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# The Müller-Lyer illusion through mental imagery

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**Abstract**

Previous studies have pointed to a link between visual perception and mental imagery. The present experiment focuses on one of the best-known illusions, the Müller-Lyer illusion, now reproduced under conditions of real perception and by means of imagery. To that purpose, a tailored ad-hoc set of combined figures was presented to a total of 161 fine art students (*M* age = 20,34, *SD* = 1,75) who individually worked with two different variations of the Müller-Lyer figures which consisted of a 10 mm long shaft and two fins set at an angle of 30º, being 15 mm long in one instance and 45 mm long in the other. In small groups, participants also completed an image control questionnaire. Results yielded that the longer the oblique lines, the larger the magnitude of the illusion both in the situation of real perception and in the imaginary situation. Also, the magnitude of the illusion augmented in the situation of perception in contrast to the imaginary situation, both with 15 mm long fins and with those of 45 mm. However, no significant differences were found in the magnitude of the illusion between high and low individuals in image control, although interactions between image control and other variables were indeed significant. The consistency of the outcome is a step forward in the study of illusions through mental images and opens the door to new lines of research that could involve innovative methods of analysis, different versions of the illusion and wider groups of participants.

**Keywords** Müller-Lyer illusion · Geometric illusion · Image control · Mental images · Fine arts students

## Introduction

The classic Müller-Lyer illusion (1889) is one of the best known and non-contested experiments on visual perception: a line of a given length looks subjectively longer or shorter according to the direction its fins are pointing to, inward (> <) or outward (< >). This inward/outward-pointing fins (Dragoi & Lockhead, 1999) have also been termed wings-out/wings-in (Greist-Bousquet & Schiffman, 1981; Porac, 1994) tail fins or arrowheads (Wang et al., 1998).

Many aspects of the Müller-Lyer illusion have already been studied. As stimuli definers, researchers have considered geometric and physical parameters (Cretenoud et al., 2020; DeLucia, 1993; Dragoi & Lockhead, 1999; Saccone & Chouinard, 2019; Schwarz & Reike, 2020; Zhang et al., 2020), neurophysiological factors (de Brouwer et al., 2015; Qiu et al., 2008; Tabei et al., 2015; Weidner et al., 2010; Zhang et al., 2013), the magnitude of the illusion as a function of age (Bondarko & Semenov, 2009; Brosvic et al., 2002), the influence of sociocultural backgrounds (McCauley & Henrich, 2006; Phillips, 2019), the influence of the illusion on interpersonal distance (Brunce et al., 2021), the illusion as related to personality traits (Zhang et al., 2017) and clinical disorders (Chouinard et al., 2013; Costa et al., 2021). Furthermore, there is a copious number of recent studies that deal with the experience of the illusion in a wide variety of animals (Costa et al., 2021; Santacà & Agrillo, 2020; Santacà et al., 2020; Schwarz & Reike, 2020).

Inaugural studies on the Müller-Lyer illusion induced by means of images were carried out during the decade of the 1980´s (Berbaum & Chung, 1981; Ohkuma, 1986; Watters & Scott, 1989) tried to demonstrate similitudes between perceptive processes and imagination by replicating the Müller-Lyer illusion through mental images. For this purpose, they

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shaped the figures by adding dots at line ends. Then they asked participants to imagine the oblique lines that formed the fins both towards the inner dots and towards the outer dots. Final results were akin to those of a situation of actual perception, so the authors concluded that imagination and perception shared similar processes and brain areas. In fact, it has been recently shown that when perception and mental imagery are externally triggered, similar neural codes get activated in sensory as well as in high-level brain areas (for reviews, see Dijkstra et al., 2019; Pearson, 2019). Current studies have also supported that the way our brain processes external inputs during perception is affected by mental imagery (Dijkstra et al., 2021; Ohkuma, 1986) compared the magnitude and nature of the image-induced Müller-Lyer illusion to those of the perceptive illusion. In order to do so, he presented three scenarios: the first with complete figures, perceptive situation; the second with wingless figures (similar to those used by Berbaum & Chung, 1981), imaginary situation; and the third with the figures of the imaginary situation but with no instructions so as to stimulate imagination, control condition. Once again, the fact that mental imagery has semi-perceptual features is confirmed. In all these three conditions, when figures are presented outwards (> <), the straight line turned out to be estimated longer than in the case of inward figures (< >). In the condition of perception, the outward figures rendered a significantly higher illusion than in the imaginary condition, whereas no differences were found in the imaginary condition and the control condition. In the case of inward figures, there was no significant difference between the condition of perception and the imaginary condition, and conversely, there was a significant difference between the imaginary condition and the control situation. Watters and Scott (1989) compared three imaginary conditions using drawings of partial lines and providing instructions to imagine the missing parts in order to generate the Müller-Lyer illusion. The three conditions rendered different illusion sizes, just in the same way as in the full perception situation.

Other illusions were also induced through mental imagery but led to contradictory data. Wallace (1984a), for his part, examined the horizontal-vertical illusion by means of mental imagery using the VVIQ (Marks, 1973) to measure the subjects' imaging ability. Those categorized as high in imaging ability experienced the illusion in the imaginary situation as much as in full figure perception. However, those low in this ability only experienced the illusion if elicited by physically present lines. The illusion of Ponzo, Hering and Wundt (Wallace, 1984b) yielded identical results. Blanuša and Zdravković (2015) looked into the differences between perception and imagination with the help of the horizontal-vertical illusion. Conclusions confirmed that there was not a significant difference in the magnitude of the illusion between the two processes: the illusion was equally strong in both cases. Varying the size of the stimulus showed that there was a gender difference in the size of the mental image for medium and large stimuli, while there was no significant difference in the strength of the illusion. Thus, women tended to overestimate size in the image condition for medium and large stimuli. There are other studies that focus on finding differences between perception and image but did not succeed in inducing illusions through images. This is the case, for instance, of the Ponzo illusion (Giusberti et al., 1998, Reisberg & Morris, 1985) or the Ebbinghaus illusion (Giusberti et al., 1998).

There is no recent review of the influence of wing length on the magnitude of the illusion in the Müller-Lyer illusion. It was only Dewar (1967) who studied this variable by randomly assigning to two experimental groups the task of valuing a figure a hundred times a day for five consecutive days. The fins formed an angle of 60º but were of different lengths for the two groups. The first group rated a figure with 1 cm fins while the second rated a figure with 3 cm fins. The author did not find any significant differences in the magnitude of the illusion as far as wing length is concerned. In the present work this variable is restudied after diverging results came out when varying stimulus sizes in the horizontal-vertical illusion (Blanuša & Zdravković, 2015).

Cretenoud et al. (2020) examined the Müller-Lyer illusion in different contexts (poor-context, moderate-context, rich-context) trying to prove the fact that the more real the context, the more intense the illusion. It is of note that the moderate and rich contexts had longer wings. Although the authors were dealing with different variables, it seems appropriate to accept that enlarged oblique lines generate richer contexts that can influence the magnitude of the illusion. In fact, Gregory's inappropriate constancy scaling theory (Gregory, 1963) stresses the perception of depth as the main cause of the illusion, which would lead to relative scales of constancy of the lines sizes (Ward et al., 1977). Alternatively, and in agreement with Howe and Purves' theory of probability in natural scenes (Howe & Purves, 2005), the Müller-Lyer illusion may well be due to a probabilistic strategy of visual processing given that visual perceptions are generated in such a way that reflects the statistic relation between retinal images and their sources in the tangible world (for more information, see Redding & Vinson, 2010).

Zhang et al. (2017) associated certain perception and personality traits to a counteraction to the Müller-Lyer illusion. All participants in this study are fine art students skilled in experiencing and resisting illusions, and in fact, they are considered to somehow embody what Pearson and Westbrook (2015) called phantom perception, which implies hallucinations, mental imagery, synaesthesia, perceptual filling-in and many illusions.

Amongst the specific attributes of fine art students is an object image processing style, that is, they focus on the literal appearance of objects and are highly skilled in visualising details such as colour, form, brightness, etc., (see Pérez-Fabello et al., 2016, 2018). They are also good at envisioning, with image control as pivotal when it comes to work formalisation (Pérez-Fabello et al., 2014). Also, they tend to have dissociative experiences, especially those related to absorption, fantasy proneness and imagination (Pérez-Fabello & Campos, 2022). These types of experiences, essential to artistic work and creativity, are highly boosted throughout their undergraduate studies (Pérez-Fabello & Campos, 2022).

## The present study

This research stems from pioneering works on the Müller-Lyer illusion induced through mental images (Berbaum & Chung, 1981; Ohkuma, 1986; Watters & Scott, 1989). Despite the abundance of recent work on the Müller-Lyer illusion (Costa et al., 2021; Cretenoud et al., 2020; Santacà & Agrillo, 2020; Santacà et al., 2020; Schwarz & Reike, 2020; Zhang et al., 2020), no studies are found on the induction of the illusion by mental imagery and few are concerned with the influence of the wings length on the magnitude of the illusion. Also, fine arts students are of the utmost interest because they have certain personality and perceptual traits that seem to be related to resistance to the Müller-Lyer illusion (see, Pérez-Fabello et al., 2016, 2018; Pérez-Fabello & Campos, 2011a, b, c, 2022; Zhang et al., 2017). On account of this, the present study is designed to inquire into the efficacy of mental images in the said illusion as compared to the illusion provoked by a real situation. Our aim was also to estimate the influence of wing length on the illusion. To that end, we used either the Bentano version or a combined version of the Müller-Lyer illusion, both specifically tailored for the particular purpose of increasing results reliability. Besides, we used the term bias as the mean deviance from actual length (Kahneman et al., 2022) in order to measure the magnitude of the illusion. Therefore, our basic hypothesis was the following: Bias, i.e., the magnitude of the illusion, is affected by the situation (real and imaginary), the wings length of the Müller-Lyer figures (15 and 45 mm) and participants' image control in their attempt to match the two horizontal lines of the shapes.

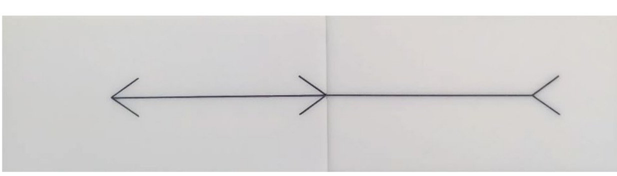
## Materials and methods

### Participants

The first group of participants comprised 219 students of whom 58 were discarded: 40 because they were already familiar with the Müller-Lyer figures and 18 because they were not able to visualize the wings in the imaginary situation. Eventually after the discard phase, the total participants were 161 (118 women and 43 men), all fine art undergraduates from the University of Vigo. The mean age was 20.34 years, ($SD = 1.75$), range 18 to 26 years. All students freely volunteered to participate in the study.

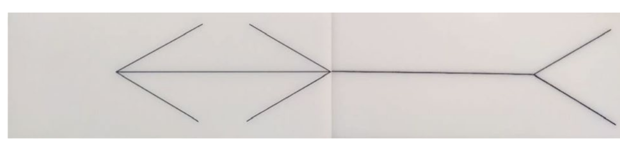
### Materials

The figures used for this study were either the Bentano version or a combined version of the Müller-Lyer figures. All of them were created in the 3D research laboratory at the faculty, redesigned in resin in a 3D printer and grouped in three sets. Two figures were similar to two of the Müller-Lyer figures created by Takei and Co. (Japan) and the third figure, consisting in only a horizontal line, kept the same size of the two previous ones (see Figs. 1, 2 and 3). Our experiment involved generating the Müller-Lyer illusion in two different moments: one when participants used the complete sets of figures (real situation) and another when they used the figure with no oblique lines and had to imagine its fins or wings (imaginary situation). For the real situation two figures were used, one with 15 mm long



Standard Stimulus Slider Stimulus

**Fig. 1** 30º and 15 mm Müller-Lyer figure



Standard Stimulus Slider Stimulus

**Fig. 2** 30º and 45 mm Müller-Lyer figure

Standard stimulus Slider stimulus

**Fig. 3** Figure used in the imaginary situation for the 30º and 15 mm figure and for the 30º and 45 mm figure fins at an angle of 30 degrees (see Fig. 1) and another with 45 mm long fins also at an angle of 30 degrees (see Fig. 2). For the imaginary situation, a version of the Müller-Lyer figures was designed but discarding all oblique lines (see Fig. 3). Participants were required to perform the same task as in the real situation, but in this case they were asked to imagine the wings of either 15 or 45 mm, as appropriate. All horizontal lines were 10 cm long and all figures consisted of a mobile part and a fixed part that contained the standard stimulus. Additionally, at the back side of the standard stimulus, there was a millimetre scale used to assess the magnitude of the illusion by determining the bias committed in the attempt to match the 10 cm shaft of the standard stimulus with that of the slider stimulus. Participants were required to manipulate the slider stimulus up to the point that it was just as long as the horizontal line of the standard stimulus. The bias was expressed in mm for every subject in perceiving each of the figures and it showed the magnitude of the Müller-Lyer illusion since a different perception of the shaft size is generated depending on the direction the wings are pointing to: inwards or outwards.

Participants were also instructed to complete an image control test, the Spanish version (Pérez-Fabello & Campos, 2004) of the Gordon Test of Visual Imagery Control (Gordon Test, Richardson, 1969). The Gordon Test measures the subject's manipulation or control of mental images. The test consists of 12 items, each one with 3 options: No = 0 points, Unsure = 1 point or Yes = 2 points. Pérez-Fabello and Campos (2004) have reported a reliability of 0.69 for the Spanish version of the test.

## Procedure

This study has been carried out over three consecutive school years. First, students were asked to complete the Gordon Test in their respective classrooms and in small groups of approximately 20 students per group. After that, each participant was asked to adjust the line to match the length of the standard stimulus and that of the slider stimulus of the Müller-Lyer illusion. The standard stimulus was 10 cm long and participants were to make it equal to the slider stimulus by manipulating the mobile part of the figure (slider stimulus) in the following four experimental situations: real 15 mm, real 45 mm, imaginary 15 mm, and imaginary 45 mm. At no time were participants informed of their scores as they ignored that their performance was being evaluated.

We counterbalanced the presentation of the figures in the real situation, in the imaginary situation and in the figure that was first presented. The first participant started with a real situation (beginning with the 15 mm figure), the second participant started with an imaginary situation (beginning with the 45 mm figure) and so on and so forth, counterbalancing both figures and situations.

All participants reported having normal or corrected-to-normal vision. The bias committed in the attempt to match shafts was measured in the four tasks.

The experiment was approved by the ethics committee of the University of Vigo and was performed in accordance with the 2013 Declaration of Helsinki. Participants gave written informed consent.

### Control of variables

All participants were presented the same figures, the same procedure and the following counterbalance: real and imaginary situation. Figures were to be at the same eye distance and with the same experimenters, lighting, and premises. All individuals who either knew the figures or achieved no image in the imaginary situation were disregarded.

### Instructions

Real situation: "You will see two figures. Place them in such a way that they are perpendicular to your line of sight and keep your arms outstretched (indications are given). Now try to match the two horizontal lines in such a way that they are the same length. In order to do so, you will have to regulate length by adjusting the figures' mobile part until you think you have got it right. The maximum time allotted for each figure is 15 seconds." This instruction was given for the 15 mm figures as well as for the 45 mm figures.

Imaginary situation: A bare horizontal line is presented. "You will see a figure. Place it in such a way that it is perpendicular to your line of sight (indications are given). Now try to imagine its fins just like they are in this set (the 15 mm and 45 mm full figures are shown, as applicable). Then try to match the two horizontal lines so as they are the same length. In order to do so, you will have to regulate length by adjusting the figures' mobile part until you think you have got it right. The maximum time allotted for each figure is 15 seconds." This instruction was given for all imaginary situations either in the case of 15 mm wings or 45 mm wings.

Once the tests were over, participants were asked whether they were already familiar with the figures and whether they were able to imagine the wings. They were also asked to assess their own performance from 0 to 3 (being 0 = not able to imagine and 3 = perfectly able to imagine).

## Data analysis

Statistical analysis was performed using the IBM SPSS Statistics, Version 25.0, statistical software (IBM Corporation, Armonk, NY, USA). The internal consistency of the tests was calculated by the Cronbach's alpha.

Our purpose was to find out to what extent the situation (real or imaginary), the wings length (15 and 45 mm) and the subjects' image control ability affected the bias committed in the attempt to match the horizontal lines in the Müller-Lyer figures. In order to do so, a mixed three-way ANOVA was. The independent variables were: 2 situation (real and imaginary) x 2 wing length (15 and 45 mm) x 2 image control (high and low) and the dependent variable corresponded to bias values when trying to match the horizontal line in the Müller-Lyer's figure.

In order to divide the participants into high and low in the Control Test, the median score in each test was taken into account. Participants who scored above the group median were considered high in image control ability and participants who scored below the group median were considered low in image control ability.

## Results

We first evaluated the reliability of the Control Test (Richardson, 1969) reaching a Cronbach alpha of 0.71. Situation, wing length and image control were all subjected to a mixed three-way analysis of variance to find out whether they affected the bias committed in the attempt to match the horizontal lines in the Müller-Lyer figures (see means and standard deviations in Fig. 4). An intra-subject contrast test revealed that in the real situation, wing length affected bias, $F(1, 150) = 621.36$, $p < .001$, $\eta_p^2 = 0.81$, power = 1. In the case of the figure with 45 mm wings, participants obtained higher bias values than in the case of the 15 mm set. In the imaginary situation, bias was affected by wing length, $F(1, 150) = 151.91$, $p < .001$, $\eta_p^2 = 0.50$, power = 1. Whenever participants used the 45 mm Müller-Lyer figure, bias values were significantly higher than in the case of the 15 mm figure.

Interactions between variables were significant. The interaction between real situation and image control was significant, $F(1, 150) = 9.38$, $p < .01$, $\eta_p^2 = 0.06$, power = 0.86 (see Fig. 5).

The interaction between imaginary situation and image control was significant, $F(1, 150) = 4.29$, $p < .05$, $\eta_p^2 = 0.03$, power = 0.54 (see Fig. 6).

Also significant was the interaction between real situation and imaginary situation, $F(1, 150) = 5.88$, $p < .05$, $\eta_p^2 = 0.04$, power = 0.67 (see Fig. 7). However, interaction between the three variables, situation, wing length and image control was not significant, $F(1, 150) = 0.01$, $p = .94$, $\eta_p^2 = 0.01$, power = 0.05. Results of the inter-subject test

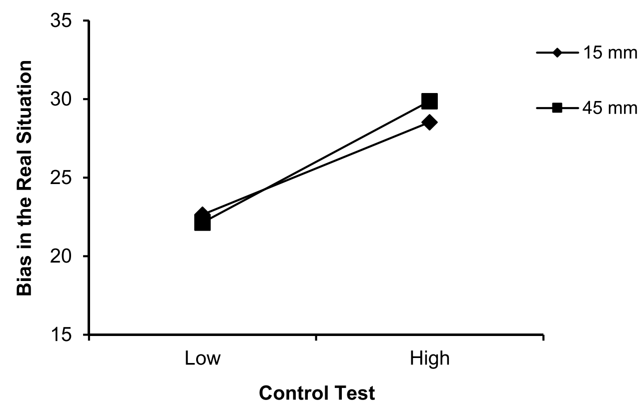



**Fig. 5** Interaction between the length of the oblique lines and control test in bias in the real situation

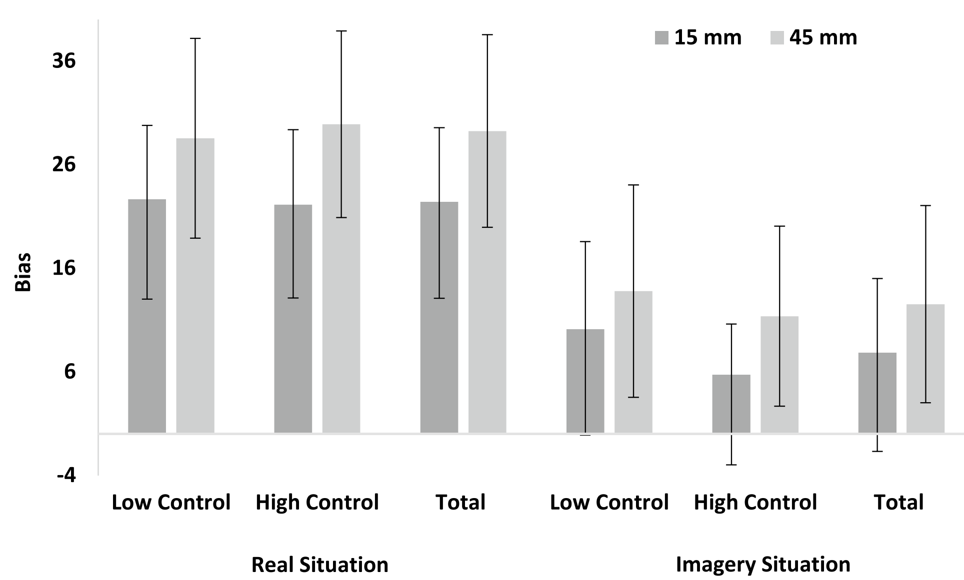



**Fig. 4** Means and standard deviations of bias according to the real and imaginary situation, the length of the oblique lines and image control

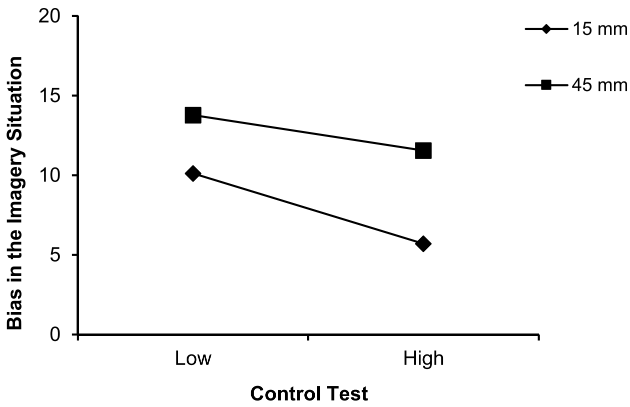



**Fig. 6** Interaction between the length of the oblique lines and control test in bias in the imaginary situation

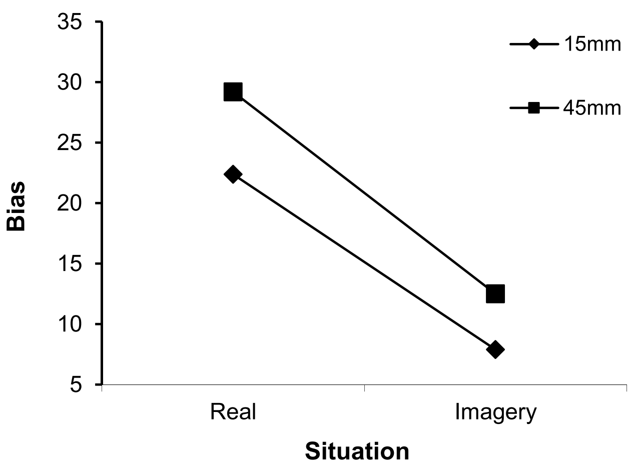



**Fig. 7** Interaction between the length of the oblique lines and real and imaginary situation in bias

showed that image control did not have a significant influence on bias either, $F(1, 150) = 2.24$, $p = .14$, $\eta_p^2 = 0.02$, power = 0.32.

## Discussion

The reliability of the Gordon Test in our study amounted to 0.71, which was similar to those previously found of 0.69 and 0.74 (Pérez-Fabello & Campos, 2004, 2020). Although Ashton and White (1974) reported that the test did not have a simple factorial structure and that the consistency of this test was low (McKelvie, 1992; McKelvie & Gingras, 1974), the reliability achieved was, according to the criteria of George and Mallery (2003), acceptable. Wing length affected the magnitude of the illusion in the real situation, namely that of perception, as much as in the imaginary situation. Participants obtained higher bias values when lines were longer. Although Dewar (1967) did not find any differences in the magnitude of the illusion, the method used now was a different one. In addition, the specific characteristics of fine arts students may also have caused the difference in results. Alternatively, the conclusions driven by Cretenoud et al. (2020) seemed to suggest that richer contexts boost illusion, so therefore, we assume that longer oblique lines imply richer contexts, generate higher depth and, according to the perceptual constancy theory (Gregory, 1963; Ward et al., 1977), could have an influence on the magnitude of the illusion. In any case, this outcome needs to be confirmed by further studies.

There was a significant interaction between the real and the imaginary situation both in the case of 15 mm fins and 45 mm fins. The magnitude of the illusion was greater for the real situation. Berbaum and Chung (1981) did not find any significant differences between the perceptive and the imaginary conditions. For his part, Ohkuma (1986) found that the size of the illusion was greater in the perceptive than in the imaginary condition in the case of outward figures (in his study > <) but did not find any differences between both conditions in the case of inward figures (in his study < >). Watters and Scott (1989) found the same illusion magnitude in the situation of actual perception as well as in the imaginary situation.

Although our hypothesis anticipated that image control might affect the magnitude of the illusion, no significant differences were found between those high and low in image control. However, the interaction between the real and the imaginary situation was significant as did as well between the imaginary situation and image control. It is adventurous to assume an explanation for these results due to the lack of previous similar investigations. Inaugural studies on images had rendered contradictory data. Ohkuma (1986) did not find any significant differences in image ability between high and low scoring subjects either in the size of the illusion using the VVIQ (Marks, 1973) nor in image control using the Gordon Test (Gordon, 1949) both in the real and in the imaginary situation. Using other types of geometric illusion such as the horizontal-vertical illusion, the Ponzo illusion or the Hering and Wundt illusion, Wallace (1984a, b) found that participants skilled on images (VVIQ; Marks 1973) experienced the illusion in the imaginary situation as much as in full perception of the lines, however, those with low scores only experienced the illusion when it was produced in the actual presence of the lines.

Despite inconsistent findings regarding the Müller-Lyer illusion, numerous work has highlighted the qualities of mental images and their similitudes with perception (Blackwell, 2019) contributing evidence on the activation of the same brain structures when perceiving or imagining (Dijkstra et al., 2019, 2021; Pearson, 2019). Even so, perception is more powerful than imagination, so a combination of neuroimaging and conductual evidence has led to suggest that mental images may be considered a "weak" form of perception (Pearson et al., 2015). All this is consistent with our conclusion, namely that the magnitude of the illusion is greater in the situation of actual perception than in the imaginary situation. In fact, similar results have been obtained in both situations. Image control can be said to influence neither the real situation nor the imaginary situation, which is essentially the same conclusion as that reported by Ohkuma (1986). On the other hand, the influence of wing length was significant in the real situation and in the imaginary situation, as formerly indicated by Watters and Scott (1989). These results consolidate similitudes between the two cognitive processes, perception and imagination, but further work is required to arrive to a more accurate explanation.

The strength of this study relies on the fact that research on illusions through mental images is retaken with the inclusion of new methods, different illusion versions and a wider sample of subjects. We believe that designing combined sets of figures to elicit the illusion contributes reliability to the study. The weak point of this work is the use of a particular group of participants instead of a sample population that, together with gender difference, hinders results generalization. New studies will address other groups of population and will connect new figure factors, geometric as well as physical, with the magnitude of the illusion. We deem of great interest to keep researching on personality traits as related to resistance to the illusion.

## Conclusion

With the help of an in-depth study of the Müller-Lyer illusion, this work sheds light on the differences and commonalities of visual perception and mental imagery. We obtained identical results for the situation of actual perception and for the imaginary situation, both rendering a higher illusion magnitude when the figures with longer fins were used. Consequently, the magnitude of the Müller-Lyer illusion is greater in the situation of actual perception than in the imaginary situation both in the case of the figures with 15 mm fins and with 45 mm fins.

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**Data availability** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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