result. This results in better and worse performance, respectively, and thus in greater or lesser exactitude of object size estimation.

To answer the question concerning the effectiveness of size estimation using the motor system in the absence of visual control, we have to acknowledge that in the second experiment we did not find that the size estimation during the reproduction trials was more accurate than during the memorization trials. This may be a consequence of the procedure. When the volunteers closed the eyes, they may have reproduced their memories about the length but it was not at the same time as they looked on the screen. On the other hand, it was interesting to find that there was a difference in memorization and reproduction length measurements for both the Ponzo and the Müller-Lyer illusions.

There are many hypotheses about the origins of visual illusions. For example, there are the constructivist theories of Helmholtz and Gregory (1970); the ecological theory of Gibson (1966); the information processing ideas of Marr (1982); the neurophysiological approach of Hubel (1995); and the Gestalt theories (Rock, 1975). Much of the research on the mechanisms that underlie visual illusions is based on a single illusion (e.g. the Müller-Lyer, Moon illusion).

Sometimes there is a group, consisting of several illusions, that are considered to have the same underlying mechanism (e.g. Gregory, 2009).

Coren proposed a particular classification in their discussion of the mechanisms of illusions (Coren, Girgus, Erlichman, Hakstian, 1976). They showed 45 different illusions that produced errors as to the size of the objects and they asked the participants of the experiment to judge perceived size. Using the comparisons of the differences in the estimates, the results suggested that there were five separate groups of illusions. Moreover, it was hypothesized that the illusory effects in the five groups were based different mechanisms; for example the Ponzo illusion was categorized in the "size contrast illusions" group and Müller-Lyer illusion categorized in the "overestimation illusions" group.

Ponzo and Müller-Lyer illusions have common visual characteristics: the observer looks at two lines of the same length, and experiences an illusion that one of the lines is shorter than the other. In Müller-Lyer illusion, the size difference depends on whether the fins are inside or project beyond the shafts; in Ponzo illusion, the size difference depends on surrounding oblique lines, which are which are closer to the upper line, with the result that the lower horizontal line looks shorter.

Despite the large number of studies on these illusions there is still on-going disagreement about the mechanisms responsible for the Müller-Lyer and Ponzo illusions. There are results that show that the strength of Ponzo illusion correlates with the activity of primary visual cortex (Murray et al., 2006), and that the Müller-Lyer illusion is based on low-level mechanisms (Shoshina, Pronin, Shelepin, 2011; Ginsburg, 1984; Carrasco, Figueroa, Willen, 1986). On the other hand, Gregory (1998) has argued that both illusions are based on perspective information. There is also evidence that these illusions exist even when the observer has genetic damage to the thalamus and the primary visual cortex (Palomares, Ogbonna, Landau, Egeth, 2009).

The experiments described here contribute to the debate about the basis of visual illusions by showing that the second experiment Group L had Müller-Lyer illusion in all four conditions but Ponzo illusion is only evident in two out of the four conditions. It is suggested that this difference may be caused by activity in left hemisphere mechanisms, that is stronger in groups that started with the right hand. In addition, it is suggested that the Ponzo illusion involves more activation of the mechanisms of the left hemisphere, in comparison to the Müller-Lyer illusion. The results also show that the Ponzo illusion is stronger in the Reproduction phase, and almost does not exist in Memorization phase, where as the Müller-Lyer illusion exists in both tasks. This suggests that the two illusions have different underlying mechanisms, based on the different levels of visual system are likely to be responsible for the illusory appearance, as has been argued by Coren et al. (1976).

Conclusion

The main results of our research are:

1) The size estimation of illusory objects using a motor task showed that there is a similar illusory effect for this type of estimation as there is for perceptual size judgments.

2) There is an illusory effect for movements of both the right and left hand, but there is less of an illusory distortion when the left hand is used. Our explanation proposes that different systems of representation are involved in the process underlying size estimation using the right and the left hands: based on a metric system of representation in the right hemisphere and a categorical representational system in the left hemeisphere.

3) It was found that the size of the Müller-Lyer and Ponzo effects are different in memorization and reproduction tasks. The Müller-Lyer illusion exists in both situations whereas the Ponzo illusion generally exists only in reproduction task. This suggests that the two illusions have different underlying mechanisms.

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