Neuroscience Letters 590 (2015) 145–149

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research article

Prism adaptation power on spatial cognition: Adaptation to different optical deviations in healthy individuals

Carine Michel [a,b,*], Remy Cruz [a,b]

[a] Université de Bourgogne, BP 27877, F-21078 Dijon, France
[b] INSERM, U 1093, Cognition, Action et Plasticité Sensorimotrice, Dijon, F-21078, France

HIGHLIGHTS

- After-effects of prism adaptation for different optical deviations were studied.
- Adaptation to an 8° optical deviation produced no cognitive after-effect.
- Adaptation to a 10° optical deviation produced a bias in manual line bisection.
- Adaptation to a 15° optical deviation produced a bias in manual/perceptual bisection.
- Sensorimotor and cognitive after-effects were correlated to the optical deviation.

ARTICLE INFO

Article history:
Received 12 September 2014
Received in revised form 13 January 2015
Accepted 1 February 2015
Available online 4 February 2015

Keywords:
Sensorimotor plasticity
Spatial cognition
Healthy subjects
Prism adaptation
Neglect simulation
Line bisection

ABSTRACT

The main objective of the present study was to determine the minimal optical deviation responsible for cognitive after-effects in healthy individuals and to explore whether there was a relationship between the degree of optical deviation and cognitive after-effects. Therefore different leftward optical deviations (8°, 10° and 15°) were used in three different groups of healthy participants. Sensorimotor after-effects (evaluating the visuo-manual realignment) were assessed using an open-loop pointing task and cognitive after-effects (evaluating changes in spatial representation) were assessed using manual and perceptual (landmark) line bisection tasks. Results revealed that exposure to 8°, 10° and 15° optical shifts produced sensorimotor after-effects. In contrast, the occurrence of cognitive after-effects depended on the optical deviation. Adaptation to an 8° leftward optical deviation did not produce cognitive after-effects. Adaptation to a 10° leftward optical deviation was responsible for after-effects in the manual line bisection task only. Adaptation to a 15° leftward optical deviation produced after-effects in both the manual and perceptual line bisection tasks. All cognitive after-effects were rightward and were similar to mild, neglect-like manifestations. Both sensorimotor and cognitive after-effects were correlated with the degree of optical deviation. Our results are of methodological and theoretical interest to those interested in sensorimotor plasticity and spatial cognition.

1. Introduction

One classic approach to the study of sensorimotor plasticity is the prism adaptation procedure. This method consists of pointing to visual targets while wearing prismatic lenses that shift the visual field laterally. The pointing errors made in the direction of the optical shift are gradually corrected over time. After prisms are removed, pointing movements are shifted in the direction opposite to the optical deviation. It has been shown that the after-effects of prism adaptation are not restricted to the sensorimotor level (i.e., sensorimotor realignement assessed by visuo-manual pointing) but extend to the domain of spatial cognition (e.g., cognitive functions assessed by 'paper-and-pencil' tests). Rossetti et al. [1] used prism adaptation to rehabilitate neglect patients who present with a neurological condition in which they fail to attend to and represent the left side of space. Since that early work numerous studies have demonstrated the benefit of adaptation to 10° rightward optical deviations on various neglect symptoms [e.g., [2–4] see [5] for a review]. In healthy subjects a mirror effect has been shown in simulating neglect-like symptoms. Following prism adaptation to a 15° leftward optical deviation, rightward neglect-like biases

* Corresponding author at: Université de Bourgogne, BP 27877, F-21078 Dijon, France. Tel.: +33 380399006; fax: +33 380396749.
E-mail address: carine.michel@u-bourgogne.fr (C. Michel).

http://dx.doi.org/10.1016/j.neulet.2015.02.001
0304-3940/

were observed on manual and perceptual (landmark) line bisection tasks which required participants to estimate the midpoint of line segments e.g., [7,8]. Many studies have replicated these results and extended the after-effects of prism adaptation to numerous cognitive functions e.g., [6,9–11]. These results demonstrate the existence of a strong link between the sensorimotor plasticity and cognitive functions.

Neglect patients show large after-effects. At a sensorimotor level, after-effects reach 75% of the optical deviation in neglect patients [1], whereas they typically don't exceed 50% of the optical deviation in healthy individuals e.g., [12]. At a cognitive level, the reduction of rightward neglect biases in line bisection reach a magnitude of several centimetres [13,14], whereas the neglect-like rightward bias in healthy subjects reaches a magnitude of only several millimeters e.g., [7,14]. It is likely that the greater amplitude for both sensorimotor and cognitive after-effects in neglect patients reflects the exaggerated sensitivity of a damaged brain to sensorimotor plasticity. This sensitivity would be partly in connection with the lack of awareness of the optical deviation [5,15]. Nevertheless, these results raise the question of whether there is a link between the amplitude of sensorimotor after-effects and the amplitude of cognitive after-effects. Several studies, using a single optical deviation, have shown that there was no linear correlation between the sensorimotor and cognitive after-effects when patients were adapted to a 10° optical deviation [13,16]. In contrast, two studies found that patients with larger after-effects showed greater improvement of neglect symptoms [17,18]. Furthermore, when different optical deviations were considered, the strength of the rehabilitation depended on the amplitude of the optical deviation [19]. On these grounds, there is a positive relationship between the magnitude of optical deviation and neglect improvement. Does the same relation apply to healthy individuals? Girardi et al. [10], along with Berberovic and Mattingley [20], showed no correlation between cognitive after-effects (measured on the circle centering task and on the landmark task, respectively), and sensorimotor after-effects (measured on subjective straight ahead pointing with eyes closed). These results suggest that the individual sensitivity to sensorimotor plasticity for a specific optical deviation does not influence the magnitude of cognitive after-effects. Nevertheless, it remains unknown whether adaptation to different optical deviations produces different magnitudes of cognitive after-effects as in neglect patients [19].

In the present experiment we explored the relationship between the magnitude of sensorimotor and cognitive after-effects induced by exposure to different optical deviations. We used a leftward optical shift because it is known to produce cognitive after-effects in healthy individuals e.g., [6]. The main objective was to determine the minimal optical deviation responsible for cognitive after-effects in line bisection and to explore whether there was a relationship between the magnitude of optical deviation and the magnitude of cognitive after-effects.

2. Material and methods

2.1. Participants

Twenty-four healthy subjects with normal or corrected-to-normal vision participated in the experiment. All participants were right-handed according to the Edinburgh Handedness Inventory. They were randomly divided into three independent groups of eight participants: Group 8° (two females; mean age: 22 ± 0.75 years), Group 10° (five females; mean: 21.43 ± 0.46 years), and Group 15° (three females; mean: 23.25 ± 0.52 years). All participants gave their informed consent prior to their inclusion in the study, which was carried out in agreement with legal requirements and international norms (Declaration of Helsinki, 1964).

2.2. Apparatus

Participants comfortably sat in a chair in front of a table and kept their head aligned with the body axis using a chin-rest. The starting hand position was placed 11 cm from the edge of the table. During open-loop pointing (without vision of movement execution), one sagittal target (colored sticker dot, diameter 6 mm) was placed on the table 45 cm from the edge of the table. During prism exposure, nine visual targets (colored sticker dots; diameter 6 mm) were placed on the table 45 cm from the edge of the table.

All arm movements for the visuo-manual open-loop pointing task were recorded using 3 TV-cameras (sampling frequency 60 Hz) of an optoelectronic system of motion analysis (Smart, B.T.S., Italy). One reflective marker (1 cm diameter) was placed on the nail of the right index fingertip. The spatial resolution for movement measurements was better than 1 mm. Data processing was performed using custom software written in Matlab (Mathworks, Natick, MA). The pointing angular error was calculated as the difference between the starting position to target position vector and starting position to final index fingertip position vector.

2.3. Experimental procedure

Each group differed from the others by the optical deviation used during prism exposure. Group 8° was exposed to an 8° leftward optical deviation, Group 10° was exposed to a 10° leftward optical deviation, and Group 15° was exposed to a 15° leftward optical deviation. For the three groups, the experimental procedure was divided into the three periods: the pre-test (before prism adaptation: manual line bisection, landmark task and open-loop pointing task), the prism adaptation procedure, and the post-test (after prism adaptation: open-loop pointing task, landmark task, manual line bisection and last open-loop pointing task). In the post-test, the manual bisection task was performed following the landmark task to prevent any de-adaptation to from taking place. Indeed, closed-loop visuo-manual guidance in manual bisection may favor de-adaptation.

2.3.1. Prism adaptation procedure

The prism adaptation procedure followed the pre-tests. Participants wore prismatic goggles and their head was stabilized by a chin-rest. They were asked to perform a closed-loop pointing task (with vision of the hand during the movement). They pointed as fast as possible to the targets and returned near the start position at a natural speed. Vision of the starting position of the hand was occluded to ensure the optimal development of the adaptation [21]. Participants were asked to point alternately to one of the nine visual targets indicated randomly by the experimenter. The adaptation procedure involved 40 different blocks of 9 pointing trials (total number of movements: 360). The nine visual targets were randomly presented in each block. Participants relaxed for 30 s (eyes closed) every 5 min. The total duration of the adaptation procedure lasted for 20 min.

2.3.2. Visuo-manual open-loop pointing task

In both the pre-test and post-test conditions, 12 open-loop pointing trials (i.e., without visual control during movement execution) were performed using liquid crystals goggles to occlude vision during movement execution. Participants were asked to make accurate movements at a natural self-paced speed to the single sagittal target. Before movement onset, participants' right index-finger was passively placed by the experimenter in the starting position. The after-effects of adaptation was assessed by the difference in the pointing errors between mean performance in post-test and mean performance in pre-test for each participant (immediate after-effects: post-test minus pre-test performance). At the end