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# PRISM ADAPTATION AND NECK MUSCLE VIBRATION IN HEALTHY INDIVIDUALS: ARE TWO METHODS BETTER THAN ONE?

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**Abstract—Studies involving therapeutic combinations reveal an important benefit in the rehabilitation of neglect patients when compared to single therapies. In light of these observations our present work examines, in healthy individuals, sensorimotor and cognitive after-effects of prism adaptation and neck muscle vibration applied individually or simultaneously. We explored sensorimotor after-effects on visuo-manual open-loop pointing, visual and proprioceptive straight-ahead estimations. We assessed cognitive after-effects on the line bisection task. Fifty-four healthy participants were divided into six groups designated according to the exposure procedure used with each: 'Prism' (P) group; 'Vibration with a sensation of body rotation' (Vb) group; 'Vibration with a move illusion of the LED' (Vl) group; 'Association with a sensation of body rotation' (Ab) group; 'Association with a move illusion of the LED' (Al) group; and 'Control' (C) group. The main findings showed that prism adaptation applied alone or combined with vibration showed significant adaptation in visuo-manual open-loop pointing, visual straight-ahead and proprioceptive straight-ahead. Vibration alone produced significant after-effects on proprioceptive straight-ahead estimation in the Vl group. Furthermore all groups (except C group) showed a rightward neglect-like bias in line bisection following the training procedure. This is the first demonstration of cognitive after-effects following neck muscle vibration in healthy individuals. The simultaneous application of both methods did not produce significant greater after-effects than prism adaptation alone in both sensorimotor and cognitive tasks. These results are discussed in terms of transfer of sensorimotor plasticity to spatial cognition in healthy individuals.**


**Key words: sensorimotor plasticity, spatial cognition, healthy subjects, prism adaptation, neck muscle vibration.**

## INTRODUCTION

To be efficient, visuo-manual coordination must be precisely calibrated. After having experienced a new visuo-motor relationship, commonly referred to as visual mapping, an adaptive control allows for the maintenance of an appropriate calibration between the visual input and the hand movement command (for a review see Gauthier et al., 2007). One of the classical models for the study of sensorimotor plasticity is prism adaptation (Stratton, 1896). It consists of pointing to visual targets while wearing prisms which deviate the visual field laterally. At the beginning of the exposure, subjects make errors pointing in the direction of the optical shift. On the basis of these error signals, subjects gradually improve their performance until they achieve accurate behavior. When the prisms are removed, the sensorimotor correlations revert to an inappropriate state and the pointing movements are shifted in the direction opposite to the prismatic shift. This post-adaptation shift is named the negative after-effect. The entire process is a form of sensorimotor adaptation.

It has been shown that after-effects of prism adaptation are not restricted to the sensorimotor level but extend as well into spatial cognition. The first observations were made in neglect patients who failed to report, respond or orient to meaningful left-sided stimuli, usually after right brain damage (e.g. Halligan et al., 1989). Indeed, after a short period of 5 min of adaptation to a 10° rightward visual shift, an important reduction in the symptoms was shown (Rossetti et al., 1998) with longer-term benefits following repeated application of prism adaptation (Frassinetti et al., 2002; Pisella et al., 2002; Humphreys et al., 2006). The amelioration of neglect was found in all spatial domains (see for reviews Luauté et al., 2006a; Rode et al., 2006; Newport and Schenk, 2012). In healthy subjects, adaptation to a 15° leftward visual field is responsible for neglect simulation. The first simulation of neglect was shown in line bisection (Colent et al., 2000) and completed with different paradigms using line bisection tasks (Michel et al., 2003a; Goedert et al., 2010). Simulation of neglect was observed in haptic tasks (Girardi et al., 2004), in postural balance (Michel et al., 2003b), in extrapersonal space using line bisection and goal-directed locomotion (Berberovic and Mattingley, 2003; Michel et al., 2008, see Michel, 2006 for a review). After-effects were shown on a variety of attentional mechanisms (Striemer et al., 2006), on non-lateralized spatial attention (Bultitude and Woods, 2010), on motor-intentional responses (Michel et al., 2003a; Fortis et al.,

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*Abbreviations:* Ab, Association with a sensation of body rotation; Al, Association with a move illusion of the LED; ANOVA, analysis of variance; C, Control; P, Prism; Vb, Vibration with a sensation of body rotation; Vl, Vibration with a move illusion of the LED; LED, Light-emitting diode.

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2011) and on the more enigmatic mental number space (Loftus et al., 2008). Altogether the results in both neglect patients and healthy individuals suggest a link between the sensorimotor plasticity and a supramodal space representation (Redding et al., 2005).

Neck vibration, by producing a bias in proprioceptive information, is also responsible for perturbation in sensorimotor coordination. In a pioneering study, Lackner and Levine (1979) showed that vibration of the posterior neck-muscles produced a proprioceptive illusion of egocentric coordinates in space. Biguer et al. (1988) showed that during vibration of the left posterior neck muscles subjects reported an apparent rightward displacement of a light in darkness. The visual illusion was responsible for errors in pointing in the direction of the illusion and in visual estimation of the subjective midline in the opposite direction. Corroborating results were observed with right neck muscle vibration (McIntyre and Seizova-Cajic, 2007). Karnath et al. (1994) observed both a visual target-shifting sensation on the side opposite of the vibration and a body rotation sensation on the same side as the vibration. Effects of neck muscle vibration also produced a displacement of the center of foot pressure, a deviation of gait trajectory and a body rotation during stepping-in-place toward the side opposite to vibration (Bove et al., 2001, 2002). As for prism adaptation, neck muscle vibration was also used for neglect rehabilitation (Karnath et al., 1993). Karnath et al. (1996) proposed that the improvement of neglect by manipulating neck input is caused by general correction of the underlying neural transformation process converting the sensory afferent input into an egocentric coordinate frame. Therapeutic effects of neck muscle vibration were also shown when vibration was used in combination with conventional exploration training (Schindler et al., 2002).

Given that the neglect syndrome is multifaceted in nature, many authors have speculated that to maximize therapeutic effects, different interventions might be applied in various combinations (Saevarsson et al., 2010, 2011). Saevarsson et al. (2010) investigated the combined intervention of left posterior neck muscle vibration and prism adaptation to 10° rightward optical deviation in neglect patients. They recorded the sensorimotor after-effects on proprioceptive straight-ahead estimation and showed clear improvements of neglect in feedback-based visual searching tasks and paper and pencil tests (star cancellation and free drawings, for instance) when both prism adaptation and vibration were combined compared to vibration used alone. The results support the view that the most effective treatment for neglect involves the combination of different interventions. In light of those observations in neurological patients and considering the link between sensorimotor plasticity and spatial cognition in healthy individuals, our present work was twofold. First, we investigated whether the simultaneous use of adaptation to a 15° leftward prismatic deviation and right neck muscle vibration would influence sensorimotor and cognitive after-effects. More precisely, we explored whether the simultaneous application of both methods is responsible for additive sensorimotor after-effects on visuo-manual open-loop pointing and on visual and proprioceptive straight-ahead estimations. Second, we explored whether neck muscle vibration is responsible for cognitive after-effects on spatial representation using the line bisection task. As for sensorimotor tasks, we asked whether the amplitude of cognitive after-effects is magnified by the double stimulation.

## EXPERIMENTAL PROCEDURES

### Individuals

Fifty-four right handed and normal-sighted healthy subjects participated in our study (25.11 years ± 8.28). They were divided into six independent groups according to the exposure conditions: 'Prism' (P) group (five women, four men, mean age: 23.11 ± 2.57 years); 'Vibration with a sensation of body rotation' (Vb) group (five women, four men, 23.33 ± 2.96 years); 'Vibration with a move illusion of the sagittal LED' (Vl) group (five women, four men, 26.44 ± 9.98 years); 'Association with a sensation of body rotation' (Ab) group (five women, four men, 22.0 ± 3.08 years); 'Association with a move illusion of the sagittal LED' (Al) group (eight women, one man, 22.89 ± 3.48 years); and 'Control' (C) group (four women, five men, 32.89 ± 14.94 years). All participants gave their informed consent and the study was carried out in agreement with legal requirements and international norms (Declaration of Helsinki, 1964) and approved by the regional ethics committee of Burgundy (C.E.R).

### Prisms

The prisms shifted the vision 15° to the left without changing the width. The goggles were fitted with wide-field point-to-point lenses creating a leftward optical shift of 15° (Optique Peter, Lyon, France). The total visual field with the goggles was 105°, including 45° of binocular vision.

### Vibrator

The vibrator was half of a small cylinder (diameter: 2.8 cm, length: 5 cm). It was fixed with adhesive tape on the right posterior neck muscles of the subjects (splenius). The position was determined before the training procedure and corresponded to the optimal position allowing the greatest sensation of right body rotation or left visual target movement. This sensation depends on the subjects. No indication was previously given to the subjects on the expected sensations. The vibration was continuous and set at 80 Hz. For C group, the procedure was the same but the vibrator was turned off.

### Sensorimotor tasks table

For the sensorimotor tasks and the adaptation procedure, the participants comfortably sat in a chair with the possibility of adjusting the height in order to place the head in a chin-rest. The chair was positioned in front of a wooden box placed on a table. The apparatus used in our experiment was similar to that employed by Rossetti