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Visual illusions and the control of children arm movements

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Abstract

The aim of the present study was to determine whether children like adults (Gentilucci M, Chieffi S, Daprati E, Saetti MC, Toni I. Visual illusion and action. Neuropsychologia 1996;34:369–76; Gentilucci M, Daprati E, Gangitano M, Toni I. Eye position tunes the contribution of allocentric and egocentric information to target localisation in human goal directed arm movements. Neurosci Lett 1997;222:123–6) are influenced by visual illusions when they transform visual information in motor command. Children and adults pointed to a shaft extremity of the Müller-Lyer configurations, as well as to an extremity of a control configuration. Movements were executed in two experimental conditions. In the vision condition subjects saw both the stimulus and their hand before and during movement. In the no vision (memory) condition subjects saw the stimulus and their hand before, but not during movement. Movement started 5 s after vision was precluded. The Müller-Lyer illusion affected pointing kinematics of both children and adults. As found previously (Gentilucci M, Chieffi S, Daprati E, Saetti MC, Toni I. Visual illusion and action. Neuropsychologia 1996;34:369–76; Gentilucci M, Daprati E, Gangitano M, Toni I. Eye position tunes the contribution of allocentric and egocentric information to target localisation in human goal directed arm movements. Neurosci Lett 1997;222:123–6), subjects undershot and overshot the shaft extremity of the closed and of the open configuration, respectively. The illusion effect was greater in the no vision than in the vision condition. These results show that in children like in adults the system underlying visual perception in an object-centered frame of reference and that involved in motor control functionally interact with each other. Although the processes of target localisation were the same, the transformation of target position information in a sequence of motor patterns was different in children from that in adults. Even if both children and adults lengthened duration of the deceleration phase in the vision condition, only adults shortened duration of the acceleration phase in order to maintain constant movement time (Viviani P, Schneider R. A developmental study of the relationship between geometry and kinematics in drawing movements. J Exp Psychol 1991;17:198–218). This result suggests that children are yet unable to co-ordinate temporally acceleration with deceleration phase.

Keywords: Müller-Lyer illusion; Children; Pointing; Kinematics; Vision and no vision conditions

1. Introduction

It is commonly accepted that an object is analysed differently in the ventral and dorsal visual streams of cortex in order to perceive an object and to prepare a motor response, respectively. Corresponding to this anatomical and functional separation, behavioural dissociations have been observed [3,13,34]. However, other behavioural studies show that visuo-motor transformation can be influenced by perception [6,8,10,14]. This suggests that the analyses performed in two visual streams can be functionally related to each other [11]. In particular, the Müller-Lyer illusion [25] affected pointing to the shaft extremity of the configurations and grasping them [6,8,10]. The illusion effect was found on movements executed under visual control and it was even greater for memory driven movements. In these studies not only movement amplitude and movement time, but also initial kinematic parameters more related to planning, were influenced by the illusion. In addition, in memory driven movements the illusion effect increased when time delay was longer and it did not affect final variability and deviation of arm trajectory. Taken together these results suggest that, according to movement constraints, target was localised by using also perceptual representation, and, in particular, object centered cues.

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The capability of adaptation to movement constraints can develop with age. Alternatively, it is possible that object perceptual representations can be used in order to control a movement since childhood. The first hypothesis assumes that some relations between perceptual and motor representations are due to structural maturation and/or reinforcement by repetitive practice, whereas the second one assumes that some relations between the two representations are functionally active since childhood. Previous experiments [21,22] showed that 7-year-old children do not yet use appropriately object-centered representations for the control of grasping movements. In contrast, 10–12-year-old children use them appropriately. Consequently, it is possible that also the capability to use perceptual object representations in order to control better an arm movement is not completely developed at the age of 7. It is known that the Müller-Lyer illusion starts to be effective from the age of 5 [28,29], and a previous study [28] reports that it is more powerful in children than in adults. Consequently, if 7-year-old children are already able to use also perceptual object representations to control a movement, we expect an illusion effect also on their arm movements directed to the shaft extremity of the Müller-Lyer configurations, when the illusion surely affects perceptual judgement. The effect should be greater during memory driven movements. In contrast, if children are yet unable to use them, we expect either no effect or no selective effect of the illusion on movement control according to movement constraints. We verified these two hypotheses in the present study, in which children and adults pointed to the shaft extremity of the Müller-Lyer configurations. A control experiment of drawing, in which a perceptual judgement of the shaft length was required, was carried out on children.

Previous behavioural studies [4,18,20] showed that pointing of 6-year-old children executed under visual control was similar to pointing of adults. Kinematic studies on reaching–grasping reported similar results [21,22,31]. However, in the latter studies the temporal structure of 7-year-old children reach was influenced by their inability to shape fingers correctly during grasp. This was observed especially when movements were executed without visual feedback, and, consequently, without the possibility of on-line corrections. Consequently, no conclusion can be drawn on the development of the structure of the reach program at this age, because of the influence of incorrect grasp on reach. That is, it is unclear whether the visual information on target position is transformed in the same sequence of arm motor patterns as observed in adults. In the present study we addressed also the problem of how the reach motor program is temporally structured in child.

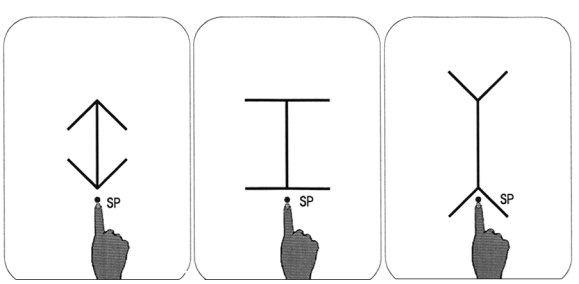

Fig. 1. The open (right position) and the closed (left position) configurations of the Müller-Lyer illusion and the control configuration (middle position). SP, starting position.

2. Methods

2.1. Drawing task

2.1.1. Subjects

Twenty-one healthy children (12 females and nine males, aged 7–8 years) performed the task. They were recruited from a primary school after approval of the teacher council and informed consent of their parents. All children were right-handed according to Edinburgh Inventory [26] and had normal or corrected to normal vision.

2.1.2. Apparatus and stimuli

Stimuli were presented on an easel, located on a table, in front of which children sat comfortably. The easel was 30 cm distant from their frontal plane, and was inclined by 45° with respect to the plane of the table. Stimuli were the open and the closed configurations of the Müller-Lyer illusion, drawn in black ink on the centre of white panels (Fig. 1). Ratio between lengths of wing and shaft was 0.47. Wings were 45° inclined with respect to the shaft. Control stimuli were also presented. They consisted of shaft and wings as the Müller-Lyer configurations, but the wings were perpendicular to the shaft. The shaft of all stimuli was aligned with the children's sagittal plane and could be 8 or 16 cm long.

2.1.3. Procedure and data analysis

Children were required to draw a vertical line as long as the stimulus shaft. At the beginning of each trial, children held a pencil in their right hand placed on the plane of the table. They were required to inspect the stimulus, and to draw the line on a white sheet, at a go-signal 5 s after stimulus presentation. During drawing the stimulus was visible. Seven stimuli for each stimulus length (8, 16 cm) and configuration (open, closed, control) were presented in pseudo-random order. In total, 42 trials were run. The session lasted $\sim$30 min.