T he perception of body orientation relative to earth gravity requires integration of information provided by vestibular, visual, proprioceptive, and tactile signals. Continuous exposure to these covariant signals during static and dynamic postures provides multimodal configurations of indices corresponding to a great variety of body orientations.

The subjective vertical (SV) seems liable to interaction with body orientation. When assessed in the visual modality, SV corresponds to the orientation of a visual stimulus perceived as earth vertical (in the absence of relevant visual cues). This SV is known to depend on actual body orientation according to well-established effects. Although it is precise and accurate in upright healthy subjects, the visual SV is biased in roll-tilted subjects. In patients with right hemisphere injury, the visual SV was evaluated only when sitting, head upright, with methods providing or not providing additional tactilo-kinesthetic cues. An anticlockwise (ACW) deviation occurred, which was amplified when the lesion causes spatial neglect (N) syndrome.

In the present experiment, we investigated whether the modulation of gravitational inputs conveyed by the otolithic and somatosensory systems affects the deviation of the visual SV in N. In fact, we compared 4 body configurations, from sitting to supine conditions. Thus, the perception of SV of right brain–damaged patients with spatial N was assessed with a visuohaptic method when: (1) sitting with plantar sole support (SS); (2) sitting without plantar sole support (SNS); (3) sitting with legs extended (SLE); and (4) lying in supine position. In the second condition, the plantar input was suppressed; in the third, the proprioceptive input from legs was also suppressed; and in the last only, otolithic influence was changed.

### Subjects and Methods

#### Subjects

Patients were recruited in the neurological rehabilitation department of Le Centre Hospitalier Universitaire de Lille. They were informed of the protocol and signed an informed consent form before inclusion. All had experienced a relatively recent right hemispheric hemorrhagic or ischemic stroke, demonstrated by MRI or computed tomography scan.

Patients with bilateral lesions, previous neurological or psychiatric disorders, impairment in primary visual perception, behavioral disorders, motor difficulties in the right upper limb, or psychotropic treatment and pusher syndrome were not included in the study. The pusher syndrome (ie, severe contralateral trunk deviation with active resistance to any attempt of external correction) was evaluated with the Scale for Contraversive Pushing and patients’ self-report of instability in a correct sitting position. They were regarded as pusher if they scored ≥3 on this scale and reported a feeling of rightward
imbalance in vertical position, with and without perception of the visual environment.

Spatial N was assessed using bell cancellation,11 line bisection,12 and scene copy13 tests. Patients were considered N when performance was pathological in 2 of the 3 tests.14

Eight N patients (mean age 61.0 years) were compared with 6 right-handed healthy control subjects (C; 51.0 years). Hemianopia was observed in 5 of 8 cases and somatosensory disorders in 8 of 8 cases (Table). Two of these patients (D and F) participated in a previous study that compared SV in pitch and in roll after a right-hemisphere stroke.9

Experimental Setup

The subject was installed on a chair or a medical device that enabled testing in sitting or supine positions. In fact, there were 4 conditions: (1) SS; (2) SNS; (3) SLE; and (4) supine position. The head, aligned with the trunk, was fixed by a headrest with lateral stabilizers; it was slightly raised when lying. The left arm was placed along the left thigh and maintained by a scarf in patients with severe hemiplegia. An abdominal strap helped to maintain a vertical position when sitting.

A metal rod (25-cm long, 1.5-cm wide, 1.5-cm thick) that could rotate in roll plane (relative to the participant) was placed before a vertical black panel. A fixed metal disk (25 cm in diameter), centered on the rotation axis and inserted between the rod and the panel, avoided tactilo-kinesthetic cues that could be given by the panel. A precision potentiometer, mounted in the rotation axis, was connected on the rotation axis and inserted between the rod and the panel, and explained 95% of the variance of body position factor. Post hoc analysis showed that the visuohaptic

position. The participant had his/her eyes closed during the setting of the initial tilt. No information was given on performance. Trials were separated by ~20 seconds. The order of initial tilt of the rod and the order of positioning were counterbalanced.

Statistical Analyses

For each participant and each body position, the 6 repetitions recorded were averaged. The ANOVA (Statistica software) performed on the resulting means included the factors group (2 groups) and body position (4 positions). Post hoc analyses used the Newman–Keuls test. The α-risk was fixed at P<0.05.

Results

The effect of group was significant (F(1,12)=10.91; P<0.001). Healthy participants accurately adjusted the rod to the vertical (mean±SD: 0.01°±0.3°). N patients inclined the rod in the ACW direction (−4.5°±1.6°). The significant group×body positions interaction (F(3,36)=3.07; P=0.022) revealed that the posture effect differed between groups. As the Figure suggests, posture did not affect the SV of C group. On the contrary, the N group presented with a decrease in the ACW deviation, from the SS to the SNS, the SLE, and the supine positions; the linear trend was significant (F(1,7)=9.32; P=0.018) and explained 95% of the variance of body position factor. Post hoc analysis showed that the visuohaptic
SV in the SS, SNS, and SLE positions was significantly different from that observed in the supine position ($P<0.05$).

**Discussion**

The aim of the study was to assess the role of otolithic and somatosensory afferences in the perception of the visuohorizontal SV among N patients. We showed that progressive change in body positioning, from the sitting to the supine position, associated with a reduction of graviceptive inputs, resulted in a progressive reduction of the visuo-horizontal SV bias of N patients.

To the best of our knowledge, this effect has never been reported in the literature. In fact, the only available information is about the effect of body position on another clinical aspect of spatial N, i.e., the ipsilateral deviation in line bisection. In 8 patients with N, Pizzamiglio et al.\(^1\) investigated the influence of body position on the patients’ ability to bisect lines. This latter was measured when the body was either in an upright body position (sitting) or in a supine position. The rightward directional error found in the upright position (+6.3 cm or 5.1° of visual angle) was significantly reduced in the supine position (+2.9 cm or 2.4° of visual angle). A similar tendency, although not significant, was observed in a study by Karnath et al.,\(^5\) with a reduced exploratory bias to the right when patients were pitched 30° backward. Data from Pizzamiglio et al.\(^5\) suggest that this tendency could have been more pronounced if patients were placed in a full supine position.

Pizzamiglio et al.\(^1\) interpreted their finding as evidence that the gravitational input from the left and right otolithic system may be processed in a nonsymmetrical fashion by the neural circuits disrupted by a unilateral cerebral lesion. They assumed that the reduction of the otolithic input obtained when placing patients in the supine position reduced the ipsilesional distortion of a higher-order representation of space. In fact, the literature suggested that otolithic input is reduced in a supine position\(^17\) or when the head is pitched backward with subjects in a standing position.\(^18\)

The outcome of our study is consistent with the view that supine position results in a reduction of the otolithic influence. However, the somatosensory changes occurring when passing from the lying to the sitting position could also play a role. Indeed, an influence of somatosensory inputs was suggested by the effect of limb manipulation and deserves further investigation. The role of somatosensory afferences have been emphasized by other authors for explaining the modulation of the subjective visual vertical resulting from lateral body tilt in patients with bilateral peripheral vestibular lesion.\(^19\) By analogy with the hypothesis put forward about vestibular input,\(^15\) one may consider that reducing somato-
sensory input could reduce the deficit because of a processing system biased by the lesion.

Concerning rehabilitation, the present study suggests that patients could benefit from performing exercises in supine position at the beginning of care, before they pass to the sitting position.

**References**


Effect of Posture on the Perception of Verticality in Neglect Patients
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