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Research report

Where is straight ahead to a patient with unilateral vestibular loss?

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ABSTRACT

The vestibular system is classically associated with postural control, oculomotor reflexes and self-motion perception. The patients with vestibular loss are primarily concerned with balance and gait problems including head and trunk tilt and walking trajectory deviation to the lesioned side. These long-lasting postural and locomotor biases are thought to originate from changes in spatial perception of self. Indeed, we show here that vestibular cues are necessary for an accurate representation of body orientation. Patients with right (RVN; $n = 11$) or left vestibular neurotomy (LVN; 9) as a treatment for Menière's disease were compared with 10 healthy controls. The subjective straight ahead (SSA) was investigated using a method disentangling lateral shift and tilt components of error. In the horizontal plane, subjects were required to align a rod with their body midline. In the frontal plane, they were asked to align the rod with the midline of head or trunk. The analysis of SSA clearly showed distinct results according to the side of the lesion. The LVN patients had a contralesional lateral shift of SSA. In addition, they showed an ipsilesional tilt, more severe for the head than for the trunk. By contrast, in RVN patients, the representation of the body midline was fairly accurate in both the horizontal and frontal planes and did not differ from that of control subjects. The present study shows deviations in body orientation representation after unilateral vestibular loss. Deviations are observed in the horizontal as well as in the frontal planes. Interestingly, only patients with left vestibular loss were concerned with these changes in perception of self-orientation in space. These data support the hypothesis of an asymmetric vestibular function in healthy subjects and confirm the similarity of functional disorders in patients with vestibular deficits or spatial neglect. For the first time, this similarity is found at the level of body representation.

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1. Introduction

Studies on the vestibular system have shown that a unilateral lesion yields a tonic imbalance of the peripheral vestibular inputs which contributes to stabilize the eyes, the head and the body in space. Loss of vestibular sensory inputs results in postural (loss of balance), oculomotor (nystagmus, oscillopsia), neurovegetative (nausea), perceptive (vertigo) and cognitive (deficits in spatial representation) symptoms (for a review see Smith et al., 2005; Hanes and McCollum, 2006; Borel et al., 2008). In case of unilateral vestibular disease, motor deficits are oriented toward the lesioned side: ocular cyclotorsion, bias of head and trunk, deviation of the locomotion path (for a review see Nashner and Peters, 1990; Baloh et al., 1998; Lacour, 2006; Fetter, 2007; Bronstein and Lempert, 2010). These spectacular symptoms decrease with time in a process known as vestibular compensation. However, some functions remain asymmetric after a vestibular loss, especially during high frequency movements (for a review see Curthoys, 2000; Lacour, 2006; Horak, 2009). The literature also extensively describes the effects of vestibular loss in the internal representation of orthogonal coordinates, with a tonic ipsilesional tilt of the perceived vertical and horizontal (Friedmann, 1970; Vibert and Häusler, 2000).

The present study was designed to investigate the role of vestibular signals in the representation of the body orientation in space, which remains poorly considered in vestibular patients. In subjects tilted in the frontal or the horizontal planes, it has been shown that vestibular loss did not change the estimation of body verticality but affects its sensitivity (Bisdorff et al., 1996). A classical test of body orientation at rest is the subjective straight ahead (SSA), which consists in indicating the position of the mid-sagittal plane, most often by manually pointing out this plane (proprioceptive SSA; Heilman et al., 1983) or by stopping a moving visual target when it reaches this plane (visual SSA; Bridgeman and Graziano, 1989). In unilateral vestibular defective patients, the scarce data at hand concern visual SSA in acute or subacute lesions. The visual SSA proved to be deviated at rest to the side of the lesion (Hamann et al., 2009) and this deviation was abnormally increased during vibratory stimulation of neck muscles on the lesioned side (Strupp et al., 1998). Both these studies stressed that the side of the SSA deviation could constitute a perceptual correlate of the directional change of gaze (tonic deviation or slow phase of nystagmus). It is noteworthy that in healthy subjects, the visual SSA was also influenced by vibratory stimulation of the neck and, more interestingly, by caloric vestibular stimulation (Karnath, 1994). However, data on body orientation without concomitant changes in eye position are needed in order to solve the following issue: does the SSA deviation reflect a change in body orientation representation, or is it a secondary change related to eye position? To answer this question we investigated how the body orientation is perceived in the chronic stage several months after a total unilateral vestibular loss. In particular, we wondered if this perception depended on the body part (head and trunk) and if the error reflects a translation or a rotation of the body representation. These questions were examined in patients tested after right and left vestibular loss.

However, there is a drawback with the proprioceptive or visual methods used in most studies of SSA. Indeed, the investigators inferred a direction from a single measured point, i.e., a finger tip or a small luminous target. The problem was raised in studies of neglect patients whose rightwards errors had been interpreted as rotations of the body representation, i.e., the second point necessary to define SSA direction was implicitly located on the vertical body axis. In fact, as Vallar et al. (1995) pointed out, the errors recorded with these one-point methods could be interpreted as translations of the representation as well. In fact, translations of body representation are not rare in brain-damaged patients experiencing out-of-body phenomenon (Blanke et al., 2004) or suffering from neglect (Richard et al., 2004). To our knowledge, only two studies (Vallar et al., 1995; Ferber and Karnath, 1999) have addressed the issue of SSA direction by measuring two points, but in separate trials. Unfortunately, their outcomes proved to be contradictory. Moreover, Saj et al. (2006) claimed that in order to track the representation of the mid-sagittal plane, a measure of its vertical orientation is also needed. In order to overcome these difficulties, some of us devised a new test of SSA which consists in marking with a line (a luminous rod) the intersections of the subjective mid-sagittal plane with the horizontal plane (Richard et al., 2004) or with the frontal plane (Saj et al., 2006).

In the present study, we used the latter method for evaluating the representation of body orientation in unilateral vestibular patient. In particular, we wondered if this perception differed according to the body part (head and trunk) along the longitudinal axis and if the errors reflected a translation or a rotation of the body part representation.

2. Methods

2.1. Subjects

Twenty patients with complete unilateral vestibular loss participated in the experiments around two years after a neurotomy underwent as a treatment of their Menière's disease (Table 1). The surgical procedure was a retrosigmoid vestibular nerve section (see Magnan, 2000). All the patients included exhibited pure unilateral deficits; those with additional motor or visuomotor disorders were excluded from the study. Subjects were either emmetrope or had a correct vision with glasses. Of the twenty patients, nine had a left side neurotomy (LVN; mean age $= 63.1 \pm 9.6$ years; delay between testing and neurotomy $= 21.4 \pm 6.0$ months; 9 right-handed; 9 right-dominant eye) and eleven had a right side neurotomy (RVN; mean age $= 54.6 \pm 9.1$; delay $= 20.8 \pm 10.7$ months; 10 right-handed; 9 right-dominant eye). None of the patients had a residual spontaneous nystagmus. Patients' performance was compared with that of 10 healthy controls subjects (C; mean age $= 50.8 \pm 11.7$; 9 right-handed; 9 right-dominant eye). All participants signed an informed consent form following the principles outlined in the Helsinki Declaration, before taking part in the study.