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Research report

Perception of the Müller–Lyer illusion in capuchin monkeys (*Cebus apella*)

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Abstract

Visual illusions are formed by differences between the perception of one figure and its real physical characteristics. The Müller–Lyer illusion is the best known and most studied geometric illusion, consisting in the subject's judgment between two parallel lines that have the same size, one flanked with outward-pointing arrowheads, and the other with inward-pointing arrowheads. These arrowheads act as inductors that make the lines to be perceived as having different sizes, inward-pointing stimuli being estimated as longer. This study aimed to investigate the Müller–Lyer illusion in capuchin monkeys (*Cebus apella*), a New World primate not yet investigated for this illusion. For this purpose, stimuli were presented on a touch screen monitor. Ten adult subjects (five females and five males) were used. Before the tests, they were trained to discriminate between two physically different lines with and without arrowheads. The longer lines were always the positive (rewarded) stimuli. Regarding the Müller–Lyer Illusion test, all monkeys, unrespective of gender, demonstrated susceptibility to the illusion, by choosing preferentially the line with inward-pointing arrowheads. In order to determine the degree of the illusion, a point of subjective equality test (PSE) was performed. The PSE without arrowheads values were lower than the PSE with arrowheads. Thus, it was demonstrated that capuchin monkeys were susceptible to the Müller–Lyer illusion, once the perception of the lines' size was influenced by the presence of the arrowheads and by their orientation.

Keywords: Müller–Lyer; Visual illusion; Capuchin monkeys; *Cebus apella*; Perception

1. Introduction

Visual illusions occur when the individual perceives a figure as having characteristics different to its own real physical properties [20]. Geometrical optical illusions belong to one class of visual illusions where figures present context-induced subjective distortions of their visual features, such as length, orientation, or curvature of lines. One of the best-known and most extensively investigated geometrical illusion is the Müller–Lyer configuration [6], in which two identical straight lines appear perceptually different in length. In this case, one of the lines is flanked by inward-pointing arrowheads, always appearing as being longer, while the other is flanked by outward-pointing arrowheads, always appearing shorter [12].

Many different physiological and cognitive theories have attempted to explain the Müller–Lyer illusion, but none of them has been fully satisfactory. It is possible that a complete explanation of this illusion involves a combination of several theories, which explain multiple mechanisms that are involved in many of the illusions. Also, small modifications to the figure enhance some of the mechanisms while inhibit others. Despite of this, the most cited cognitive theory that explains the Müller–Lyer illusion is Gregory's classical perspective theory, in which the linear perspective perceived by the observer, either consciously or unconsciously, elicits "inappropriate" compensation based on the size constancy leading to a perceptual magnification of the figures that appear farther. This occurs because the visual system tries to adjust the small retinal image to maintain size constancy [10].

The similarity between humans and non-human primates' visual system allows the use of primates as models for human illusory perception. Therefore, studies performed with non-human primates have permitted a better comprehension

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of the neural mechanisms involved in illusory perception [11,14].

In line with that, some non-human primates have shown to be susceptible to geometric illusions. For instance, rhesus monkeys (*Macaca mulatta*) [2,8,9] and chimpanzee (*Pan troglodytes*) [9] perceived the Ponzo illusion; chimpanzees were also susceptible to the Kanizsa illusion [7]; olive baboon (*Papio anubis*) experienced the Zöellner illusion [3]; baboons (*Papio papio*) were susceptible to the corridor illusion [1]; and rhesus monkeys (*Macaca mulatta*), sooty mangabey (*Cercocebus fuliginosus*), and capuchin monkeys (*Cebus capucinus*) perceived the vertical–horizontal illusion [5]. However, as far as we know, the Müller–Lyer illusion has not yet been studied in non-human primates, pigeons standing for the only non-human animal in which this illusion has been tested [15,20].

Capuchin monkeys were chosen as subjects for this study for several reasons: (1) visual acuity and scotopic sensitivity are similar to humans' [4]; (2) their ability for solving problems using an abstract rule [19]; (3) high encephalic coefficient, indicating their developed cognitive capacity [13].

Thus, this study aimed to investigate the visual perception of the Müller–Lyer illusion in capuchin monkeys (*Cebus apella*), a primate for which there is no literature reference on this type of research.

2. General method

2.1. Subjects

Ten adult (6–10 years old) capuchin monkeys (*C. apella*), five females and five males, were used as subjects in this study. All subjects had no experience in illusory tests, although four females and three males had experience in tests involving the use of computer apparatus. They were kept in cages (4 m long, 2.9 m wide, and 2 m high) surrounded by natural vegetation and were maintained in couples or in groups of three at the Primate Center of the University of Brasilia, Brazil. The animals were tested in their own cages and were only separated from the rest of the group during the experimental session. They were not food deprived and water was available *ad libitum* except during the sessions. All procedures were approved by the University of Brasilia Animal Care and Use Committee.

2.2. Apparatus and computer program

A laptop (Acer, TravelMate 521TE) connected to a 15 in. touch-screen monitor (LG Studio Works 440, Microtouch) was used to collect all data. A food pellet dispenser (Med Associates ENV-203) was not controlled by the computer software, but operated manually by one of the experimenters. The experimental apparatus was set up inside a portable wooden cart set in a way that the monitor faced the cage.

A computer program ILU (using Delphi language and Windows XP compatible), developed to conduct the experiments, permitted the display of illusory figures, manipulation of the stimuli's exposure time, intervals between stimuli, number of trials, and screen's background color. Data such as subject, session, trial, phase of the experiment, and animal response accuracy were recorded by the software as well as manually by the experimenter.

2.3. General procedure and stimuli

This study was divided into three stages: training (phases 1–4), the Müller–Lyer illusion test (MLT), and determination of the point of subjective equality (PSE) with and without arrowheads (Fig. 1).

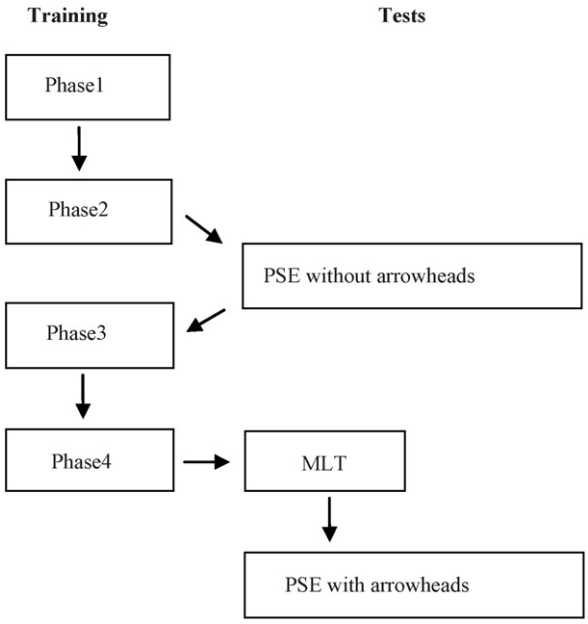

Fig. 1. Sequence of experimental stages.

Stimuli consisted of black graphic patterns on a white background with a 180° orientations and 1.0 mm thickness. The viewing distance was about 200 mm.

2.4. Data analysis

Statistical analysis was run using Statistical Package for Social Sciences (SPSS) 13.0 Software. The Kolmogorov–Smirnov test was applied to determine the kind of test (parametric or non-parametric) to use. In Section 3.5, the Wilcoxon test was used to compare the number of trials done to acquire the learning criterion among each phase. In addition, to compare the performance between genders in all training phases, the Student *t*-test (independent simple *t*-test) was applied. The same test was carried on to verify the animals' performance due to the previous apparatus experience in phase 1. For phases 2–4, the Mann–Whitney test was used. In Section 4.1, the Wilcoxon test was applied to analyze the number of times that the line with inward and outward-pointing arrowheads was chosen. The same test was run to compare the animals' performance in the 10 initial warm-up trials and the 10 constancy verification trials. To compare the performance between genders, the Mann–Whitney test was conducted. Furthermore, the Student *t*-test (paired simple *t*-test) was applied to compare the mean number of correct responses in the first 10 test trials with the last 10 test trials and in the first 20 test trials with the last 20 test trials. In Section 5.3, the Student *t*-test (paired simple *t*-test) was conducted when the group was analyzed as a whole in the PSE test with and without arrowheads. Finally, the Student *t*-test (independent simple *t*-test) compared the performance between females and males.

3. Training

Training was composed of four phases, each one lasting until the subjects reached the criterion of 90% correct answers in two consecutive sessions, composed of 45 trials each. The intertrial intervals were 2000 ms. Monkeys were always rewarded with food pellet when they accomplished the phase's objective.

3.1. Phase 1: touching on the stimulus

The stimuli were single horizontal lines (60, 70, and 80 mm) not flanked by arrowheads. The line was located either on the